Water safety plans: bridges and barriers to implementation in North Carolina

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ABSTRACT

First developed by the World Health Organization, and now used in several countries, water safety plans (WSPs) are a multi-step, preventive process for managing drinking water hazards. While the beneficial impacts of WSPs have been documented in diverse countries, how to successfully implement WSPs in the United States remains a challenge. We examine the willingness and ability of water utility leaders to implement WSPs in the US state of North Carolina. Our findings show that water utilities have more of a reactive than preventive organizational culture, that implementation requires prioritization of time and resources, perceived comparative advantage to other hazard management plans, leadership in implementation, and identification of how WSPs can be embedded in existing work practices. Future research could focus on whether WSP implementation provides benefits such as decreases in operational costs, and improved organization of records and communication.

Key words | drinking water hazards, implementation, North Carolina, water safety plans, water supply

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INTRODUCTION

Water safety plans (WSPs) are a comprehensive drinking water quality risk management process, emphasizing prevention, instead of reaction, to hazardous events (WHO 2004, 2012; Davison *et al.* 2005; Bartram *et al.* 2009; Howard & Bartram 2014). WSPs require the proactive identification and management of risks in a drinking water system through six primary steps: (1) assembling a team; (2) system analysis; (3) operational monitoring; (4) management and communication; (5) review, approval and audit; and (6) assessing experience and future needs (Bartram *et al.* 2009; see Figure 1) (for a detailed step-by-step guide to implementing WSPs, see Bartram *et al.* (2009)). Benefits of using WSPs include increased regulatory compliance, decreased microbial growth in the water system, and lower incidence of clinical diarrhea (Gunnarsdottir *et al.* 2012). The goal of WSPs is to provide safe drinking water through effective water supply practices, prevention of source water contamination, adequate water treatment to meet water quality targets, and prevention of re-contamination during storage and distribution of drinking water (Davison *et al.* 2005).

A dynamic methodology, a WSP is embedded in the daily operations and culture of a water system. Implementing a WSP requires a team that drives the plan, understands the water catchment area, treatment and distribution systems, has the capacity to maintain the water system, continues internal training and consumer awareness, and pursues continuous review and refinement of the WSP. While a WSP is a large undertaking for a water system team, the World Health Organization (WHO) points out that, 'The time it will take to establish a WSP will depend upon a number of factors: staff experience; amount of data available on the water supply; size and complexity of the supply; and other systems that have already been adopted' (Davison *et al.* 2005, p. 126).

Organizational culture that is shared assumptions about work practices influences the adoption and implementation

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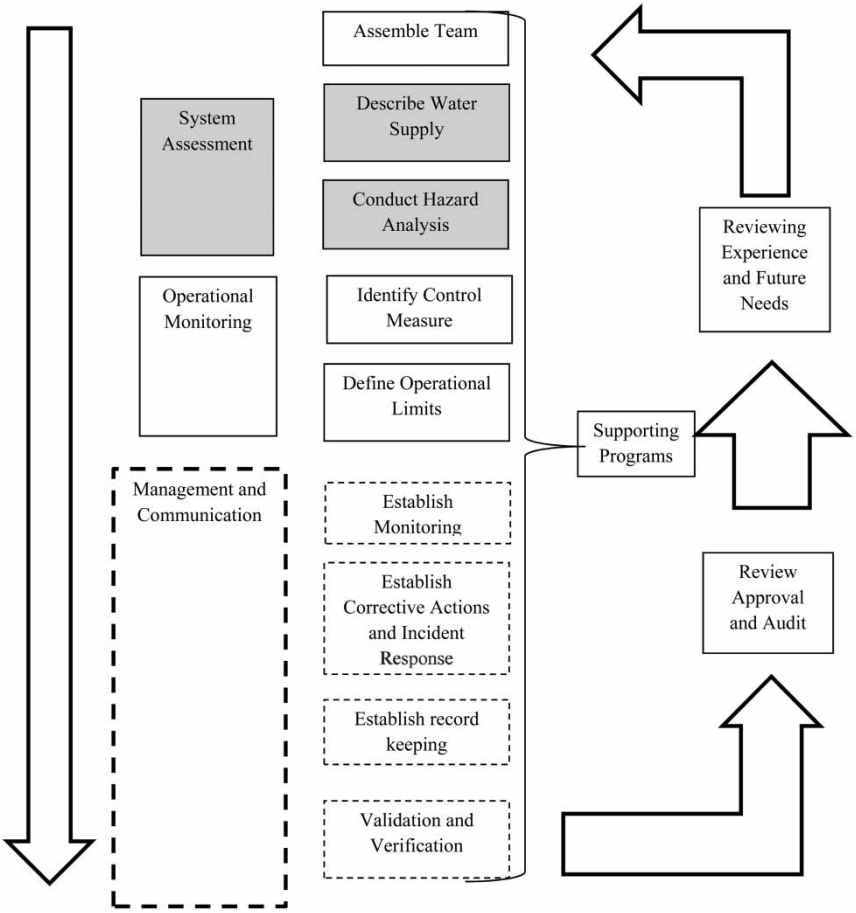

