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Hazard Analysis Critical Control Point (HACCP) Strategies for Distribution System Monitoring, Hazard Assessment and Control

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Background and Disclaimer

The USEPA is revising the Total Coliform Rule (TCR) and is considering new possible distribution system requirements as part of these revisions. As part of this process, the USEPA is publishing a series of issue papers to present available information on topics relevant to possible TCR revisions. This paper was developed as part of that effort.

The objectives of the issue papers are to review the available data, information and research regarding the potential public health risks associated with the distribution system issues, and where relevant identify areas in which additional research may be warranted. The issue papers will serve as background material for EPA, expert and stakeholder discussions. The papers only present available information and do not represent Agency policy. Some of the papers were prepared by parties outside of EPA; EPA does not endorse those papers, but is providing them for information and review.

Additional Information

The paper is available at the TCR web site at:

http://www.epa.gov/safewater/disinfection/tcr/index.html

Questions or comments regarding this paper may be directed to **TCR@epa.gov.**

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Evaluating HACCP Strategies for Distribution System Monitoring, Hazard Assessment and Control

1. Overview

The USEPA is revising the Total Coliform Rule (TCR) and is considering new possible distribution system requirements as part of these revisions. As part of this process, the USEPA is publishing a series of issue papers to present available information on topics relevant to possible TCR revisions. This paper on the Hazard Analysis Critical Control Point (HACCP) system was developed as part of this effort. The HACCP system provides an alternative approach to identifying and controlling microbiological contamination in the distribution system. It offers a more proactive and comprehensive framework that reduces the reliance on end-point monitoring and organizes all utility programs and practices related to maintaining distribution system integrity. Through implementing a HACCP program, a water utility identifies and prioritizes hazards that can allow contamination to enter their distribution system, and establishes and implements control measures to control these hazards.

The purpose of this paper is to review and summarize existing literature, research data and case studies on the HACCP system to illustrate how HACCP can be applied to distribution system protection. It includes examples of HACCP applications in regulatory frameworks and draws on utility experiences summarized in a recent AwwaRF study (Martel et al., 2006). The scope of this paper does not include a discussion of how the HACCP system could be integrated into the existing U.S. drinking water regulatory framework.

2. Introduction

Current distribution system management practices may leave some systems vulnerable to contamination, as evidenced by failures linked to waterborne disease outbreaks. U.S. waterborne disease records from 1920 to the present show that up to 40 percent of waterborne disease outbreaks have been caused by distribution system problems (Lippy and Waltrip, 1984; Kramer et al., 1996; Levy et al., 1998). For example, a *Salmonella typhimurium* outbreak in Gideon, Missouri, was likely caused by bird droppings in two finished water storage facilities when poor distribution system flushing practices caused the complete draining of the two tanks into the system (Clark et al., 1997; Geldreich, 1996). An outbreak of hemorrhagic *Escherichia coli* (*E. coli*) serotype O157:H7 occurred in Cabool, Missouri during December 1989 and January 1990 and resulted in 243 cases of diarrhea and 4 deaths (Swerdlow et al., 1992). Shortly before the peak of the outbreak, 45 water meters were replaced and two water mains ruptured. Swerdlow et al. (1992) concluded that system wide chlorination as well as hyperchlorination during repairs might have prevented this outbreak.

Inadequacies in design, operation, and maintenance of water distribution systems have also been documented through recent research funded by the American Water Works Association Research Foundation (AwwaRF). Kirmeyer et al. (2001) identified the various potential pathways for contaminants to enter the distribution system, including poorly designed, constructed, or maintained storage facilities, unprotected cross-connections, and water main break and repair sites. Kirmeyer et al. (2001) also documented evidence of fecal pollution and enteric viruses in the vicinity of water main break sites, confirming the potential for pathogen intrusion given an available pathway and favorable pressure conditions. Further research on pathogen intrusion during pressure transients by Friedman et al. (2004) confirmed that transient negative pressures do occur in distribution systems, and that significant volumes of water have been shown to enter a pilot-scale distribution system through small leaks during transient pressure events. Based on surveys of tank inspection firms, State primacy agencies and utilities, Kirmeyer et al. (1999) concluded that many storage facilities in the United States are never inspected, and many facilities are inspected less frequently than the 3-year frequency recommended by the American Water Works Association (AWWA) (AWWA Manual M42, 1998). A comprehensive survey on cross-connection control programs (Lee et al., 2003) showed that 91 percent of survey respondents have developed cross-connection control programs, but only 49 percent have a requirement for reporting backflow incidents [to state primacy agencies]. There is no Federal reporting requirement for cross connections. Most survey respondents were community water systems (99 percent of those surveyed).

In addition to inadequacies in water system processes and procedures, the human element affects a water system's susceptibility to contamination. Kuslikis and White (2004) give several examples of how water system employees can impact risks and risk management:

- Competent and loyal employees sometimes take shortcuts to save time or money, and unknowingly take major risks
- Employees may not see the big picture and may have a much higher tolerance of risk than water system management

Smith (2004) also acknowledges that some utility personnel may occasionally be careless, understaffed or poorly trained.

Recently, the water industry has begun to move towards a more proactive approach to managing the safety of water supplies by incorporating quality assurance principles. The U.S. drinking water industry employs several quality assurance principles, especially for the control of pathogens. For example, the Surface Water Treatment Rule (SWTR), as amended, sets goals for pathogen occurrence in the finished drinking water, and has regulatory provisions for meeting those goals. Provisions include watershed control, source water quality, treatment performance requirements, and periodic on-site sanitary surveys. Pathogen monitoring is not required under this rule. The goal of monitoring for the SWTR and other microbial regulations is to assess the effectiveness of pathogen control measures, using monitoring tools such as total coliforms, fecal coliforms, *E. coli*, water turbidity, and disinfectant levels.

The USEPA Office of Groundwater and Drinking Water (OGWDW) encourages water utilities to develop voluntary treatment optimization programs such as Comprehensive Performance Evaluation (CPE) programs and Area-Wide Optimization Programs. Both of these programs focus on treatment facilities for surface water supplies. The CPE is a thorough review and analysis of treatment plant performance and associated administrative, operation and maintenance practices. The Area-Wide Optimization Program (AWOP) may be used by state primacy agencies to identify systems with the highest public health risk and to help these systems implement proactive measures to improve performance. The focus of the AWOP is to optimize treatment performance of existing particle removal, disinfection and distribution system facilities.

The USEPA has established numerous partnerships with industry and regulatory agencies that encourage cooperation and sharing of resources for drinking water and other environmental projects. For example, the Adopt Your Watershed program encourages stewardship of the nation's water resources. The Water Use Efficiency Program focuses on creating market enhancement for water efficient products. The National Nonpoint Source Management Program seeks to maintain and restore water quality in areas affected by nonpoint source pollution. EPA's Volunteer Monitoring Program encourages volunteers who conduct water quality monitoring on local resources to share their data and become involved in watershed stewardship and education.

The AWWA has several voluntary programs that incorporate quality assurance principles for controlling pathogens in drinking water: QualServe, the Partnership for Safe Water, and a new distribution system standard. QualServe is a continuous quality improvement program that helps utilities improve overall service using a self-assessment tool, a peer review process, and a benchmarking clearinghouse. The Partnership for Safe Water, a joint initiative among AWWA, USEPA and other drinking water organizations, also uses a self-assessment tool and a peer review process to optimize treatment plant performance for systems using surface water supplies. AWWA Standard G200, Distribution Systems Operation and Maintenance, effective May 1, 2004, describes critical elements for the operation and management of water distribution systems.

In Australia, the McClellan Inquiry into the 1998 Sydney Water *Cryptosporidium* contamination incident recommended introducing quality assurance procedures as a framework for guiding water quality protection (Davison et al., 1999). A major revision to Australian food legislation (Exposure Draft Food Bill) in 1999 included tap water in the definition of food, and required a quality assurance system incorporating HACCP principles for all food suppliers to assure food safety (Davison et al., 1999). More recently, the Walkerton Inquiry in Canada also concluded, "Perhaps the most significant recommendations in this report address the need for quality management through mandatory accreditation and operational planning." (O'Connor, 2002) The recommended quality management system should include real time process control and preventive strategies to identify and manage risks to public health (O'Connor, 2002). This proactive, risk-based management approach is further emphasized by the new WHO guidelines (3rd edition) and the complementary Bonn Charter for Safe Drinking Water that are discussed later in this report (see section entitled Use of HACCP in Regulatory Frameworks).

3. Background

Quality assurance (QA) principles and procedures, such as the HACCP system, are important in controlling risk. EPA defines QA as

> … an integrated system of activities involving planning, quality control (QC), quality assessment, reporting and quality improvement to ensure that a product or service meets defined standards of quality with a stated level of confidence. (EPA, 1991)

EPA defines QC as

> … the overall system of technical activities whose purpose is to measure and control the quality of a product or service so that it meets the needs of users. The aim is to provide quality that is satisfactory, adequate, dependable, and economical." (EPA, 1991)

Application of QA principles may have some value for water supply since it is very hard to manage the QC of drinking water between release from storage and the point of consumption. In the water distribution system, QC is accomplished using water quality monitoring, typically a combination of on-line monitoring and manual grab samples. Because the monitoring samples represent a very small percentage of the actual volume of finished water produced, it is difficult to measure and control the quality of the finished drinking water strictly by QC measures. However, it is possible to improve quality control over the transfer of water from treatment and storage to the customer using QA principles so as to be confident that the water is likely to be safe. For example, control measures may be instituted to improve safety of the finished water downstream from water main construction sites. These control measures may include inspector training, policies that restrict use of system valves and disinfection procedures for water mains being returned to service, among others.

QA systems are incorporated into production and service delivery processes across the developed world. There are a number of standards and guidelines available, with International Organization for Standardization (ISO) being the internationally recognized standards that are commonly applied in Europe, Australia, and Asia. Two ISO Standards commonly employed by water utilities include ISO Standards 9001 and 14001. ISO Standard 9001 defines a Quality Management System that demonstrates the ability to consistently provide products and services that meet customer needs, regulatory requirements and internal goals (Nyman, 2004). ISO Standard 14001 defines an Environmental Management System (EMS) that addresses potential impacts on the environment (Nyman 2004). These ISO standards evaluate current utility processes, policies and procedures for specific business systems (i.e. accounting, customer service). The ISO standards do not include an evaluation of risks/hazards and safety of the product so cannot be considered as an alternative to HACCP certification/registration.

Most utilities that have implemented HACCP have first implemented quality management systems such as ISO 9001 and ISO 14001. "These management systems helped the utility to gain management control of people and processes which made implementing HACCP relatively straightforward." (Martel et al., 2006) Integrated management systems are becoming a new trend in the water industry where one quality assurance system covers all business management aspects, including general quality management (ISO 9000), protection of the environment (ISO 14001), drinking water safety to the user (HACCP), and worker health and safety. The benefit of implementing one integrated system is that only one audit would be required and utility staff will implement only one set of policies and procedures (Deere, 2005).

3.1 The HACCP System

Originating in the 1960's, HACCP was designed to ensure safety of food and beverages from microbiological hazards for the first NASA manned space missions thus preventing astronauts from falling victim to gastroenteritis while in space (NASA, 1991). HACCP has been applied to food production processes since the 1980s and to drinking water systems since the mid-1990s. The World Health Organization (WHO) guidelines for HACCP, *Codex Alimentarius*, have been adopted internationally as the primary recognized food safety methodology for risk management. The current HACCP guideline was developed in 1997 by the Codex Alimentarius Commission (http://www.who.int/foodsafety/codex/en).

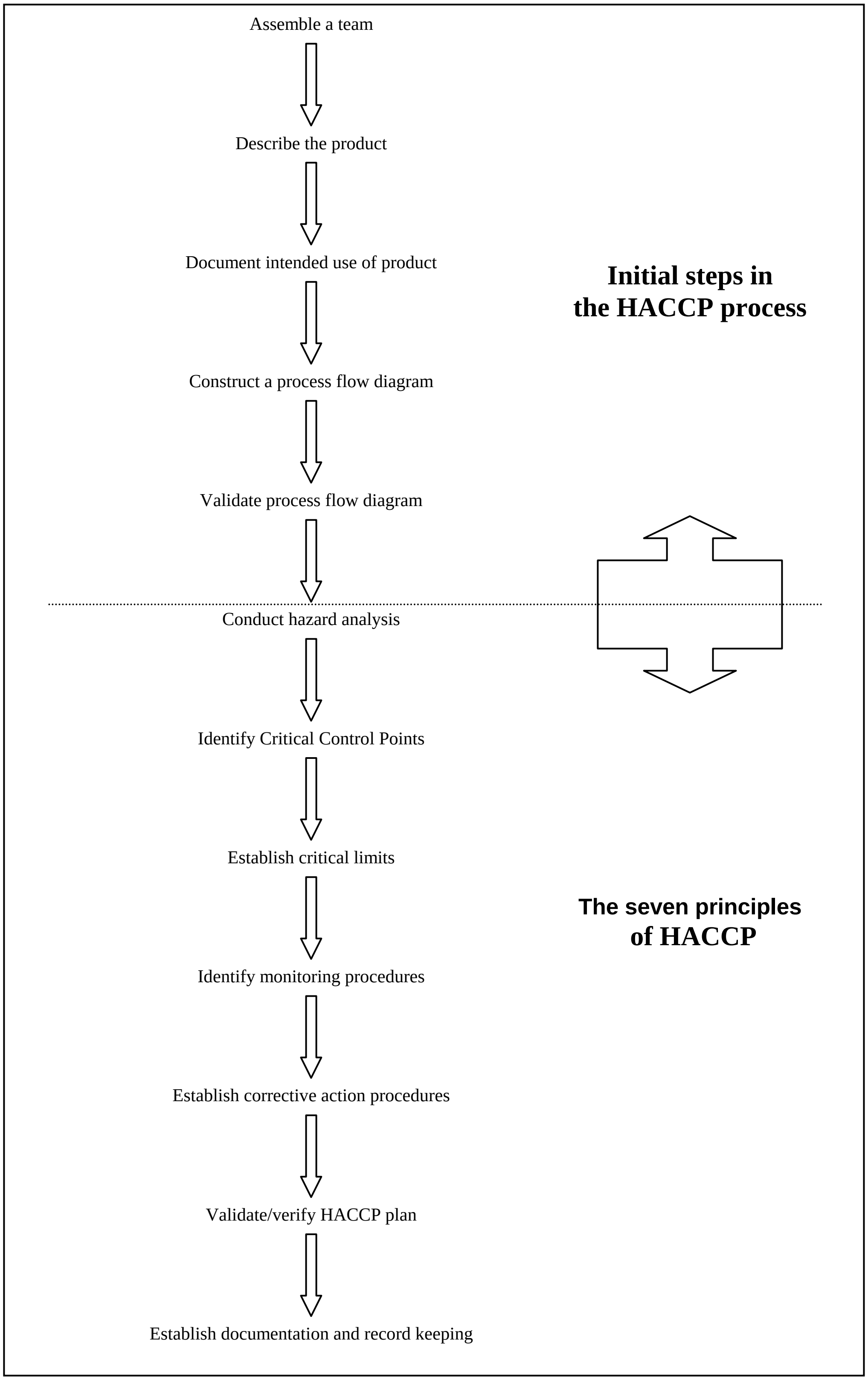
For drinking water, the HACCP system promotes a "source to tap" philosophy for utilities to identify the critical points throughout the entire system, i.e., those points within the system or its operation whose disruption or failure would result in a greater public health risk compared to other points, and then to focus resources on these critical locations and processes. This systematic approach would help the utility to identify potential hazards closer to their source, thus minimizing the occurrence and effects of incidents that degrade water quality and cause a public health threat. This type of philosophy is already employed to some degree by many water utilities. For example, utilities that use surface water supplies comply with the Federal SWTR using the multiple barrier concept to control microorganisms in the finished drinking water. The multiple barriers include source protection, coagulation/filtration, primary disinfection and distribution system control measures. Under the multiple barrier approach, all process steps are optimized to reduce risk (Smith, 2004). To integrate HACCP with existing practices based on the multiple barrier approach, the utility could select critical control points within several of the barriers or process, depending on the hazards of concern.