Figure 1 | Water safety plan (Davison *et al.* 2005, p. 20).

of WSPs (Summerill *et al.* 2010a). Examples of enabling characteristics of organizational culture are proactive, involved leaders, attention to staff and stakeholder needs, accountability, and commitment to continual improvement. Disabling cultural characteristics include poor communication, inflexibility, and complacency. Challenges in the implementation of WSPs are partly due to the difficulty in evaluating the benefits of WSPs, although frameworks for evaluation have been suggested, as shown in Iceland, Bangladesh and Latin America (Gunnarsdottir *et al.* 2012; Mudaliar 2012; Gelting *et al.* 2012).

WSPs have been used in water systems in diverse countries such as Iceland, Bangladesh, New Zealand, and England (Mahmud *et al.* 2007; Gunnarsdottir *et al.* 2012; Parker & Summerill 2013; Nijhawan *et al.* 2014), thus demonstrating their use in both developed and developing countries. For countries that have consistently high compliance with water safety standards, WSP implementation arose from a desire to improve public health, especially following a contamination event. For example, in Australia in 1998, the treated water supply for Sydney had high levels of *Cryptosporidium* that led to discussions about how to prevent such contamination from happening (Hamilton *et al.* 2006). This event led to the introduction of national regulations requiring water systems to carry out hazard analysis and critical control points, which are similar to WSPs, in identifying potential hazards (Hamilton *et al.* 2006). Other countries, such as New Zealand and Germany, also had a desire to improve public health. In New Zealand, the Ministry of Health developed national regulations requiring WSPs, and in Germany, the Federal Ministry of Health and the Federal Environment Agency led the dialogue promoting adoption of WSPs (Health Amendment Act 2007; Schmoll *et al.* 2011). For the successful implementation

of WSPs, clear public health messages and goals are critical (Summerill *et al.* 2010b).

The focus on improving public health and the involvement of the Ministry of Health in countries such as Australia, New Zealand, and Germany differs in attitude from the USA. While the USA develops water quality standards based upon protecting public health, regulations reflect an environment of meeting regulatory standards for contaminant levels rather than preventing contamination at each water system. Additionally, the US Environmental Protection Agency (USEPA) regulates 114 contaminants across the country and does not specify different contaminants for different contexts. While these regulations have substantially reduced the risk of waterborne disease, system-specific risks exist and can cause contamination events that pose a risk to public health. Since these risks are different depending on the water system, it becomes important to identify specific hazards and risks for each water system in addition to meeting national guidelines and regulations.