A second example of utility experiences with the HACCP-type approach is the State-mandated sanitary survey. The sanitary survey is a system audit conducted by an independent, qualified third party to review a water system's effectiveness in producing and distributing safe drinking water. Through the sanitary survey, the inspector may identify current or potential breaches in one or more of the multiple barriers including physical facilities and/or utility procedures. The results of the sanitary survey may inform the utility of facilities and procedures that need improvement in order to protect the finished drinking water. However, the sanitary survey is not uniformly applied in all

States and is dependent on state allocated resources and interpretation of federal guidelines. The sanitary survey could be improved to be a more proactive inspection with more emphasis on follow-up activities to assure that existing deficiencies are corrected and action is taken to prevent potential deficiencies from occurring.

The Codex Alimentarius Commission defines 12 sequential steps (or 5 initial steps and 7 major principles) for planning and implementing a HACCP system (WHO, 1997). The information prepared in completing these 12 steps constitutes the utility's HACCP Plan. These steps are summarized in Figure 1 and described in more detail as applied by the City of Austin, Texas as part of a continuing research project funded by the Awwa Research Foundation and the USEPA (City of Austin, 2003).

The City of Austin developed a HACCP Plan for one pressure zone of their water distribution system. Austin's HACCP Plan, included in Appendix A to this paper, illustrates how the 12 steps of HACCP apply to their distribution system. The first seven steps were developed in a training workshop held at the utility location in May 2003. Workshop attendees included staff with a broad array of skill sets from various divisions within the utility including individuals from the Water Lab, Systems Planning, Cross-Connection Control, Process Engineering, Distribution System Operation, Water Quality, Regulatory Compliance, and the State's Regulatory Agency. At the workshop, a HACCP team was formed to finalize the remaining steps of the HACCP plan as well as to guide its implementation. Austin's HACCP Plan was finalized in September 2003, and implemented over a 12-month pilot study period from October 2003 through September 2004.



Source: WHO (1997)

Figure 1. Steps and Principles of the HACCP System

Step 1 – Assemble a HACCP Team. Pull together a multidisciplinary team to plan, develop, verify, and implement the plan.

The City of Austin's HACCP team is composed of a state regulatory manager plus seven utility employees: the water quality manager, a water laboratory supervisor, a construction superintendent, an engineer, a cross-connection control program superintendent, an infrastructure supervisor, and the assistant director of treatment. It is important to include utility staff across all departments that have responsibilities and expertise in drinking water quality and management. To foster employee empowerment and acceptance of HACCP, it is equally important to involve as many employees as possible including staff with all levels of seniority.

Step 2 – Describe the Product. Describe the product, in this case drinking water, including its source, treatment, storage, distribution and any existing standards for product safety.

Austin's source of supply is the Colorado River. Raw water for the pilot study area is currently diverted at Lake Austin and treated at the Ullrich Water Treatment Plant using lime softening, recarbonation/pH adjustment, chloramination, filtration, and addition of ferric sulfate, fluoride, and sodium hexametaphosphate. Treated water is stored at the Ullrich Plant in two 10 MG clearwells, and in the distribution system in tanks. The Utility owns a contiguous distribution system that serves a population of approximately 770,000 through roughly 183,000 service connections. The distribution system contains 2,995 miles of water mains of a wide variety of materials including cast iron, ductile iron, PVC, asbestos cement, and reinforced concrete cylinder. The distribution system also contains 30 tanks ranging in size from 300,000 to 34,000,000 gallons. Because of the varied topography in the utility's service area, the distribution system is divided into eight major pressure zones. Austin's product description also describes Federal and state regulations that pertain to the distribution system as well as Austin's internal water quality goals for the distribution system.

Step 3 – Identify Intended Use. Describe how the product is used and the major users.

The City of Austin has residential, commercial and industrial customers. The City's finished drinking water is used for the following purposes:

- Drinking
- Manufacturing, including semi-conductor manufacturing processes that are sensitive to total organic carbon and trihalomethane levels
- Irrigation
- Culinary uses
- Fire fighting
- Construction uses
- Sanitary uses (toilet flushing and showers)
- Medical uses (hospitals, dialysis centers, dental offices)
- Product water (Coca Cola and Abbott Labs)

Step 4 – Construct a Flow Diagram. For a comprehensive HACCP, this would be a schematic showing sources of water, details of treatment, storage, pumping, and distribution to end users. For a HACCP directed toward a distribution system, the schematic would be restricted to showing the water flow path from the treatment plant to end users.

Austin's process flow diagram is included in Appendix A.

Step 5 – Validate Process Flow Diagram. As a critical element around which the HACCP is based, the flow diagram needs confirmation of accuracy by the HACCP team.

The City of Austin's HACCP team validated the process flow diagram in a meeting held following the training workshop. The process flow diagram is signed and dated by a HACCP team representative to document that the validation step has been completed.

Step 6 – Conduct Hazard Analysis. Using the process flow diagram, identify hazards, their likelihood of occurrence, potential consequences, and control measures.

Austin's HACCP team identified many potential hazards for the pilot study area, but the team decided to base the pilot study on two particular hazard events that scored high marks in the hazard analysis – unprotected cross-connections and hazards at new construction sites that can potentially degrade the finished water quality. Additional details on Austin's hazard analysis and the scoring for each hazard are provided in Appendix A.

Step 7 – Identify Critical Control Points. For each significant hazard, identify points in the process where the consequences of failure are irreversible.

In Austin's case, for the hazard of unprotected cross-connections, each service connection is considered to be a critical control point. For the hazards at new construction sites, each construction site is a critical control point.

Step 8 – Establish Critical Limits. Determine critical limits for the critical control points that will trigger a corrective action. A critical limit is a criterion that separates acceptability from unacceptability.

For Austin's hazard of unprotected cross connections, one control measure is to maintain system pressure at all times. The critical limits for this control measure are to maintain pressure above 35 psi under normal conditions and above 20 psi during emergency conditions. A second control measure is to inspect plumbing of new customers. For this control measure, the critical limit is compliance with the local plumbing code.

Step 9 – Identify Monitoring Procedures. Establish monitoring points, frequency, and responsibility.

For the examples used in Step 8, monitoring procedures are described. System pressure is monitored continuously using pressure transducers and data loggers located at pump station discharge points. Pressure data are collected and tracked with the SCADA system. The plumbing of new customers is inspected visually by City plumbing inspectors.

Step 10 – Establish Corrective Action Procedures. Develop plans for follow up activities when critical limits are exceeded. These activities may include operations and/or maintenance activities, water quality monitoring and/or communications with customers.

For the examples used in Steps 8 and 9, corrective action procedures are described. If system pressure falls below the critical limits, additional pumps are turned on to raise the pressure. At the same time, the utility would search for main breaks. If necessary, the utility would issue a boil water advisory. If a new customer's plumbing does not meet the local plumbing code, enforcement action is taken per the Plumbing Code and Cross-connection Ordinance.

Step 11 – Validate/Verify HACCP Plan. Have the HACCP team and other affected parties check the HACCP plan for accuracy, ability to implement, and potential effectiveness.

Austin's HACCP plan was validated at meetings on August 15 and 28, 2003 by members of the HACCP Team. Additional validation was done with inspection staff and staff of the On-Site Sewage Facilities Division.

Step 12 – Establish Documentation and Recordkeeping. Develop a record keeping system to track system performance at critical control points.

In Austin's HACCP Plan (Appendix A), documentation and recordkeeping activities are listed for each critical control point. These "tracking" methods include the utility's SCADA system, various databases, log books and a work order system. Water quality samples collected for new mains prior to their release to service are tracked using water laboratory approval letters. The completion of inspector training is documented using attendee sign-in sheets.

4. Use of HACCP in Regulatory Frameworks

The HACCP concepts have been incorporated into regulatory frameworks in several countries as summarized in Table 1. These applications of HACCP are described in more detail in the following sections.

Table 1
HACCP Programs for Controlling Public Health Risks in Drinking Water

Country/ Organization	Regulation or Regulatory Guideline	Website for current information	Reference
World Health Organization	Guidelines for Drinking Water Quality (3rd Edition)	www.who.int/water_sanitation_health/dwq/guidelines2/en/	Davison and Bartram (2004)
U.S./EPA	Aircraft Drinking Water Rule (under development)	http://www.epa.gov/safewater/airlinewater/regs.html	USEPA (2006)
Australia	Australian Drinking Water Guidelines (Guideline)	www.nhmrc.gov.au/publications/synopses/eh19syn.htm	NHMRC and NRMMC (2004)
New Zealand	Health (Drinking Water) Amendment Bill (Proposed regulation)	www.moh.govt.nz/water	
Switzerland	W1002 Regulatory guideline: Recommendations for a Simple Quality Assurance System for Water Supplies (Guideline)		Swiss Gas and Water Industry Association (2003)
	Hygiene Ordinance (SR 817.051, HyV), Article 11 (Regulation)		Bosshart (2003)
Iceland	Food legislation: Act no. 93/1995	http://english.ust.is/media/log/L1995-93_ensk.htm	Gunnarsdottir and Gissurarson (2006)
France	French National Transcription: Decree 2001-1220 (Dec. 20, 2001) Water Safety for Human Health, Risk Assessment and Management; Article 18-2 (Regulation)		Metge (2003); DeBier and Joret (2004)
Ontario, Canada	Water quality management standard based on HACCP, ISO 9001, and ISO14001 (Guideline)	http://www.ene.gov.on.ca/envision/env_reg/er/documents/2006/Drinking%20Water%20Quality%20Management%20Standard%20-%20October%202006.pdf	Ministry of the Environment (2006)

4.1 World Health Organization Drinking Water Guidelines

The third edition of the World Health Organization (WHO) drinking water guidelines outline a framework for drinking water safety based on the multiple barrier approach and several risk management and quality management approaches including the HACCP principles (Davison and Bartram, 2004). The WHO framework has three main components: health-based water quality targets based on public health protection and disease prevention; a Water Safety Plan (WSP) as described below; and independent surveillance activities including audits of the WSP and final checks on the finished drinking water. Countries that use WHO guidelines as the minimum criteria for water system regulation will need to recommend or require that water utilities develop WSPs. WHO recommends that water suppliers develop a WSP that documents the following major elements:

1. A source-to-tap system assessment that determines whether a water system can deliver water meeting certain water quality targets.
2. Control measures for identified hazards and operational monitoring of control measures.
3. A management plan that documents the system assessment, control measures, the monitoring plan, corrective action procedures to address water quality incidents, communication plan and supporting programs such as standard operating procedures (SOPs), employee training and risk communication.

The WSP concept continues to evolve as the water industry gains experience by developing and implementing Water Safety Plans. Table 2 provides a comparison of HACCP and the two slightly different approaches for Water Safety Plans as presented in the WHO drinking water guidelines (WHO, 2004) and a more recent WHO guidance manual (Davison et al., 2005). The only significant difference between the two WHO approaches is that the 2004 guidelines do not utilize the term “critical control points” in determining where control measures should be implemented, and instead rely on the multiple barrier principle. The 2005 guidelines acknowledge that control measures sometimes represent a process step (e.g., filtration) that can be referred to as a “critical control point.” The intent is to enable the effect of the multiple barriers to be assessed together (Davison et al., 2005). Other differences between these two approaches listed in Table 2 appear to be either semantics (different words used to describe similar tasks) or a different sequence of tasks.

The Bonn Charter for Safe Drinking Water complements the new WHO guidelines in providing international guidance on drinking water quality management (Breach, 2004). This Charter is the end product of two expert workshops held in Bonn, Germany in October 2001 and February 2004, and is applicable to all water systems worldwide. The Charter’s key principles include the following (Breach, 2004):

1. Good safe drinking water can only be provided reliably and consistently through an integrated, source-to-tap approach.

Table 2
Comparison of HACCP and Water Safety Plan Risk Management Approaches

Step	HACCP Approach (WHO, 1997)	Water Safety Plan Approach (WHO, 2004)	Water Safety Plan Approach (Davison et al., 2005)
1	Assemble Team	Assemble Team	Assemble Team
2	Describe the Product	Document & Describe System	Describe Water Supply (construct & confirm flow diagram)
3	Document Intended Use of Product	Undertake Hazard Assessment & Risk Characterization	Conduct Hazard Analysis
4	Construct a Flow Diagram	Assess the Existing System with Flow Diagram	Identify Control Measures and Critical Control Points
5	Confirm Flow Diagram	Identify Control Measures	Define Operation Limits
6	Conduct Hazard Analysis (e.g., Identify Hazards, Assess Risks and Identify Control Measures)	Define Operational Limits and Monitoring Procedures	Establish Monitoring
7	Identify Critical Control Points	Establish Procedures to Verify WSP is Working	Establish Corrective Action & Incident Response
8	Establish Critical Limits	Develop Supporting Programs	Establish Record Keeping
9	Identify Monitoring Procedures for Critical Limits	Prepare Management Procedures Including Corrective Actions for Normal and Incident Conditions	Validation & Verification
10	Establish Corrective Action Procedures	Establish Documentation & Communication Procedures	
11	Validate/Verify HACCP		
12	Establish Documentation & Record Keeping		

Source: USEPA (2006)

2. The integrated approach requires close cooperation and partnerships among governments, water suppliers, health agencies, environmental agencies, land users, contractors, plumbers, consumers, and manufacturers of materials, products and devices used in the water supply system (Breach, 2004).
3. Traditional verification of drinking water quality based on measurement of various parameters against predetermined standards or guidelines will continue to play a critical role in ensuring drinking water quality. In the future, there should be much greater emphasis on use of preventive, risk-based management control systems.
4. The quality assurance process and derivation of specific standards need to be transparent to assure consumer confidence.
5. The standards used to measure water quality and safety can legitimately vary between different countries and regions depending on local circumstances (Breach, 2004). However, these standards should ensure the provision of water that has the trust of consumers, is affordable, and meets the following minimum criteria (Breach, 2004):
   a. Does not pose a health threat to consumers
   b. Is acceptable to consumers in terms of taste, odor, and appearance
   c. Is reliable in terms of both quality and quantity
6. Effective approaches to managing drinking water quality rely on an interlinked set of processes that must involve the following three elements (Breach, 2004):
   a. Establishment of clear responsibilities and institutional arrangements for the different stakeholders
   b. Implementation of effective control systems directed to identifying and managing risks, thereby mitigating their impacts (Drinking Water Quality Management Plans)
   c. Assessment of compliance against the necessary minimum standards for drinking water quality (verification)
7. A Drinking Water Quality Management Plan that includes the following three elements (Breach, 2004):
   a. A system wide risk-based assessment of safety from source-to-tap
   b. Identification of the most-effective control points to reduce the risk
   c. Effective systems and operational plans to deal with both routine and abnormal operating conditions

4.2 USEPA Aircraft Drinking Water Rule

EPA has initiated a rulemaking effort that will tailor the requirements of the National Primary Drinking Water Regulations to the unique characteristics of aircraft. The existing NPDWRs were designed to regulate water quality in stationary public water systems, not mobile water systems with the capability of flying throughout the world. The rulemaking effort utilizes a systematic risk management approach that draws on the principles of the HACCP approach and a multiple barrier approach. EPA established a multi-disciplinary, interagency Aircraft Drinking Water Rule team that includes representatives of several EPA offices, Regions 1-7 and 9, representatives of the Food and Drug Administration, and the Federal Aviation Administration. EPA is working collaboratively with stakeholders representing airline and airport owners and operators, pilots, flight attendants, passengers, fixed base operators, and environmental/public health interests.

4.3 Australian Drinking Water Guidelines

In Australia, drinking water is regulated by State health agencies. The Australian Drinking Water Guidelines (ADWG) ensure the accountability of drinking water suppliers (as managers) and of state/territory health authorities (as auditors of the safety of water supplies) (NHMRC and NRMMC 2004) but they are not mandatory, legally enforceable standards. The current revision of the ADWG includes the "Framework for Management of Drinking Water Quality" that provides guidance on establishing preventive, source-to-tap risk management systems for drinking water quality. The State of Victoria promulgated the *Safe Drinking Water Act* 2003, which came into effect on July 1, 2004 and requires all water utilities to implement a risk management plan based on the ADWG. The Australian Framework for Management of Drinking Water Quality was derived by supplementing the information on preventive system management already provided in the ADWG with principles described in existing quality management systems such as ISO 9001 (Quality Systems), ISO 14001 (Environmental Management Systems), Australian and New Zealand Standard 4360 (Risk Management) and the HACCP system. The Framework includes 12 main elements (NHMRC and NRMMC, 2004):

1. Commitment to Drinking Water Quality Management
2. Assessment of the Drinking Water Supply System
3. Planning-Preventive Strategies for Drinking Water Quality Management
4. Implementation-Operational Procedures and Process Control
5. Verification of Drinking Water Quality
6. Incident and Emergency Response
7. Employee Awareness and Training
8. Community Involvement and Awareness
9. Research and Development
10. Documentation and Reporting
11. Evaluation and Audit
12. Review and Continual Improvement

The Framework promotes monitoring as a verification tool for assuring that preventive measures are working effectively and reduces the reliance of compliance monitoring as the primary means for managing water quality.

4.4 New Zealand Public Health Risk Management Plans

In New Zealand, proposed new legislation would amend the Health Act of 1956 by introducing a legislative framework that is based on risk management principles. The Health (Drinking Water) Amendment Bill, introduced to Parliament on June 21, 2006, would require compliance with drinking water standards that are now voluntary. The Bill would also require water suppliers serving more than 500 people to develop a "Public Health Risk Management Plan" (PHRMP). The proposed legislation is driven by a concern that the current reliance on voluntary drinking water standards is inadequate to safeguard the treatment and distribution of drinking water. New Zealand has relatively high rates of enteric or gastro-intestinal disease. For example, the campylobacteriosis rate in New Zealand is twice that of England and three times that of Australia and Canada (http://www.moh.govt.nz/moh.nsf/indexmh/drinking-water-proposed-legislation).

To assist water suppliers in developing and implementing this PHRMP, the Ministry of Health prepared a series of guides that are based on the risk management framework contained in AS/NZS 4360:1999 (Standards Australia/Standards New Zealand, 1999) and HACCP methodology (Codex Alimentarius, 1993). These guides contain the following information:

- Potential problems during different processes and operations that might allow contaminant intrusion
- Corrective actions when contamination occurs
- Preventive measures to reduce the likelihood of the problems recurring

A separate booklet discusses the overall approach to developing and implementing a Plan as outlined in Table 3 (Ministry of Health, 2005).

Table 3
New Zealand Approach for Preparing Public Health Risk Management Plans

Step	Description	Contribution to the Public Health Risk Management Plan
1	Identify the elements in the supply and the PHRMP Guidelines needed.	Flow diagram of the supply
2	Identify which barriers to contamination are present.	Check-list of barriers present in the supply
3	Identify events that may introduce hazards into the water.	Risk information table for the supply overall
4	Use the Guides to identify: • Causes • Preventive Measures • Corrective Actions	
5	Decide where improvements should be made	Improvement Schedule • Improvements needed • Levels of importance • Timetable • Responsibilities
6	Decide on the order in which improvements need to be made	
7	Draw up a timetable for making the improvements	
8	Note links to other quality assurance systems	Note of other quality assurance systems
9	Prepare contingency plans	Contingency plans for each supply element
10	Prepare instructions for Performance Assessment of the Plan	Set of instructions for review of the performance of the PHRMP
11	Decide on communication policy and needs	Set of instructions for reporting

Source: Ministry of Health (2005)
PHRMP – Public Health Risk Management Plan

4.5 Switzerland Hygiene Regulations

In Switzerland, Article 11 of the hygiene regulation (SR 817.051, HyV), requires application of the HACCP principles. A regulatory guideline (W1002) entitled "Recommendations for a Simple Quality Assurance System for Water Supplies" has been prepared to assist water utilities in complying with this requirement. The regulatory guideline recommends the following nine-step approach (Swiss Gas and Water Industry Association, 2003):

1. Organization, Responsibilities and Expertise
2. Survey of the Water Supply (develop process flow diagram)
3. Assessment of the Water Supply (evaluate hazards, list critical points)
4. Elimination of Hazards (Critical Points)
5. Reduction of Hazards by Maintenance
6. Control of Hazards (Critical Points)
7. Practical Implementation of the Instructions
8. Annual Evaluation of the Water Supply
9. Confirmation of Self-Assessment by Third Party

4.6 Iceland Food Legislation

Since 1995, drinking water in Iceland has been classified as food and waterworks have been classified as food processing companies per amendments to The Foodstuffs Act (http://english.ust.is/media/ljosmyndir/matvaeli/Log_um_matvali_a_ensku.pdf) (Gunnarsdottir and Gissurarson, 2006). Water systems of certain sizes are required by food legislation to implement a HACCP Plan or similar risk management system. Small water systems are required to implement a simpler water safety plan. By 2006, 21 waterworks serving 67 percent of the Icelandic population had implemented HACCP plans or a simpler water safety plan. Guidelines for a simple water safety plan, called "The Five Steps" were developed for small systems by Samorka Federation of Icelandic Energy and Water Works.

4.7 France Regulation on Water Safety

In France, Article 18-2, Optimization of Monitoring, of the French National Transcription: Decree 2001-1220 (Dec. 20, 2001) entitled Water Safety for Human Health, Risk Assessment and Management requires risk assessment, identification of critical control points and control measures.

4.8 Ontario Water Quality Management Standard

In Canada, the legislative responsibility for providing safe drinking water to the public generally falls under provincial or territorial jurisdiction. Each province and territory has adopted legislation to establish requirements to provide clean, safe, and reliable drinking water. In British Columbia, Manitoba, New Brunswick and the territories, the authority for drinking water rests with ministries of health; in all other provinces, this authority is provided by ministries of environment (http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/doc_sup-appui/phi-isp/i_e.html#3)

The Ontario Ministry of the Environment promulgated revisions to the Drinking Water Systems Regulation (O. Reg. 170/03) effective June 5, 2006 in response to waterborne disease outbreaks in Walkerton, Ontario, and North Battleford, Saskatchewan. Owners and operators of municipal residential drinking water systems are required to have an accredited operating authority by establishing and maintaining a quality management system. Minimum requirements for the quality management system are outlined in the Drinking Water Quality Management Standard (Ministry of the Environment 2006). Although this standard does not make specific reference to HACCP or a Water Safety Plan, it includes many comparable elements. The Quality Management Standard includes the following 21 elements:

1. Develop an Operating Plan that establishes and maintains a Quality Management System (QMS)
2. Document a Policy on QMS that illustrates commitment to customers and to maintenance and continual improvement of QMS
3. Include a written endorsement by top management and owner in Operating Plan
4. Identify a Quality Management System representative in the Operating Plan
5. Document a procedure for document and records control in the Operating Plan
6. Describe the water system in the Operating Plan including sources of supply, treatment facilities, distribution system components, and a process flow diagram
7. Conduct and document a risk assessment that identifies and ranks hazards, and that identifies control measures and critical control points
8. Document risk assessment outcomes in the Operating Plan including procedures to monitor and respond to deviations in critical control limits
9. Describe the organizational structure, roles and responsibilities of the Operating Authority
10. Document competencies and training needs for water system staff to maintain water quality
11. Document a procedure for providing sufficient numbers of competent employees to operate the water system and maintain water quality
12. Document procedure to communicate elements of QMS between top management and system owner, Operating Authority personnel, suppliers and the public
13. Identify essential supplies and services for providing safe drinking water, and develop a procedure to ensure the quality of supplies and services
14. Document a procedure to conduct an annual review of system infrastructure
15. Document the Operating Authority’s infrastructure maintenance, rehabilitation and renewal programs
16. Document monitoring programs for process control and finished drinking water quality
17. Document procedures for calibration and maintenance of measurement and recording equipment
18. Document emergency preparedness procedures
19. Document internal audit procedures to evaluate conformity with QMS

20. Document management review procedures for evaluating the effectiveness of the QMS
21. Strive to continuously improve the effectiveness of the QMS

5. Benefits of HACCP

The HACCP system may provide both tangible and intangible benefits to water utilities, including (Fok and Emde, 2004; Davison and Deere, 2004; Smith, 2004; and Kuslikis and White, 2004; Gunnarsdottir and Gissurarson, 2006):

- Improvements in public health protection
- Improved regulatory compliance
- Demonstration of due diligence
- Improvements in design and operation of water system processes
- Improved understanding of risks and risk management
- Improvements in employee skills related to system operation
- Improvements in work processes such as SOPs, monitoring strategies, documentation procedures, and communication methods

The WHO framework for drinking water safety that is based on HACCP and other risk management programs offers many benefits to water utilities. Schmoll (2003) indicates that implementation of a Water Safety Plan provides the following benefits:

- Support in setting priorities
- A structure to organize risk-based management
- Support of multi-agency and multi-stakeholder involvement and communication, as it requires an approach from source to tap
- Demonstration of due diligence and justification of decisions on all levels up to senior management
- Improved system understanding reduces uncertainty in decision-making
- Water Safety Plans change the mindset, impacting the organizational culture
- Having a Water Safety Plan is positive for the reputation
- For small supplies, a Water Safety Plan may be a resource, i.e. instrumental in using resources more efficiently

This section summarizes documented benefits of HACCP. Because the application of HACCP to water systems is relatively new and not well documented in the published literature, several examples are included from the food industry and from personal communications such as e-mails and written correspondence. Some examples given below are not strict applications of HACCP principles but programs or procedures that are similar to HACCP.

Although some benefits have been documented, it is difficult to tie water quality and public health improvements directly to HACCP since the utility may implement multiple system improvements while implementing HACCP. Five Australian utilities that have implemented HACCP and attained certification reported that they have continued to be audited and re-registered each year since they believed that, overall, the benefits of the HACCP system, including the certification discipline, outweighed the costs (Martel et al., 2006)

5.1 Improvements in Public Health Protection

By helping to improve food production processes to prevent contamination, the HACCP system can reduce or prevent the occurrence of food borne illnesses. In October 2003, the USDA/FSIS reported four consecutive annual drops in human *Listeria* infection and a 70 percent decline in positive food samples compared with years prior to HACCP implementation (Fok and Emde, 2004).

5.2 Improved Regulatory Compliance

A preliminary evaluation of HACCP applications in Iceland found that water systems improved compliance with drinking water regulations after implementing HACCP (Gunnarsdottir and Gissurarson, 2006). In the City of Reykjavik, the percentage of samples that complied with regulations increased from a mean value of 94 percent to 99 percent after HACCP implementation in 1997. In Akureyri, a similar analysis showed that after HACCP implementation in 1999, the percentage of samples meeting regulatory requirements increased from 88 percent to 99 percent. Major corrective actions implemented at Akureyri included improvements to 22 water intakes for spring supplies; distribution pipe renewal in areas with high bacterial counts; and cleaning an over-sized main serving the airport.

5.3 Demonstration of Due Diligence

Davison and Deere (2004) illustrate how HACCP can help a utility to demonstrate "due diligence" or the "prevention of foreseeable harm." This demonstration of due diligence is accomplished using five elements of the HACCP system (Davison and Deere, 2004): (1) assessing risks from the sources of supply through to the customer's tap; (2) implementing a risk management system; (3) employing a "culture of compliance;" (4) seeking out and incorporating new knowledge into system processes and procedures; (5) planning for emergencies.

Three of five Australian utilities that participated in the AwwaRF HACCP project (Martel et al., 2006) - South East Water, Yarra Valley Water, and Gold Coast Water - found that HACCP implementation has helped to improve system credibility and demonstration of due diligence or the "prevention of foreseeable harm."