In the USA, many water utility operators, while unfamiliar with the term 'water safety plan', are already practicing many parts of a WSP that are required by US drinking water regulations, such as the National Primary Drinking Water Regulations and National Secondary Drinking Water Regulations (Code of Federal Regulations Title 40 – Protection of the Environment, Parts 141–143). Some of these similarities between WSPs and US drinking water regulations include carrying out a source water quality assessment, meeting water treatment requirements, and identifying hazards through sanitary surveys. However, there are also gaps between WSPs and US drinking water regulations, stemming from the differences in the preventive nature of WSPs compared to the national standards and best treatment processes required by US national regulations. These differences can be seen in the areas of internal risk assessments and prioritization, management procedures and plans, and team procedures and training (Baum *et al.* 2015). WSPs offer an improved sense of ownership and greater understanding of a specific water utility's risks compared to the rules-based approach for national water regulations. WSPs could potentially benefit US regulations through enhanced management of procedures and plans, internal risk assessment and prioritization, and team procedures and training.

The purpose of this study was to examine attitudes toward deciding to use WSPs (adopting), and bridges and barriers of practicing risk management with WSPs (implementation) by water suppliers in the US state of North Carolina. To the knowledge of the authors, WSPs are not being used by US water utilities. Since WSPs are not legally required in the USA, they would be a voluntary risk management approach. Water utilities in North Carolina provide an insightful case study due to diverse characteristics, such as urban and rural settings, varied hydrological and geographical contexts, and rapid population growth. The overarching research question which guided the study was: 'What are the institutional conditions for implementing WSPs in North Carolina water utilities?' We examined this question in two parts: (1) What is the willingness of water utilities to implement WSPs? and (2) What is the ability of water utilities to implement WSPs? *Willingness* refers to the explicit verbal expression of interest, by water utility personnel, in deciding to use a WSP approach. *Ability* refers to the explicit description of the capability of a utility to integrate WSPs into their risk management practice by utility personnel.

METHODS

We employed qualitative methods because the study examined perceptions of water operators and managers, and in some cases town administrators, regarding how and why they would use WSPs. The unit of analysis is a water utility that distributes water to households. Since interviewing all personnel within a utility and aggregating their perspectives was not realistic due to time and resource constraints, we instead interviewed individuals who work closely with water quality management, such as water operators and managers.

Water utility selection

We selected utilities in five of the seven administrative regions defined by the North Carolina Department of Natural Resources, based on our ability to connect with water utility managers and operators during the period of the study. These utilities varied in size, as defined by USEPA based on

population served (Table 1). The authors selected utilities based on their willingness to participate in this study, determined by an initial email or telephone call to the utility.

Data collection

Data were collected through semi-structured interviews (after Wengraf 2001) because of the open and flexible nature of the research questions. This method was advantageous because operators provided insightful information that the researchers may not have been aware to ask. Utility personnel, and some town managers if they were speaking on behalf of the utility, were asked about their willingness and ability to implement parts of or all of a WSP. All water utility names, locations, and identities of personnel who were interviewed were kept confidential to protect the interview participants from repercussions for voicing their views, and to encourage candidness. The average duration of each interview was 1 hour, which provided ample time for the interview participant to narrate their views. Interviews were audio recorded and transcribed verbatim to maintain accuracy of responses by interview participants in the analysis. The study is exempt from further review from the Institutional Review Board of the University of North Carolina at Chapel Hill (record number 12-2522).

After explaining the basic principles of WSPs to the interview participant(s), three main questions were asked of participants: (1) What are your current practices of risk management of drinking water quality? (2) Based on our description of WSPs, how do your existing practices match WSP processes? (3) Would your utility be willing to implement the WSP approach? Why or why not?

Table 1 | Characteristics of North Carolina water utilities interviewed

Utility size defined by USEPA (population served) (SDWIS 2014)	Number of utilities interviewed
Very small (25–500)	0
Small (501–3,300)	2
Medium (3,301–10,000)	5
Large (10,001–100,000)	3
Very large (> 100,001)	1

Data analysis

Ethnography and grounded theory perspectives (Miles *et al.* 2014) were appropriate for analyzing interview transcripts because staff perceptions were gathered in their natural work environment of their water utility. Using Nvivo qualitative analysis software to assist with organizing the eleven interview transcripts and notes, we analyzed the interviews in two phases: Phase 1: Identification of themes to group words, phrases, or sentences (e.g. 'background information on water utility' or 'information sharing'); and Phase 2: Categorization of themes into sub-themes to explain and describe results of the interviews in relation to the research questions (e.g. 'tariffs' and 'non-revenue water' as sub-themes of 'infrastructure maintenance').