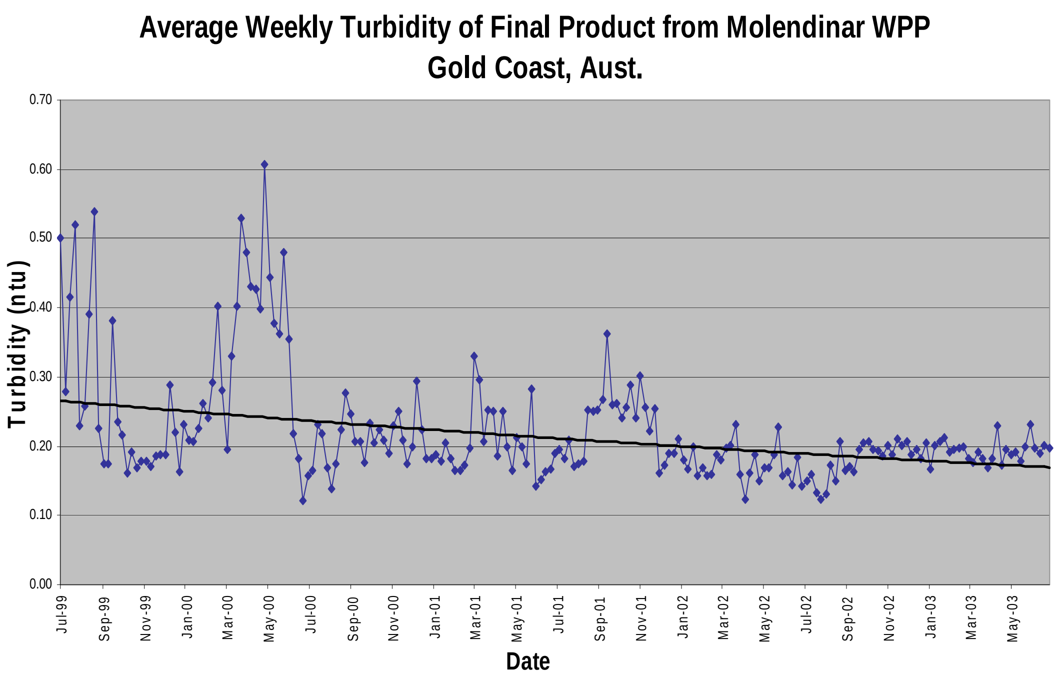
> South East Water attributed these improvements to improved record-keeping practices. At Yarra Valley Water, employees have an improved awareness of water quality risks and management processes. Gold Coast Water noted that the structure of the HACCP system has helped with system credibility and demonstration of due diligence. (Martel et al., 2006)

5.4 Improvements in Water System Processes

Since the Gold Coast Water, Australia HACCP system was put into place in 2001, the water treatment and distribution system performance parameters have seen steady improvement (Smith, 2004). The average weekly turbidity of the finished water has improved from 0.28 NTU in July 1999 to 0.18 NTU in June 2003 as shown in Figure 2. Gold Coast Water implemented a "modified" HACCP system that draws from several risk management techniques (e.g. multiple barrier approach, Partnership for Safe Water, WHO Water Safety Plans, ISO 9000, and the Australian Framework for Water Quality Management) and ties them together within the HACCP system framework (Smith, 2004).

> HACCP has several features that make it appealing as the framework to bind the other philosophies together. Its structure is well known, it is certifiable, it is proven to be robust and it has the flexibility to incorporate different circumstances. (Smith, 2004)

Five Australian utilities have found that water quality improvements did become evident following the implementation of HACCP, but in most cases, those changes did not appear conclusive for three or more years (Martel et al., 2006). Observed water quality improvements included reduced numbers of customer complaints and water quality incidents, and fewer microbial indicators.



Source: Smith (2004)

Figure 2. Average Weekly Turbidity of Final Product

Before HACCP, 0.8 water quality complaints were registered per 1000 properties per year. Within 6 months of implementing HACCP, water quality complaints were reduced to 0.4 per

1000 properties per year.

5.5 Improved Understanding of Risks and Risk Management

Smith (2004) documents a case study at Gold Coast Water in Australia that illustrates how a HACCP excursion report helped the utility to identify a previously unidentified risk in an existing manganese control procedure and its reporting instructions. "The loophole in the HACCP manganese control procedure meant that staff did not technically have to report this particular failure to anyone and this became an attractive option." (Smith, 2004) The HACCP excursion reporting system was developed as part of the HACCP Plan, specifically addressing HACCP Principle 7, Documentation and Recordkeeping. The HACCP excursion report showed that the daily limit of six dirty water calls (Smith, 2003b) had been exceeded on 1 day. Although Gold Coast Water's HACCP Plan includes critical limits on customer calls, they are not really considered to be critical control points (Smith, 2003b). (All of the storage facilities in the distribution system are regarded as CCPs. However, because each reservoir zone is only sampled once per month and each storage facility is inspected on a quarterly basis (Smith, 2003b), the customer calls often provide timely information. A follow-up investigation revealed

a problem where plant staff failed to adequately respond to changes in raw water quality. The existing procedure was subsequently tightened.

5.6 Improvements in Employee Skills

While implementing an integrated risk management system based on HACCP and ISO 9001 and ISO 14001 for 14 water supply systems in the regional municipality of Durham, Canada, Kuslikis and White (2004) found that employee awareness of legislation and regulations improved. Also, training programs across this regional municipality became more consistent and hence more effective and efficient.

The City of Austin, Texas conducted a pilot study on HACCP as part of an AwwaRF-funded research effort. The HACCP pilot study helped the utility to raise employee awareness on several issues (Pedersen, 2004):

- The need to respond quickly to main breaks in small pressure zones
- The location of pressure zone boundaries
- The possible occurrence of boundary zone violations
- The possibility of pressure transients causing low or negative pressure in the distribution system
- The need to maintain positive pressure at all times
- Existing data sources

The HACCP study also helped Austin to improve internal communications (Pedersen, 2004). Survey responses collected at the conclusion of the HACCP training workshop showed that all workshop attendees gained new information on the utility's distribution system management practices or potential hazards. One survey respondent commented that the workshop's dialogue between different departments helped them to better understand how other utility employees do their jobs.

5.7 Improvements in Work Processes

Australian utilities that have implemented HACCP have integrated the HACCP system with systems for quality management, occupational safety, water quality and safety, and environmental considerations (Martel et al., 2006). The utilities found that the principal benefit of this integrated management system was the avoidance of duplication, leading to reduced staff time and costs, and improved process integration.

The Capitol Health region in Edmonton, Alberta, Canada used HACCP principles to develop a new boil water advisory protocol in 1998 (Fok and Emde, 2004).

> The use of the HACCP process resulted in a better understanding of monitoring parameters and fostered communication and understanding between …[the health department and the water utility]. (Fok and Emde, 2004)

While implementing an integrated risk management system based on HACCP, ISO 9001, and ISO 14001, Kuslikis and White (2004) found that the consistency of region-wide procedures improved. The risk management system, implemented from source to tap, also helped to resolve some maintenance issues at water plants, and spurred the undertaking of a comprehensive chemical inventory and cleanup. As part of implementing the risk management system, an electronic library was established to make water system permits, procedures and forms more accessible. It should be noted that no two risk management or HACCP plans will be identical. In identifying and prioritizing hazards, each system has its own needs and priorities, and will therefore focus their plan on the highest ranked hazards.

Gold Coast Water has observed a progressive change in the organizational culture since implementing HACCP (Smith, 2004). For example, at the Mudgeeraba water treatment facility, there was cultural resistance to compliance in year 2002 (Smith, 2003b). The lack of cultural acceptance was dealt with by close internal auditing during the early stages of HACCP implementation and eventually the staff realized that there were benefits to adhering to the system (Smith, 2003b). "Managerial and operational staff has indicated they would be reluctant to go back to the rather 'loose' arrangements that existed 4 years ago." (Smith, 2004)

At Gold Coast Water, procedures have been developed for each process step or significant risk. Each procedure is a formal instruction from the manager to the operational staff (Smith, 2004). These procedures, typically 1 to 3 pages in length, outline the process steps, the risks, the monitoring strategies, control measures, corrective actions, and assignment of responsibilities.

Another case study from Gold Coast Water illustrates how certain operational practices were improved based on data collected for a HACCP excursion report (Smith, 2004). The HACCP excursion report indicated that the water's chlorine residual at a suburban booster station had fallen below a critical limit. An investigation by senior management revealed that the chlorine gas cylinders were empty because no one had been given the responsibility to keep them full. Also, the chlorine residual and other instruments at the booster station had not been calibrated since their installation simply because the instruments had never been placed on a calibration schedule. Although the low chlorine residual may have been detected prior to HACCP, it is unlikely that the incident would have been investigated since no one had been given that responsibility. As a follow-up to this incident, operational and asset management staff improved their practices not only at this booster station, but across the system (Smith, 2004).

6. Challenges of Implementing HACCP

Although the HACCP system may provide many benefits to a water utility, it also may present challenges that are difficult to overcome, such as:

- Resource needs
- Management support and commitment
- Employee support and commitment
- Small system issues
- Large system issues

Case studies from the published literature and personal communications are used to document the challenges of implementing HACCP.

6.1 Resource Needs

The resource needs for developing and implementing a HACCP system are outlined in the AwwaRF report, *Application of HACCP for Distribution System Protection* (Martel et al., 2006) based on experiences of five Australian utilities:

- One-time costs for HACCP training, coaching, technical advice and documentation. Costs can vary depending on the extent to external service providers are utilized.
- Increased water quality monitoring and instrumentation to further evaluate risks or as part of control measures to manage risks. Costs can vary as deemed appropriate by the HACCP team.
- Special investigations, professional services, and/or laboratory testing, to further evaluate risks or to implement control measures.
- Annual HACCP awareness training for new staff and existing staff as needed.
- Personnel costs such as the HACCP coordinator and other staff requirements. The time requirement for a full-time HACCP coordinator varied by utility from 1 month to 12 months depending on how tasks were delegated amongst the HACCP coordinator and other staff, and the amount of work required to implement the HACCP plan.

Since these Australian utilities had all implemented other quality management systems prior to implementing HACCP, their actual costs cannot be compared to a utility implementing only HACCP.

The City of Austin, Texas completed a pilot study for the AwwaRF project but was unable to estimate costs of developing and implementing the HACCP Plan (Martel et al., 2006). Austin found that implementing the HACCP plan was a lengthy time commitment that included HACCP team meetings, coordination meetings with other staff, and time spent on database management. The HACCP team only tracked the time required for team meetings and not other staff time spent implementing HACCP procedures. Because Austin's HACCP Plan was only implemented for one small portion of their distribution system, the resource requirements for implementing HACCP system-wide were not developed. Austin found that existing databases would need to be modified to facilitate the implementation of HACCP system-wide. Databases that track plumbing inspections, cross-connection inspections, waterline disinfection, etc., were not set up with HACCP in mind. Therefore, data retrieval for the pilot study was undertaken manually and was cumbersome.

Gold Coast Water did not add any other staff to implement HACCP but purchased additional instrumentation and increased water quality testing (Smith, 2004). Smith (2004) estimates a 4 to 6 week timeline for developing and implementing a HACCP system for a catchment, treatment or distribution system with no serious process flaws. However, the cultural change could take as long as 6 months (Smith, 2004).

The regional municipality of Durham in Ontario, Canada has learned that the following resource commitments are needed to successfully implement a risk management system (Kuslukis and White, 2004): management support at all levels; top management commitment and participation; a full-time coordinator familiar with the water industry; and involvement of all staff throughout the process. Kuslukis and White (2004) also express caution against underestimating the time commitment, which is huge.

Based on their experiences implementing HACCP in 45 water systems in France, DeBeir and Joret (2004) estimate an average of 30 to 60 person-days to implement HACCP in one system (from the catchment to the customers' taps).

A preliminary evaluation of HACCP implementation in Iceland has shown overall success but limited resources have prevented full implementation of auditing steps (Gunnarsdottir and Gissurarson, 2006).

6.2 Management Support and Commitment

Sydney Water Corporation in Sydney, Australia is also participating in the on-going AwwaRF-funded project, *Application of HACCP for Distribution System Protection*. Sydney Water has initiated development of a HACCP Plan; however, Sydney Water management has not made a decision to utilize the HACCP system (Stevens and Martel, 2004). As a result, the HACCP plan has not been implemented at the operational level. Sydney's experience shows that even a large utility requires commitment at a relatively high management level if HACCP plans are to be implemented operationally. Sydney Water has implemented some of the HACCP steps as part of implementing ISO 9000 and, therefore, do not feel that they need an additional audit (Deere, 2005).

The City of Austin, Texas found that HACCP is more complex than initially envisioned (Pedersen, 2004). Originally, the Utility thought that HACCP would involve identifying critical flow paths within the distribution system and monitoring them more intensively to assure water quality to downstream sites. Instead, the HACCP plan focused on operations and maintenance activities that occur in the distribution system, adding layers of complexity to the existing monitoring program.

6.3 Employee Support and Commitment

Smith (2004) cites the need for a HACCP "champion" who is solely dedicated to administering the HACCP system. "The HACCP champion should have a background in chemistry and microbiology, plus experience in water industry processes." (Smith, 2004)

6.4 Small System Issues

Small systems may face several challenges in implementing HACCP, as summarized by Martel et al. (2006):

- Small systems often lack expertise in one or more topic areas covered by the HACCP Plan. This challenge may be overcome by using consultants or other experts as necessary to help facilitate the HACCP training workshop and to support the utility HACCP team.
- The small utility may lack adequate historical water quality and system data to identify and rank risks/hazards in the HACCP hazard analysis (Step 6). This dilemma, experienced by the South Berwick Water District as part of their Project-pilot study, was addressed by initially focusing the HACCP Plan to collect additional information to evaluate, document, and improve control over these hazards.
- In practice, the small utility may lack adequate manpower or other necessary resources to develop and implement a HACCP Plan independently. In some cases, a small system has received assistance from larger systems with more resources and technical knowledge. For example, the Katherine system that serves 10,000 people in the Northern Territories of Australia received help from its corporate organization, Power and Water Corporation, that is responsible for providing energy, water, sewerage, and communications services throughout the Northern Territory (Martel et al., 2006). In Iceland, guidelines for a simple water safety plan, called "The Five Steps", were developed for small systems by the Samorka Federation of Icelandic Energy and Water Works.

The South Berwick Water District in South Berwick, Maine, a small system serving 4,000 people, participated in the AwwaRF project but was unable to implement their HACCP plan due to limited staff (Martel et al., 2006). Nadeau (2004) explained that, in addition to operating and maintaining the water system, the Water District's three staff members were simultaneously involved in building a new treatment facility, developing a new rate structure, dealing with local and state political issues, and struggling with unanticipated personnel and medical issues.

6.5 Large System Issues

Large water utilities face different types of challenges as compared to small systems in implementing HACCP, as summarized by Martel et al. (2006):

- Communication across departments and between management and operational staff
- Organization-wide coordination on water quality management issues

These challenges can be addressed through the HACCP training workshop and through careful selection of HACCP team members and, most importantly, through strong, proactive support from the highest levels in the organization.

7. HACCP Approach in Hazard Assessments

The first HACCP principle (Conduct Hazard Analysis), as presented in Figure 1, includes three elements: hazard identification, hazard assessment, and identification of control measures. The first two elements are discussed in this section. Control measures are discussed in the next section.

Most U.S. water utilities are familiar with hazard assessments from their experiences with completing federally mandated vulnerability assessments and developing cross connection control programs. For example, in developing a cross connection control program, a utility may identify and rate possible cross-connections as low, medium, or high hazards, and then install (or require the customer to install) backflow prevention devices for high hazard locations. The applicability of utility experiences with vulnerability assessments to the HACCP approach is discussed later in this section.

7.1 Hazard Identification

Once a HACCP team is formed and the preliminary steps completed (e.g., constructing and validating the process flow diagram as presented in Figure 1), "…the HACCP team should list all of the hazards that may be reasonably expected to occur at each step from primary production…and distribution until the point of consumption." (Codex Alimentarius, 1993). To perform this step, the HACCP Team relies on their experience, system knowledge, historical data, and current technical knowledge. In identifying potential distribution system water quality hazards, the HACCP Team should consider:

- Potential physical, chemical, microbiological, and radiological hazards
- Whether the elimination or reduction of the hazard to an acceptable level is essential for water to be considered potable.

Examples of potential hazards to a water distribution system are summarized as follows:

- Contamination due to treatment failure
- Fecal contamination of storage tanks and standpipes
- Backflow event causing contamination
- Contamination caused by negative or low pressure transient resulting in intrusion of

untreated water through submerged air valve, faulty seal or point of leakage
- Contamination caused by fecal material or by foreign inanimate objects (e.g., dirt, mud, timber, plastic) during repair, alterations, or connection to existing mains
- Contamination by hazardous substances as a result of use of products, materials or coatings that are not approved for contact with potable water
- Contaminants introduced by permeation, pipe degradation or corrosion

The system supplying water to Zurich, Switzerland considers four categories of potential risks: personnel that are not properly trained or experienced; materials in contact with drinking water; machines in contact with drinking water; and faulty methods or procedures related to distribution system management (Bosshart, 2003).

The Swiss regulatory guideline (W1002) entitled "Recommendations for a Simple Quality Assurance System for Water Supplies" includes checklists of possible hazards (Swiss Gas and Water Industry Association, 2003). Checklist items that pertain to distribution system reservoirs include the following hazards:

- Natural risks (e.g., trees, landslides, animals, vermin)
- Unsecured access (e.g., doors, windows, ventilation)
- Poorly separated water chambers
- Poor building condition (e.g., concrete, coating, piping)
- Poor water circulation (e.g., fire water reserve)
- Poor ventilation (e.g., water chamber, dehumidification plant)
- Pollution (e.g., wastewater, soiled clothing)
- Unsuitable process control (e.g., no displacement of inlet)
- Materials (e.g., chemicals, cleaning agents)

Checklist items that pertain to piping networks include the following hazards (Swiss Gas and Water Industry Association, 2003):

- Natural risks (e.g., line breaks)
- Unsecured access (e.g., hydrants, gate valves)
- Unfavorable pressure conditions (e.g., suction of external water)
- Impaired functionality (e.g., motors, controllers)
- Blocked access (e.g., shut-off valves)
- Missing or incorrect flushing (e.g., mains, hydrants, fountains)
- Improper repair work and connections
- Unsecured customer installations (e.g., immersions, pressure pumps)
- Consumer behavior (e.g., seasonal operation)

7.2 Hazard Assessment

The first HACCP principle (Conduct Hazard Analysis) also includes an assessment of each identified hazard (WHO, 1997). For each hazard, the HACCP Team determines its likelihood of occurring, and its potential seriousness. Mullenger, Stevens and Deere (2003) outline several considerations to be included in this evaluation:

- The path(s) that could allow contamination to occur;
- Frequency of occurrence of the hazard;
- Perseverance of contaminants; and
- Severity of consequences if the hazard was to occur (including potential adverse health effects and survival or growth of microorganisms of concern)

This assessment is typically completed in a workshop setting through group discussions and consensus.

The HACCP Team should determine the most appropriate manner for incorporating assessment criteria into their risk assessment. This could be either qualitative or quantitative (Mullenger, Stevens and Deere, 2003). For example, the Team could use a risk score or risk rating factor to compare hazards. At its most simple, a semi-quantitative analysis could be used as follows (Standards Australia/Standards New Zealand, 1999):

Risk Factor = Likelihood x Severity of Consequences.

Figure 3 presents an example matrix for assigning a numerical value to the “Likelihood” and “Consequences” factors.

Risk Factor Matrix:		***Severity of Consequences***				
		Insignificant (No impact / not detectable)	**Minor** (Customer Complaint)	**Moderate** (Impact on Customer Charter)	**Major** (Impact on Operating License)	**Catastrophic** (Public Health Risk)
Likelihood	Almost Certain (Once a day)	5	10	15	20	25
	Likely (Once a week)	4	8	12	16	20
	Moderate (Once a month)	3	6	9	12	15
	Unlikely (Once a year)	2	4	6	8	10
	Rare (Once every 5 years)	1	2	3	4	5

Source: Standards Australia/Standards New Zealand (1999)

Figure 3. Example Risk Factor Matrix

Depending on available resources, the HACCP team decides how many hazards can be addressed by the HACCP Plan (e.g., all hazards with a risk score >10 will be addressed) and how they will be prioritized.

An example hazard analysis is summarized in Table 4. This example is a subset of the hazard analysis completed for the South Berwick Water District in South Berwick, Maine on June 25, 2003 as part of the ongoing AwwaRF 2856 project entitled *Application of Hazard Analysis Critical Control Point for Distribution System Protection* (Nadeau, 2003). Utility staff identified the potential hazards of concern. The risk scores for each hazard were assigned as a result of discussions and consensus by workshop attendees. In addition to utility staff, the HACCP workshop attendees included several “outside experts” including engineers familiar with the South Berwick system, state and EPA regulators, and a microbiologist.

Table 4 Example Hazard Analysis and Control

Hazard Event	Severity of Consequences (score using 1 to 5 scale with 5 being most severe)	Likelihood of Occurrence (score using 1 to 5 scale with 5 being most likely)	Risk Factor = Likelihood x Severity	Existing Control Measures	Additional Control Measures Recommended by HACCP Team
Backflow through an unprotected cross-connection	4	5	20	• Utility installs double check valves on residential services • Commercial customers install backflow prevention device as required • Utility maintains good records of backflow prevention devices • System static pressure >40 psi system-wide	• Utility needs to enforce testing of commercial backflow prevention devices. • Public education • The feasibility of testing backflow prevention devices at multi-family units should be further evaluated (Nadeau et al. 2003).
Contamination via Storage Facility Vents	5	2	10	• Storage tank site fenced and well-maintained • Gravel road to site is gated • Site inspection 3x weekly • Insect screening on vents kept in good repair	• On-site security camera • SCADA enabled intrusion alarm
Main Break	5	2	10	• Disinfection and flushing of all main breaks before placing back into service	• Review inspection procedures • Review water quality testing procedures

Source: Adapted from Nadeau (2003)

Note: The information presented in this table has been made possible through funding from the Awwa Research Foundation. The information is based upon intellectual property which is jointly owned by Cooperative Research Centre for Water Quality and Treatment and the Foundation. The Foundation retains its right to publish or produce the jointly owned intellectual property in part or its entirety.

8. HACCP Approach in Control of Contamination

Once hazards have been identified and ranked according to their likelihood of occurrence and severity of consequences, the HACCP Team focuses on how to eliminate or reduce the seriousness of the highest ranked hazards. This is accomplished with HACCP Principles 1 through 5 (aka steps 6 through 10) as illustrated in Figure 1.

In HACCP Principle 1 or step 6, the HACCP team identifies existing control measures that are being used within the distribution system, and any additional control measures that systems may consider for future operations. Typical control measures for distribution system hazards include maintenance of positive pressure at all times; use of sanitary procedures during construction; and adequate construction of all storage and distribution facilities. Table 3 lists control measures for several hazards identified by South Berwick Water District (Nadeau, 2003).

In HACCP Principle 2 (aka step 7), the HACCP team identifies critical control points, defined as steps at which control can be applied and is essential to prevent or eliminate a safety hazard or reduce it to an acceptable level (WHO, 1997). If a subsequent step in the process will further control the hazard, then the point being considered may not be a critical control point. The process flow diagram, developed in Step 4, is a helpful reference when evaluating critical control points. Examples of critical control points in the distribution system include chemical addition points, storage facilities, water main repair sites, and points of possible cross connections.

In HACCP Principle 3 (aka step 8), the HACCP team establishes critical limits to assess whether a particular control measure is effective. If this critical limit is exceeded or not met, it triggers the need for a corrective action. The critical limit can be either a numerical limit (e.g., chlorine residual concentration, system pressure) or a yes/no type response on whether a particular control measure was completed (e.g., a site inspection, training course, communication with contractor). For example, the City of Austin, Texas identified each construction site as a critical control point (City of Austin, 2003). Several control measures were developed to manage potential hazards at new construction sites. One control measure is to maintain intact pressure zone boundaries. The critical limit for this control measure is that no valves are to be opened by contractors between pressure zones. If this critical limit is breached, corrective actions include closing valves to isolate the area, and issuing a written warning to the contractor or a verbal warning to the site inspector. Utilities are familiar with the critical limit concept through compliance with Maximum Contaminant Levels established by the SDWA regulations for various water quality parameters.

In HACCP Principle 4 (aka step 9), the HACCP Team develops a monitoring plan to measure the status of the distribution system water quality and efficacy of the control measures in place. Monitoring is discussed in the next section.

In HACCP Principle 5 (aka step 10), the HACCP team develops the corrective action procedures needed for each significant potential hazard identified through the hazard analysis. Examples of corrective actions used in the distribution system include flushing, disinfection, and cleaning storage facilities.

9. HACCP Approach in Distribution System Monitoring

Monitoring is a critical component of the HACCP approach to control contamination as discussed in the previous section. Each monitoring activity is documented in the HACCP Plan, including the following information:

- Monitoring parameters
- Monitoring locations
- Monitoring procedures
- Frequency of monitoring
- Responsible Person

The results of the hazard analysis can help the utility redefine monitoring and inspection points within the distribution system.

At Gold Coast Water in Australia, improved monitoring and reporting procedures implemented as part of the HACCP Plan have provided more information to management and have motivated operational staff to work harder to avoid failures (Smith, 2004). Operational staff was consulted during development of the HACCP plan to identify realistic critical limits and monitoring procedures. When a critical limit is exceeded at Gold Coast Water, the operators submit an excursion report to management (Smith, 2004). For example, a plant operator may file an excursion report because they have failed to maintain treated water pH for 4 hours due to aging lime dosing equipment. Management can quickly review these excursion notices and decide if they represent minor incidents or if further inquiry is warranted. Operators do not like reporting excursions so they try harder to avoid having failures in the first place. It is hard to cover up failures because the utility has numerous on-line devices (e.g., turbidity, pH, chlorine) and close internal auditing methods that reveal cover ups (Smith, 2004). Auditing methods are discussed below in Section 10.

At Gold Coast Water's Mudgeeraba plant, Smith (2003b) reports that there was initially under reporting of a turbidity problem due to inferior monitoring (one combined meter compared to six meters at another plant). There was also more cultural resistance to compliance at this plant and it took a change to instrumentation and some close internal auditing to reveal serious problems at that plant in 2002. Two problems were revealed. One was that operators had poor skills in dosage optimization in changing conditions. Secondly, the backwash system components were in poor condition, which compromised filter performance under certain conditions. The lack of cultural acceptance was dealt with by closer internal auditing in the early stages and eventually staff realized that there were benefits all round if everyone adhered to the system (Smith, 2003b).

Monitoring strategies associated with a HACCP Plan do not rely solely on water quality testing but may also include inspections and checks on various databases or other utility records. For example, as summarized in Appendix A, the City of Austin, Texas focused on two hazards for their HACCP Plan – cross-connections and new construction sites (City of Austin, 2003). Monitoring strategies for evaluating control measures for the cross connection hazard include the following:

- Plumbing inspections and water protection surveys to identify any unprotected cross connections and to check for working backflow prevention devices
- Plumbing inspections and water protection surveys to check on repairs of failed backflow prevention devices
- Pressure monitoring throughout the distribution system to evaluate whether system pressure is being maintained
- Reviews of the utility's database to check if annual inspections of backflow prevention devices were conducted
- Visual inspection of on-site septic systems to check for system failures

Monitoring strategies for the new construction site hazard include the following:

- Phone and radio contact with site personnel to check on unauthorized use of system valves
- Visual inspection of contractor disinfection practices on new water lines
- Water quality samples to check coliform bacteria counts and free chlorine levels of water in new mains prior to being placed into service
- Monitoring tank water level and pressure point alarm levels that would indicate if any valves were opened between two pressure zones
- Site inspections to check if contractors utilized the One-Call system (a communication system that provides a toll-free number for contractors/designers to call facility owners prior to excavating to prevent damage to underground facilities and utility lines) to mark water utility lines
- Reviews of sign-in sheets for training workshops to check whether site inspectors attended required training sessions

10. HACCP Approach for Verification

Verification is the use of methods, procedures, or tests to determine if the water utility is in compliance with the HACCP Plan and/or whether the HACCP Plan needs modification and revalidation. HACCP principle 6 (Step 11), illustrated in Figure 1, requires the water supplier to conduct internal verification activities to assure that the HACCP plan and its associated procedures are being followed. HACCP principle 6 also encourages external verification of the utility's HACCP plan and procedures by an independent third party. To pass a HACCP audit, the system would be scrutinized for conclusive evidence that the HACCP Plan is effective when followed properly. For example, the Plan's monitoring procedures should be effective at identifying failures; failures should be detected early enough to allow corrective actions to be implemented; corrective actions should be effective in protecting the drinking water (Deere and Davison, 1998).

Australian utilities that have implemented HACCP reported that verification activities (auditing), though sometimes uncomfortable for operating staff, is a necessary and useful element of HACCP (Martel et al., 2006). Auditing ensures that periodic reviews will be conducted, and also keeps utility staff and management up-to-date on important issues.

This section describes internal verification procedures at one Australian utility, and external verification programs in the U.S., Switzerland and New Zealand.