RESULTS

The results are divided into four sections according to the size of the water utilities – small, medium, large, and very large – following USEPA guidelines of water utility sizes for populations served. We find it useful to categorize the results as such because management characteristics tend to be similar among water providers that serve similarly sized populations, as they have somewhat similar numbers of employees, financial resources, and infrastructure size. Findings for each of the categories of utility size are summarized according to four themes: willingness to implement WSPs; ability to implement WSPs; current risk management practices for distributing safe water; and perceived benefits of WSPs to water quality risk management. Maintaining confidentiality of each utility and their personnel, we refer to the utilities as Small 1 (S1), Small 2 (S2), Medium 1 (M1), Medium 2 (M2), etc.

Small water utilities

Staff from two small water utilities (501–3,300 population served) that purchase their water from external sources and have approximately four staff members were interviewed (Table 2). S1 was not willing to implement WSPs, as its staff perceived that WSPs were not applicable to their system because they purchase water from another water system, and therefore stated that they have no control

Table 2 | Summary of small water utilities' views on implementing WSPs

Small utilities pop. served: 501–3,300	Willingness to implement WSP	Ability to implement WSP	Current risk management practices (water quality)	Perceived benefits of WSPs
Small 1 (S1) Purchases water from other source	No	No direct comment on ability. Utility did not perceive that WSPs are applicable to their system because they purchase water from another system	Flushing the polluted water out of the system	Communication with county level administration
Small 2 (S2) Purchases water from other source	Yes If financial benefits and relevance to the North Carolina case were clear	No, not enough staff time	Operation and maintenance in emergency protocol	Prevention scenarios

over the initial quality of the water or how a WSP would influence its risk management. In contrast, S2 staff reported that they would be willing to implement WSPs if financial benefits for the North Carolina case were clearer.

Willingness to implement WSPs may have roots in utilities' perceived ability to do so. As mentioned above, S1 does not treat its own water, but instead purchases water from another supplier and then distributes the purchased water to households. Even though S1 is transporting water from a supplier from which S1 claims they have no control over the quality, S1 still monitors water quality by analyzing samples once a week for chlorine levels. According to S1, a primary way for them to correct poor water quality is to flush the water in the distribution system. Therefore, S1 commented that WSPs may be more applicable to a larger system that treats its own water, and has more 'control' over the options for managing water quality.

Willingness to implement WSPs may also be linked to current risk management practices in a utility. Four employees work in S1, which contributes to more efficient information sharing and problem solving, '*…there's just four of us, so it's easy to pass information back and forth, and everybody's got input*' (S1, Water Operator). S1's review of risk management practices involves their four employees evaluating options and learning from infrastructure malfunctions shortly after an event, and determining how to make repairs. S1 is developing a database that records leaks and breaks through basic Geographic Information Systems mapping software and use of Google Nexus tablets for taking photos, and entering and checking data in the field. S1 also has an emergency management protocol that works through scenarios, steps, and stakeholders. In contrast, S2 does not have an emergency management protocol: '*… we don't have a playbook* [*that states*]*, if this happens this is what you need to do*' (S2, Town Manager). On preventive action, S2 is concerned about the tradeoff of immediate needs and long-term planning, '*If you give me the choice of implementing it* [*WSPs*] *and not implementing it, I'm going to look at the fact that I've got two people and I'm going to say we need to worry more about the bypass we had at the sewer plant that hit the creek than going out and back flushing some lines or something like that*' (S2, Town Manager).