10.1 Internal Verification Procedures

At South East Water Ltd. in Australia, internal verification procedures include the following (Mullenger, 2002):

- Random water quality sampling to substantiate that the water is safe
- Daily check records such as indicator organisms and customer complaints
- Weekly audits to ensure that only equipment designated for water use is being used for repairs
- Checks on appropriate corrective actions (booster chlorine dosing or flushing)

The HACCP Plan is reviewed annually at a minimum both internally and by an independent auditor. The Plan is also reviewed in the following circumstances (Mullenger, 2002):

- Changes to water quality zone boundaries or the disinfection process
- Equipment or facility modifications such as covering an open reservoir
- Regulatory amendments
- Changes in piping materials or repair techniques
- Occurrence of a significant hazardous event such as a security breach

10.2 External Verification Programs

In the United States, NSF International provides a HACCP registration program that verifies that a water utility's HACCP Plan is controlling known hazards based on the internationally accepted standard, *Codex Alimentarius* (www.nsf.org). NSF International's registration process involves the following elements:

- A desktop audit of HACCP documentation to identify strengths, weaknesses and opportunities for improvement
- An on-site readiness review to evaluate whether the utility is ready for registration
- An on-site registration audit to comprehensively assess the HACCP system
- On-going surveillance audits to ensure the HACCP system is being maintained

Currently, no systems in the United States have become registered for HACCP, but there are United States utilities that are registered for NSF ISO 9000 and ISO 14001. More than 300 systems in Europe and elsewhere have NSF registration for HACCP. The ISO registration process does not include an evaluation of risk.

Health authorities in Switzerland developed an inspection method for evaluating food production and distribution enterprises including drinking water suppliers (Walker 2003). Four aspects of a water supplier are judged: their self-assessment program; water quality; processes (e.g., monitoring, disinfection) and activities (e.g., staff training) used to control hazards; and buildings/equipment/devices. Each of the four aspects is given a score related to the perceived safety level (bad, poor, fair or good). The overall safety score is the arithmetical average of the four scores. In 2002, inspections conducted at 1,500 water systems rated 95 percent of water suppliers at the "good" or "fair" safety levels. The inspection criteria, methods and reports are practical and use simple language so that results can be clearly understood by the water distributor, the regulators and the consumers. The inspection can be completed in 2 to 8 hours, depending on the size of the company or water utility. Problems identified during inspections are specified in the inspection report along with recommended corrective measures. More frequent inspections are conducted at water suppliers with poor scores.

Proposed legislation in New Zealand will require water supplies to be audited to ensure that the Public Health Risk Management Plans have been prepared and are being implemented (Nokes, 2001). Health Protection Officers will carry out this assessment by performing the following tasks:

- Verification of the adequacy of the risk assessment, the risk management plans and the contingency plans prepared by water suppliers
- Verification that the risk management plans are being implemented
- Verification of operator competence in sampling and "field" and "process control" analyses, and checking the validity of calibration of field analysis methods
- Verification that continuous analyzers have been properly calibrated
- Verification of data quality in the Water Information System New Zealand (WINZ), an electronic database system for water quality data for public drinking water systems
- Management of the link between district and national WINZ
- Verification that the drinking-water supply complies with the Drinking-Water Standards for New Zealand: 2000
- Sampling for surveillance and some field testing
- Training small laboratory operators in sampling and approved analytical tests (optional function)
- Assessment of the effectiveness of water suppliers' complaint management procedures
- Drawing inconsistencies in the Ministry of Health drinking-water management procedures to the attention of the Ministry

To be able to carry out these tasks, assessors will be trained, and their competence accredited by an internationally recognized accreditation agency (Nokes 2001). Assessors will need the following competencies (Nokes, 2001):

- A public health qualification
- Good knowledge of legislation relating to drinking-water
- Good knowledge of the Ministry of Health drinking-water policy and documentation

- Good working knowledge of drinking-water treatment and distribution practice
- Good competence with the WINZ electronic drinking-water information base
- Knowledge of the concepts of risk, risk management and risk communication
- Knowledge of assessment and auditing of risk management systems
- Ability to assess the competence of drinking-water suppliers
- Ability to carry out "field" and "process" sampling and analyses, and to assess the competence of drinking-water supply staff in performing these functions
- Knowledge of the principles of calibration of continuous monitors, and checking that the instruments are recording correctly
- Ability to assess the "fitness for purpose" of equipment and procedures
- Knowledge of enforcement practice, chain of evidence, etc.
- Competence in training
- Communication skills

11. HACCP Approach for Documentation and Record-Keeping

"Efficient and accurate recordkeeping is essential to the application of a HACCP system. HACCP procedures should be documented." (Codex Alimentarius, 1993) Examples of HACCP documentation include all information used during the development of the HACCP Plan, site sampling plans, monitoring data, corrective actions implemented, internal and external audit reports, employee training records and regulatory reports. All HACCP documents and records should be dated and signed (Mullenger, 2002). As with other sensitive information related to water system security and vulnerabilities, the HACCP Plan and supporting documents should be controlled in a secure manner.

Smith (2004) cites a case study that illustrates the benefits of improved documentation procedures and record keeping practices. Before the HACCP system was put into place, Gold Coast Water had no record of system failures—no one reported the frequency or magnitude of failures (Smith, 2003b). A HACCP excursion reporting system was implemented as part of the HACCP Plan. In December 2002, the Health Department advised Gold Coast Water of a small outbreak of cryptosporidiosis in one part of the city. The Health Department needed to know if this outbreak was caused by the public water supply. Within 20 minutes of receiving the call, the utility was able to collate comprehensive data records that indicated the outbreak was not likely caused by the water supply. These records included weekly counts for *E. coli* at the source of supply; 24 hour trend data for various water quality parameters (e.g. raw water turbidity, dosed water pH, filtered water turbidity, plant chlorine residuals); supply reservoir inspection reports; weekly water quality data for a sampling location adjacent to the area of concern; and consumer call records. The utility had a high degree of confidence in the information provided to the Health Department because the sampling and laboratory work was carried out by a certified lab and the trended data was provided by instruments with up-to-date calibration records and verified several times daily against a reference instrument (Smith, 2004). No *Cryptosporidium* monitoring records were available.
Another case study from Gold Coast Water (Smith, 2004) illustrates how HACCP documentation and recordkeeping can provide improved information to regulators. For example, regulators "…have access to almost real time results *representative* of the

utilities supply system." (Smith, 2004) The HACCP excursion reporting system also provides explanations for each event where a critical limit was breached.

12. Supporting Programs

The HACCP system alone is not enough to ensure the quality and safety of the water reaching customers' taps. Like all risk management systems, HACCP depends on key supporting programs to be effective:

- Commitment from all levels of the organization to HACCP
- Good operational practices as described in standard operating procedures (SOPs)
- A compliance culture with strong auditing to ensure procedures are followed
- Document control and data management systems
- Raw material and product traceability
- Ongoing education and training of personnel (Mullenger, Stevens and Deere, 2003)

Prior to initiating a HACCP Plan, it is important to identify these other programs that may contribute valuable information related to the condition of the distribution system and distribution system water quality. The distribution system HACCP plan may be integrated with these programs to avoid duplicative work. The programs may already exist in some form but may need improvement or augmentation.

The AWWA Standard G200-Distribution Systems Operation and Maintenance provides specifications for distribution system programs and standard operating practices that can be important tools for maintaining water quality. Examples of supporting programs may include a water main cleaning and flushing program, a tank maintenance and inspection program, and a valve maintenance program. Examples of specific SOPs for the water distribution system may include hydrant and valve opening procedures, tank inspection procedures, and sanitary procedures associated with water main repair. The G200 standard emphasizes the need for specific water quality goals, action plans to respond to problems and written procedures. Specific water quality goals for the distribution system may include maximum retention time/water age for finished water storage facilities, minimum disinfection residual levels, and numbers of customer complaints. As with other supporting programs, compliance with the AWWA G200 standard is advisable prior to implementing HACCP.

Gold Coast Water in Australia has developed a number of SOPs to support their HACCP Plan (Smith, 2003a). SOPs for the distribution system include the following:

- Distribution Water Quality Analysis and Interpretation
- Investigating Dirty Water Complaints
- Reservoir Inspections
- Rechlorination

Each SOP references the HACCP Plan and related critical limits and critical control points. Each one also details its objective, procedures, corrective actions, and reporting activities.

Fok and Emde (2004) emphasize that the effectiveness of a HACCP program is dependent on the education level and interest by staff to implement the program.

13. Summary

The purpose of this paper is to review existing literature, research data and case studies on the HACCP system for controlling potential hazards as it applies to water distribution systems.

For some drinking water systems, current distribution system management practices may leave these systems vulnerable to contamination, as evidenced by failures linked to waterborne disease outbreaks. Recently, the water industry has begun to move towards a more proactive approach to managing the safety of water supplies by incorporating quality assurance principles. Inquiries into two recent waterborne disease incidents in Sydney, Australia and Walkerton, Canada both recommended that water utilities incorporate quality assurance principles for guiding water quality protection.

Originating in the 1960's, HACCP was designed to ensure safety of food and beverages from microbiological hazards for the first NASA manned space missions thus preventing astronauts from falling victim to gastroenteritis while in space (NASA, 1991). HACCP has been applied to food production processes since the 1980s and to drinking water systems since the mid-1990s. The World Health Organization (WHO) guidelines for HACCP, *Codex Alimentarius*, have been adopted internationally as the primary recognized food safety methodology for risk management. The current HACCP guideline was developed in 1997 by the Codex Alimentarius Commission (http://www.who.int/foodsafety/codex/en).

The Codex Alimentarius Commission defines 12 sequential steps (or 5 initial steps and 7 major principles) for planning and implementing a HACCP system (WHO, 1997):

Step 1 – Assemble a HACCP Team
Step 2 – Describe the Product
Step 3 – Identify Intended Use
Step 4 – Construct a Flow
Step 5 – Validate Process Flow Diagram
Step 6 – Conduct Hazard Analysis
Step 7 – Identify Critical Control Points
Step 8- Establish Critical Limits
Step 9 – Identify Monitoring Procedures
Step 10 – Establish Corrective Action Procedures
Step 11 – Validate/Verify HACCP Plan
Step 12 – Establish Documentation and Recordkeeping

The information prepared in completing these 12 steps constitutes the utility's HACCP Plan.

In several countries, HACCP steps and principles are being incorporated into national guidelines or regulations. WHO's current drinking water guidelines include a framework for drinking water safety based on HACCP and other risk management systems. Countries that use WHO guidelines as the minimum criteria for water system regulation are in the process of developing Water Safety Plans.

The HACCP system may benefit the water utilities in the following ways:

- Improvements in public health protection
- Improved regulatory compliance
- Demonstration of due diligence
- Improvements in design and operation of water system processes
- Improved understanding of risks and risk management
- Improvements in employee skills related to system operation
- Improvements in work processes such as SOPs, monitoring strategies, documentation procedures, and communication methods.

The HACCP system may present challenges that are difficult to overcome, including the following:

- Resource needs
- Management support and commitment
- Employee support and commitment
- Small system issues
- Large system issues

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Appendix A

Application of HACCP Principles
City of Austin, Texas

Note: The information presented in this Appendix has been made possible through funding from the Awwa Research Foundation. The information is based upon intellectual property which is jointly owned by Cooperative Research Centre for Water Quality and Treatment and the Foundation. The Foundation retains its right to publish or produce the jointly owned intellectual property in part or its entirety.

AUSTIN WATER AND WASTEWATER UTILITY

HAZARD ANALYSIS AND CRITICAL

CONTROL POINT PLAN

(September 10, 2003)

Prepared By:

City of Austin
Water and Wastewater Utility
Environmental and Regulatory Services Division
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XXX-XXX-XXXX

January 19, 2007

HAZARD ANALYSIS AND CRITICAL CONTROL POINT PLAN

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INTRODUCTION

Hazard Analysis Critical Control Point (HACCP) is a food quality control program originally developed for the National Aeronautics and Space Administration (NASA) in the early 1960's. It focuses on the process of preparing food for consumption by astronauts in space that is safe to eat. HACCP looks at each step in the process of preparing, packaging, storing, and delivering food. Critical points where the food might become contaminated are identified and monitored so that food safety is assured. In subsequent years, HACCP has been widely adopted in the food industry.

In recent years there has been discussion of applying HACCP to the drinking water industry. The Partnership for Safe Water, in which the Utility participated, is in many respects a HACCP program. It focuses on turbidity as a critical control point in the treatment of drinking water. Australian Utilities have been in the forefront of applying HACCP to control source water quality prior to treatment. Even though the application of HACCP to distribution systems is not yet fully developed, the EPA has been studying it as they revise the Total Coliform Rule and in the development of a Distribution System Rule.

BACKGROUND

In March 2002, the American Water Works Association Research Foundation released a request for proposal entitled Application of Hazard Analysis and Critical Control Points (HACCP) for Distribution System Protection. The objective of the research is to evaluate the HACCP model for application in protecting and maintaining distribution system water quality. The first major tasks in the research project is to review previous HACCP plans to see how they were tailored to meet the unique needs of the users and tailoring a HACCP for use in the distribution system. The next step is to develop a model HACCP system and have it reviewed by Utilities with an emphasis on the ability to implement the HACCP. The review was performed predominantly by Australian Utilities who have applied HACCP principals to source water protection. The final tasks are to develop and implement a HACCP Plan based on the model and adjust the model as necessary based on implementation results.

The Utility was approached by the lead researcher, Economic and Engineering Services, Inc., and asked to participate as a research team member. The Utility agreed to participate because a better understanding of the critical control points in the distribution system will assist in optimizing the operation of the distribution system. Our commitment to the project was estimated to be at least 200 man-hours, with an in-kind value of at least $15,000. Actual tasks include participating in a HACCP workshop in our office, development of a HACCP plan based on the model, implementation of the HACCP plan in at least a portion of our distribution system, assembling system records, and performing monitoring and analysis activities. The Southwest C Pressure Zone was selected as a manageable area in which to apply the HACCP plan.

The complete research team consists of Economic and Engineering Services, Inc., the Cooperative Research Centre for Water Quality and Treatment, Melbourne Water, Sydney Catchment Authority, Sydney Water Corporation, Austin Water and Wastewater Utility, South Berwick Water District, Northern Territories Power and Water Authority, South East Water, Yarra Valley Water, Gold Coast Water, Monash University, Egis, and the Victoria Department of Human Services.

MODEL HACCP PLAN DEVELOPMENT

In the initial tasks of the research, the research team developed and refined a twelve-step model for preparing and implementing a HACCP plan for a typical distribution system. The following are the twelve steps and a brief description of them:

A. STEP 1 – ASSEMBLE A TEAM

Pull together a multidisciplinary team to plan, develop, verify, and implement the plan.

STEP 2 – DESCRIBE THE PRODUCT

Describe the product, in this case drinking water, including its source, treatment, storage, distribution and any existing standards for product safety.

STEP 3 – IDENTIFY INTENDED USE

Describe how the product is used and the major users.

STEP 4 – CONSTRUCT A FLOW DIAGRAM

For a comprehensive HACCP, this would be a schematic showing sources of water, details of treatment, storage, pumping, and distribution to end users. For a HACCP directed toward a distribution system, the schematic would be restricted to showing the water flow path from the treatment plant to end users.

STEP 5 – VALIDATE PROCESS FLOW DIAGRAM

As a critical element around which the HACCP is based, the flow diagram needs confirmation of accuracy by the HACCP team.

STEP 6 – CONDUCT HAZARD ANALYSIS

Using the process flow diagram, identify hazards, their likelihood of occurrence, potential consequences, and control measures.

STEP 7 – IDENTIFY CRITICAL CONTROL POINTS

Based on the hazard analysis select the most significant hazards for control. These are typically points in the process where the consequences of failure are irreversible.

STEP 8 – ESTABLISH CRITICAL LIMITS

Determine critical limits for the critical control points that will trigger a corrective action. A critical limit is a criterion which separates acceptability from unacceptability.

STEP 9 – IDENTIFY MONITORING PROCEDURES

Establish monitoring points, frequency, and responsibility.

STEP 10 – ESTABLISH CORRECTIVE ACTION PROCEDURES

Develop plans for follow up activity when performance measures for critical control points are exceeded.

STEP 11 – VALIDATE/VERIFY HACCP PLAN

Have the HACCP team and other affected parties check the HACCP plan for accuracy, ability to implement, and potential effectiveness.

STEP 12 – ESTABLISH DOCUMENTATION AND RECORD KEEPING

Develop a record keeping system to track system performance at critical control points.

AUSTIN'S HACCP PLAN

On May 21, 2003, the Utility held a one-day HACCP workshop. Attendees included staff with a broad array of skill sets from various divisions within the Utility with varying perspectives on Utility and distribution system operation. In particular, attendees included individuals from the Water Lab, Systems Planning, Cross-Connection Control, Process Engineering, Distribution System Operation, Water Quality, Regulatory Compliance, and the State's Regulatory Agency. Workshop attendees were able to completed Steps 1 through 7 and identified a core group of people to serve as the HACCP Team. The Team met several times during the summer of 2003 to finalize the remaining steps of the plan prior to implementation. The following are the results of the workshop and work of the Team and serves as the HACCP plan that will be implemented:

B. STEP 1 – HACCP TEAM

The following are members of the Utility's HACCP team:

Name	Position	Telephone	Fax	Email
Barrios, Rosie	Water Laboratory Supervisor	xxx-xxx-xxxx	xxx-xxx-xxxx	xxxxxx@xxxxx
Bennett, Tony	TCEQ Regulatory Manager	xxx-xxx-xxxx	xxx-xxx-xxxx	xxxxxx@xxxxx
Bohr, Onnie	Infrastructure Superintendent	xxx-xxx-xxxx	xxx-xxx-xxxx	xxxxxx@xxxxx
Burazer, Jane	Asst. Director of Treatment	xxx-xxx-xxxx	xxx-xxx-xxxx	xxxxxx@xxxxx
Kuhn, Robert	Cross Connection Control Supervisor	xxx-xxx-xxxx	xxx-xxx-xxxx	xxxxxx@xxxxx
Lutes, Teresa	Engineer/Planne r	xxx-xxx-xxxx	xxx-xxx-xxxx	xxxxxx@xxxxx
Ojeda, Edward	Construction Inspector	xxx-xxx-xxxx	xxx-xxx-xxxx	xxxxxx@xxxxx
Pedersen, Dan	Water Quality Manager	xxx-xxx-xxxx	xxx-xxx-xxxx	xxxxxx@xxxxx

STEP 2 – PRODUCT DESCRIPTION

The following description of the Utility's drinking water (product) was prepared at the May 21, 2003 HACCP Workshop:

Step	Description
Source Water	Austin's source of supply is the Colorado River. Raw water for the Southwest C pressure zone is currently diverted at Lake Austin.
Treatment Processes	Raw water for the Southwest C pressure zone is treated at the Ullrich Water Treatment Plant using treatment processes consisting of: lime softening, recarbonation/pH adjustment, chloramination, filtration, ferric sulfate, fluoride, and addition of sodium hexametaphosphate
Storage After Treatment	Treated water is stored at the Ullrich Plant in two 10 mg clearwells, and in the distribution system in tanks.
Conveyance	The Utility owns a contiguous distribution system that serves a population of approximately 770,000 through roughly 183,000 service connections. The distribution system contains 2,995 miles of water mains of a wide variety of materials including cast iron, ductile iron, PVC, asbestos cement, and reinforced concrete cylinder. The distribution system also contains 30 tanks ranging in size from 300,000 to 34,000,000 gallons. Because of the varied topography in the Utility's service area, the distribution system is divided into eight major pressure zones. The flow path to the Southwest C pressure zone, which is the subject of the HACCP plan is shown in the attached flow diagram.

Step	Description
Special Controls	*Federal or State Drinking Water Regulations* • Water pressure must be maintained at 35 psi under normal conditions and 20 psi during emergencies throughout the distribution system. • Maintain a minimum total chlorine residual of 0.5 mg/L throughout the distribution system. • Monthly flushing of dead-end water mains that have a history of customer complaints. • Inspection of new service connections. • An active cross-connection control program. • Water main separation from sanitary sewers. • Finished water storage design and construction requirements. • Annual cleaning and inspection of finished water storage tanks. • Routine distribution system total coliform monitoring. *City of Austin requirements* • Maintain total chlorine residual of 1.0 mg/L throughout the distribution system. • Routine maintenance program for public and private fire hydrants • Monthly chlorine residual and total coliform monitoring at finished water storage tanks.

STEP 3 – IDENTIFY INTENDED USE

Based on the results of the May 21, 2003 workshop the following table lists the typical uses and customer classes for the Utility's drinking water:

Intended Uses	Intended Consumer
• Drinking • Manufacturing, including semi-conductor manufacturing processes which are sensitive to total organic carbon and trihalomethane levels • Irrigation • Culinary uses • Fire fighting • Construction uses • Sanitary uses (toilet flushing and showers) • Medical uses (hospitals, dialysis centers, dental offices) • Product water (Coca Cola and Abbott Labs)	• Residential • Commercial • Industrial

STEP 4 – CONSTRUCT A FLOW DIAGRAM

The process flow diagram is included as Attachment A.

STEP 5 – VALIDATE PROCESS FLOW DIAGRAM

The process flow diagram was developed on May 21, 2003, reviewed for accuracy by July 28, 2003, and finalized on August 15, 2003.

STEP 6 – CONDUCT HAZARD ANALYSIS

At the May 21, 2003 HACCP Workshop, Utility staff conducted a hazard analysis for the distribution system in the Southwest C Pressure Zone. The complete results of this hazard analysis are shown in the following table. While there were a large number of potential hazards identified for the Southwest C Pressure Zone, Utility staff decided to base its HACCP pilot study on two particular hazard events that scored high marks in the hazard analysis – cross-connections and new construction.

Hazard Analysis Table

Hazard Event	Severity of Consequences (Score Using 1 to 5 Scale)	Likelihood of Occurrence (Score Using 1 to 5 Scale)	Risk Factor = Likelihood x Severity	Existing Control Measures	Additional Required Control Measures
<u>Cross-Connection</u> Example: Irrigation(existing) or hydrant vandalism	<u>5</u>	<u>5</u>	<u>25</u>	• Identify cross-connections and install backflow prevention devices • Repair failed backflow devices • Require annual inspections of backflow prevention devices • Perform field surveys especially at commercial installations with significant potential for cross-connections • Inspect plumbing of new customers • Check for cross-connections when responding to customer complaints • Maintain distribution system pressure • Monitor OSSF and report failures	• Provide public education such as safety presentations
<u>New Construction</u> (including inappropriate valve turning)	<u>5</u>	<u>4</u>	<u>20</u>	Note: No new construction inspectors were present at the May 21, 2003 workshop and a comprehensive discussion of "Existing" and "Additional" control measures was not possible.	• Inspection • Design standards which include plan review, monitoring of pressure and bacteria upon installation, and good materials storage practices

Hazard Event	Severity of Consequences (Score Using 1 to 5 Scale)	Likelihood of Occurrence (Score Using 1 to 5 Scale)	Risk Factor = Likelihood x Severity	Existing Control Measures	Additional Required Control Measures
					• Inspector training which includes training on water quality – related issues • Coordination between Water Quality and Supply and Public Works groups • Ensure that storm water does not reach trenches • Make contractor responsible for water quality-related condition of new mains • Flushing to clean new mains • Review of finished project • Limit valve operations to approved personnel only • Disinfect new mains • Improve education of operators with respect to valve operation • Ensure the correct amount of pressure is available in areas of pressure zones and with potential for transients
<u>Septic Tanks</u>	<u>3</u>	<u>3</u>	<u>9</u>	• Inspect and certify (County) septic systems to demonstrate that they meet county criteria • Inspect (County) septic fields upon sale	• Inspect septic systems annually • Hook customers up to city sewer system

Hazard Event	Severity of Consequences (Score Using 1 to 5 Scale)	Likelihood of Occurrence (Score Using 1 to 5 Scale)	Risk Factor = Likelihood x Severity	Existing Control Measures	Additional Required Control Measures
				of home	
Water Main Repair, Breaks, and/or ground shifting	3	4	12	• Follow SOPs for repair, shut-down, water quality and pressure testing • Meet state requirements for depressurization • Supervise repair work • Maintain positive pressure during work where possible • Use standard products for disinfection, etc. • Use different tools on drinking water main repairs and wastewater repairs	
Sewer Mains	2	5	10		
Vandalism	3	3	9		
Main break external to zone	4	2	8		
Break external to zone	4	2	8		
Hydraulic transients	2	2	4		

Hazard Event	Severity of Consequences (Score Using 1 to 5 Scale)	Likelihood of Occurrence (Score Using 1 to 5 Scale)	Risk Factor = Likelihood x Severity	Existing Control Measures	Additional Required Control Measures
Nitrification or Residual below 1.0 mg/L (Austin's goal)	2	2	4		
Nitrification or no residual	4	1	4		
Tanks Example: unmaintained screens, ponding on top, or cleaning	1	4	4		

STEP 7 – IDENTIFY CRITICAL CONTROL POINTS

As mentioned in the Introduction, the Utility's role in the research project is to develop and implement a pilot of the model HACCP. To facilitate this role, the Utility selected a portion of its distribution for purpose of the pilot. Workshop participants were asked for suggestions on which portion of the distribution system was most suitable for the pilot with the Southwest C Pressure Zone given as a possibility because of a number of boil water advisories issued there in recent years. Additionally, the Southwest C Pressure Zone has other features that make it appropriate for a HACCP plan. It contains four sites (Blue 2, Blue 11, Blue 19, and Maroon 1) that are routinely monitored under the Total Coliform Rule and provides a history of water quality in the area. Additionally, one of those sites (Blue 19) is a monitoring point for compliance with the Disinfection By-Products Rule, which further enhances understanding of water quality in the area. The Southwest C Pressure Zone is located on the extreme southwestern edge of the distribution system, containing maximum water age for that portion of the distribution system. Water traveling to this area passes through two tanks and three pump stations, which have the potential to affect water quality by increasing water age. It is a growing area with new construction occurring. It is a semi-rural area with older homes on septic systems that, should they fail, might pose a hazard to leaking water mains subject to low or negative pressure transients.

At the May 21, 2003 workshop, participants identified twelve hazard events and for purposes of the HACCP selected the two highest-ranking hazards as areas to focus on. The HACCP Team met subsequently and identified specific critical control points within these two hazards. The critical control points are as follows:

Cross-connection Hazard

Each connection to a potential hazard within the customer's plumbing system
Throughout Southwest C Distribution System

New Construction Hazard

At each site of new construction

STEP 8 – ESTABLISH CRITICAL LIMITS

Critical limits for the cross-connection hazard and the new construction hazard are listed in the two tables below.

STEP 9 – IDENTIFY MONITORING PROCEDURES

Monitoring of the critical limits for the cross-connection hazard and new construction hazard are listed in the two tables below.

STEP 10 – ESTABLISH CORRECTIVE ACTION PROCEDURES

Corrective actions, in the event that a critical limit is exceeded, for the cross-connection hazard and new construction hazard are listed in the two tables below.

Table for the Cross Connection Hazard

Critical Control Point (Step 7)	Control Measure (Step 6)	Critical Limits (Step 8)	Validation (Step 8)	Monitoring (Step 9)	Corrective Action (Step 10)
Each connection to a potential hazard within the customer's plumbing system	Identify cross-connections and install backflow prevention assemblies & devices	Critical Limit #1: Presence of working backflow preventio n device	Texas Commission on Environmental Quality's regulations for public drinking water and City ordinances	*Method:* Plumbing inspections and water protection surveys	*Existing Corrective Actions:* Enforce requirements using penalties, etc.
				Monitoring Frequency: Annual testing of backflow prevention on high hazard situations.	Additional Corrective Actions Required: *Enforcement actions on non -compliant customers.*
				List Responsible Person: Plumbing Inspections – Robert Brown, chief plumbing Inspector Water Protection Surveys – Robert Kuhn, water Protection Supervisor	*Immediate Action Plan: Permit and* Inspect new and remodeled plumbing installations.
				Monitoring Location(s): At residential, commercial, industrial, and institutional customers.	*List Responsible Person:* Robert Kuhn
				Tracking: WPTS Database	
	Repair failed backflow assemblies	Critical Limit #1: Presence	Texas Commission on Environmental	*Method:* Plumbing inspections and water protection surveys	*Existing Corrective Actions:* Enforce requirements using penalties, etc.

Critical Control Point (Step 7)	**Control Measure (Step 6)**	**Critical Limits (Step 8)**	**Validation (Step 8)**	**Monitoring (Step 9)**	**Corrective Action (Step 10)**
		of working backflow preventio n device	Quality's regulations for public drinking water and City ordinances	*Monitoring Frequency:* Annual testing of backflow prevention on high hazard situations.	Additional Corrective Actions Required*: Enforcement actions on non -compliant customers.*
				List Responsible Person: Robert Kuhn, water Protection Supervisor	• *Immediate Action Plan: Permit and* Send Customer Notice • Send reminder notice • Run delinquent report
				Monitoring Location(s): At residential, commercial, industrial, and institutional customers.	*List Responsible Person:* Robert Kuhn
				Tracking: WPTS Database	
	Require annual inspections of backflow assemblies	Critical Limit #1: Backflow assemblie s pass operationa l test	Texas Commission on Environmental Quality's regulations for public drinking water and City ordinances	*Method:* On line & manual data entry	Existing Corrective Actions: *Enforce requirements using penalties, etc.*
				Monitoring Frequency: Monthly	*Additional Corrective Actions* Required: enforcement actions on non -compliant customers

Critical Control Point (Step 7)	Control Measure (Step 6)	Critical Limits (Step 8)	Validation (Step 8)	Monitoring (Step 9)	Corrective Action (Step 10)
				Responsibility: *Robert Kuhn*	*Immediate Action Plan:* • Send Customer Notice • Send reminder notice • Run delinquent report • Terminate service or file criminal charges as necessary.
				Monitoring Location(s): At residential, commercial, industrial, and institutional customers.	*List Responsible Person:* Robert Kuhn
				Tracking: WPTS Database	
Throughout Southwest C Distributio n System	Inspect plumbing of new customers	Critical Limit #1: Complian ce with Plumbing Code	City ordinances	*Method:* Visual inspection by City plumbing inspectors	*Existing Corrective Actions:* Enforcement per the Plumbing Code and Cross-connection Ordinance
				Monitoring Frequency: Each occurrence of new plumbing construction	*Additional Corrective Actions* Enforcement actions on non - compliant customers.

Critical Control Point (Step 7)	**Control Measure (Step 6)**	**Critical Limits (Step 8)**	**Validation (Step 8)**	**Monitoring (Step 9)**	**Corrective Action (Step 10)**
				List Responsible Person: Plumbing Inspections – Robert Brown, chief plumbing Inspector Water Protection Surveys – Robert Kuhn, water Protection Supervisor	*Immediate Action Plan:* Schedule at least two water protection surveys in the sample area
				Monitoring Location(s): At residential, commercial, industrial, and institutional customers.	*List Responsible Person:* Robert Kuhn
				Tracking: WPTS Database	
	Check for cross-connections when responding to customer complaints	Critical Limit #1: No potable water services with a cross-	Texas Commission on Environmental Quality's regulations for public drinking water and City ordinances	*Method:* Visual inspection	Existing Corrective Actions: *Enforce requirements using timeframe for correction and penalties, etc.*
				Monitoring Frequency: Each customer complaint upon customer demand	*Additional Corrective Actions* Required: enforcement actions on non -compliant customers

Critical Control Point (Step 7)	Control Measure (Step 6)	Critical Limits (Step 8)	Validation (Step 8)	Monitoring (Step 9)	Corrective Action (Step 10)
		connectio n		*Responsibility:* Robert Kuhn and his staff	*Immediate Action Plan:* • Send Customer Notice • Send reminder notice • Run delinquent report • Terminate service or file criminal charges as necessary.
				Monitoring Location(s): Customer properties.	*List Responsible Person:* Robert Kuhn and his staff
				Tracking: WPTS Database	
	Maintain distribution system pressure	Critical Limit #1: Pressure should be above 35 psi under normal conditions. Pressure may be as low as 20 psi during emergency conditions	Texas Commission on Environmental Quality's regulations for public drinking water	*Method:* Pressure transducer and data logger. Pump station discharge points on the SCADA System w/ tracking through SCADA.	Existing Corrective Actions: *Turn on additional pumps to raise pressure.* *Search for main breaks* *Issue boil water advisory, if necessary.*
				Monitoring Frequency: Continuous with data recorder.	Additional Corrective Actions Required:
				Responsibility: Dan Pedersen	*Immediate Action Plan:*

Critical Control Point (Step 7)	Control Measure (Step 6)	Critical Limits (Step 8)	Validation (Step 8)	Monitoring (Step 9)	Corrective Action (Step 10)
				Monitoring Location(s): SCADA monitoring locations.	*List Responsible Person:* Turning on pumps – pumping division Search for main breaks -- field crews Boil water advisory – Dan Pedersen.
				Tracking: Utility's SCADA system.	
	Monitor on-site septic facilities for failure	Critical Limit #1: No above ground discharges from failing septic systems	City ordinances	*Method:* Visual, olfactory inspection.	*Existing Corrective Actions:* On-site inspection and enforcement plan
				Monitoring Frequency: As part of customer complaints, plumbing inspections, and surveys.	*Additional Corrective Actions Required:* Municipal court fines for not correcting failing septic system
				Responsibility: Robert Kuhn Seyed Miri	*Immediate Action Plan:* Follow Utility process for correcting failing septic systems.
				Monitoring Location(s): Throughout the Southwest C Distribution System as other inspections are made.	*List Responsible Person:* Seyed Miri and OSSF staff
				Tracking: SRs and monthly report to the TCEQ.	

Table for the New Construction Hazard

Critical Control Point (Step 7)	Control Measure (Step 6)	Critical Limits (Step 8)	Validation (Step 8)	Monitoring (Step 9)	Corrective Action (Step 10)
At each site of new construction	Valve operation	Critical Limit #1: No unauthorized valve opening or closing	Standard specifications, Section 510.	*Method:* Via telephone or radio call.	Existing Corrective Actions: *Close valves to isolate affected area.* *Speed memo/warning to contractor or verbal warning to inspector.* *Special billing/fines.*
				Monitoring Frequency: Each occurrence.	Additional Corrective Actions Required:
				Responsibility: W&WW Dispatch. Infrastructure Support.	*Immediate Action Plan:* Close valve(s).
				Monitoring Location(s): At the Dispatch Office	*List Responsible Person:* Inspector or valve crew.
				Tracking: Through SRs, work orders, or log books.	
	Disinfection of water lines	Critical Limit #1: All water mains to be disinfected prior to being placed in service	AWWA Standards and City standard specifications	*Method:* Visual or olfactory.	Existing Corrective Actions: *Isolate main, disinfect, and flush.*
				Monitoring Frequency: Each occurrence.	Additional Corrective Actions Required:
				Responsibility: On site inspector.	*Immediate Action Plan:* • Isolate main • Flush • Sample • Issue Boil Water Advisory

Critical Control Point (Step 7)	Control Measure (Step 6)	Critical Limits (Step 8)	Validation (Step 8)	Monitoring (Step 9)	Corrective Action (Step 10)
				Monitoring Location(s): Job site.	*List Responsible Person:* Valve Crews, Dan Pedersen
				Tracking: Water lab approval letters.	
		Critical Limit #2: All water mains to have typical COA water (bacti and free chlorine negative) prior to being placed into service	State regulations, AWWA standards, and City SOPs	*Method:* Grab samples	Existing Corrective Actions: Flush main and resample. If necessary redisinfect.
				Monitoring Frequency: Each new main.	Additional Corrective Actions Required:
				Responsibility: On site inspector.	*Immediate Action Plan:*
				Monitoring Location(s): Job site.	*List Responsible Person:*
				Tracking: Water lab approval letters.	
	Intact Pressure Zone Boundaries	Critical Limit #1: No valves opened between pressure zone boundaries	Standard Operating Procedures	*Method:* SCADA tank or pressure point alarm levels.	Existing Corrective Actions: *Close valves to isolate affected area.* *Speed memo/warning to contractor or verbal warning to inspector.* Special billing/fines.
				Monitoring Frequency: Each occurrence.	Additional Corrective Actions Required:
				Responsibility: Water and Pumping Division	*Immediate Action Plan:* Close valve(s).

Critical Control Point (Step 7)	Control Measure (Step 6)	Critical Limits (Step 8)	Validation (Step 8)	Monitoring (Step 9)	Corrective Action (Step 10)
				Monitoring Location(s): South First Street Office.	*List Responsible Person:* Inspector or valve crew.
				Tracking: Through the SCADA system.	
	No contractors to accidentally hit water mains while performing their work	Critical Limit #1: Contractors to contact One-Call prior to conducting work.	One-Call Law requirements in place except for emergencies. Contractor's responsibility to locate underground utilities and renew One-Call ticket every 30 days. A general construction notes requirement	*Method:* Visual – markings on the ground.	Existing Corrective Actions: *Job site shut down.* *Speed memo/warning to contractor.* Special billing/fines.
				Monitoring Frequency: Each occurrence and periodically throughout the project.	Additional Corrective Actions Required:
				Responsibility: Project Inspector.	*Immediate Action Plan:*
				Monitoring Location(s): Job site.	*List Responsible Person:*
				Tracking: An access database.	
	Inspector Training	Critical Limit #1: Inspectors to have essential knowledge to perform their work.	Standard operating procedures	*Method:* Attendance sign in sheets.	*Existing Corrective Actions:* None, course attendance is voluntary.
				Monitoring Frequency: Annually at each bacti sampling training session.	*Additional Corrective Actions Required:*
				Responsibility: Water Quality Manager – Dan Pedersen.	*Immediate Action Plan:*

Critical Control Point (Step 7)	Control Measure (Step 6)	Critical Limits (Step 8)	Validation (Step 8)	Monitoring (Step 9)	Corrective Action (Step 10)
				Monitoring Location(s): Bacti sampling training session classroom.	*List Responsible Person:*
				Tracking: Attendance sign in sheets.	

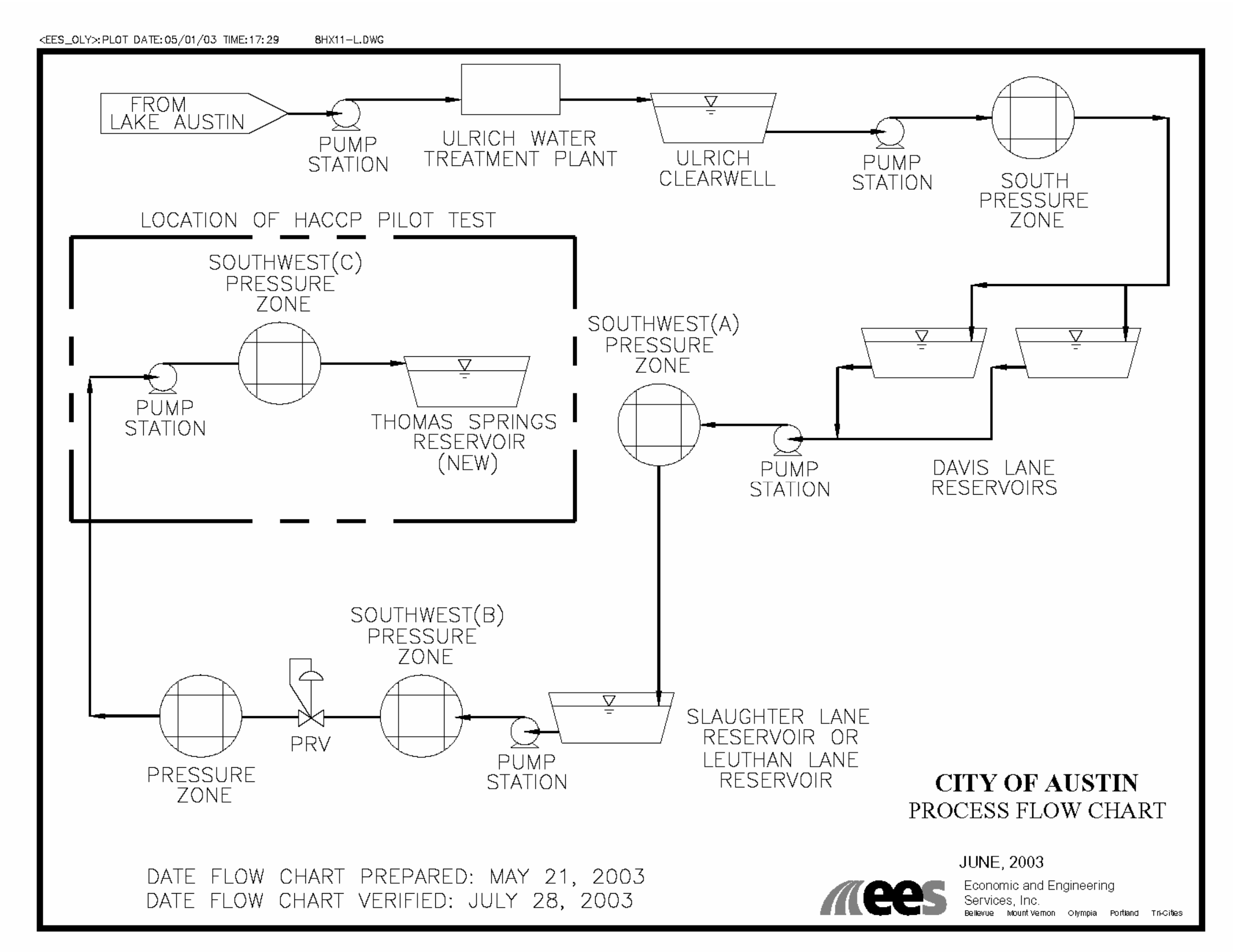
STEP 11 – VALIDATE/VERIFY HACCP PLAN

The HACCP plan was validated at meetings on August 15 and 28, 2003 by members of the HACCP Team. Additional validation was done with inspection staff and staff of the On-Site Sewage Facilities Division.

STEP 12 – ESTABLISH DOCUMENTATION AND RECORD KEEPING

Tracking of monitoring of the critical limits is shown in the cross-connection hazard and new construction hazard tables.

Attachment A – Process Flow Diagram



Attachment B – List of Streets in the Southwest C Pressure Zone

Street	Block
Acton Drive	
Anchusa Trail	
Arroyo Canyon	
Black Mountain Cove	
Black Mountain Drive	
Blue Hill Drive	
Boling Drive	
Bright Star Lane	
Candelaria Drive	
Chiplea Cove	
Cima Circle	
Circle Drive	
Claxton Drive	
Clear Night Drive	
Cobble Stone	
Conifer Cove	
Copper Path	
Covered Bridge Cove	
Covered Bridge Drive	
Crackling Creek Drive	
Crest View Road	
Dawning Court	
Deer Haven Road	
Distant View Drive	
Dorella Lane	
El Dorado Drive	
El Rey Boulevard	8400-9300
Espanola Trail	

Street	Block
Medicine Creek Drive	
Midwood Parkway	
Mowinkle Cove	
Mowinkle Drive	
Murmuring Creek Drive	
Nandas Trail	
Oak Valley Road	
Old Bee Caves Road	8700
Phoenix Pass	
Pitter Pat Lane	
Putnam Drive	
Rawhide Trail	10100-10700
Rehobeth Circle	
Rehobeth Cove	
Rising Smoke Loop	
Roaring Springs Cove	
Roaring Springs Drive	
Roaring Springs Road	
Rockwood Circle	
Rosson Drive	
Sam Carter Drive	
Samuel Bishop Drive	
San Diego Road	
San Juan Pass	
Scenic Brook Drive	7900-8100
South Bend Avenue	
Southview Road	
State Hwy 71 West	8700-11000

Feather Hill Road	
Felts Lane	
Fenton Drive	8600-8800
Foggy Mountain Drive	
Fort Benton Drive	
Granada Hills Drive	8400-9000
Haskel Drive	
Hudson Loop	
Indian Scout Trail	
Jay Creek Cove	
Kathleen Drive	
Kingston Drive	
La Fauna Path	
La Fauna View	
La Tosca Drive	
Lauralan Drive	
Lenape Cove	
Lenape Trail	
Streamside Drive	
Summer Sky Drive	
Sunset Ridge	
Superview Drive	
Thomas Springs Road	
Thomas Wood Lane	
Thunderbird Cove	
Thunderbird Road	
Towana Circle	
Towana Trail	
Trenton Drive	
US Hwy 290	7700-8600
Weir Hills Road	5800
West Creekview Drive	
West View Road	
Williamson Creek Drive	

Attachment C – Southwest C Pressure Zone Map