S1 stated that a potential benefit of WSPs for them may be communication to various stakeholders, such as county officials and municipal customers to discuss how to maintain water quality. S2 did not see the clear benefits of implementing WSPs in North Carolina and stated the need for a balance of cost and prevention, and relevance to the North Carolina context, '*Well, we need to do this, it happened in Milwaukee but we need to be doing this* [*too*] *in North Carolina when maybe the problem was entirely different and there is not that problem here*' (S2, Town Manager).

Medium water utilities

Five of the eleven utilities interviewed were of medium size, each serving a population between 3,301 and 10,000 (Table 3). While three utilities were willing to implement WSPs (with two utilities not willing), all medium sized

Table 3 | Summary of medium water utilities views on implementing WSPs

Medium utility Pop. served: 3301–10,000	Willingness to implement WSPs	Ability to implement WSPs	Current risk management practices (water quality)	Perceived benefits of WSPs
Medium 1 (M1)	No	No Low on staff time, but has open attitude to exploration of new ideas	Using VSAT/local university resources	Improved communication and understanding between utility and town management
Medium 2 (M2)	Yes If WSPs reduce costs	No Insufficient staff time	SCADA system	Enhanced protection of source water Prevention-oriented utility
Medium 3 (M3)	Yes	No Busy with other obligations, though initially attempted to participate in implementation of WSP	Emergency management plan/risk management plan/SCADA Records incidents on a complaint log	Decrease risk of untreated water reaching the distribution system
Medium 4 (M4)	Yes If WSPs support time and cost savings	No Insufficient staff time	Source protection, improvising on chemical feed, compliance with Safe Drinking Water Act	Enhanced protection of source water
Medium 5 (M5)	No Added value of WSPs not clear to basic water treatment practices. Costs and benefits important	No Insufficient staff time	Well-head protection program started but dropped – paper trail incomplete. Working with their external contacts to re-start it	May help with lack of continuity of staff, lack of records on water quality programs, ability or willingness of attitudes to prevention by city officials

utilities responded that they were not able to implement WSPs because of insufficient staff time, financial resources, or senior level support. The responses of the utilities were similar, indicating that utilities would consider using WSPs if there were documented case studies of cost savings and if utilities did not have other priorities or understaffing:

> '… *especially if it could save time, if there was a cost savings involved, monetary or something like that. I'd love to, but a lot of times I just don't have the time to really think about it and say, 'Well, which way's going to work best here?' I've got to get the water up on the hill*' (M4, Water Operator).

Each of the five medium sized utilities have risk management practices such as technological monitoring systems, for example VSAT (vulnerability self-assessment) (M1) or SCADA (supervisory control and data acquisition) (M2), and emergency plans (M3), or planning processes such as source protection (M4), well-head protection (M5).

In terms of perceived benefits of WSPs, utility managers see WSPs as a way to deal with challenges they face. Climate conditions such as freezing is one example of reoccurring challenges, '*We had a lot of lines frozen, tanks froze, meters froze that came really unexpected. We hadn't seen that temperatures in years here*' (M2, System Operator). Monitoring and recording pollution incidents is another challenge for utilities. M3 does not record incidents but uses a guide, somewhat of a template complaint log. With regard to water quality risks that could be addressed by using a WSP, a common theme that emerged was source water protection and the need for improved communication and understanding between the utility and mayor's office. For example, M2 was concerned about prevention and unknown pollutants:

> '… *we test for contaminants but we don't test for, 'What if I get a big gasoline spill?,' I don't have a process that tests for that … We look for bacteria. We look for pesticides. We look for all the things that we know [are] out there …*' (M2, Water System Operator).

Large water utilities

Personnel from three large utilities were interviewed (10,001–100,000 people served) (Table 4). L1 and L2 were not willing to implement WSPs, and L3 briefly explored how to embed WSPs into their practices before other urgent infrastructure maintenance and staffing changes halted the exploration.

The three large water utilities stated that they were not able to implement WSPs in their utilities because of perceived duplication and infrastructure maintenance. According to L2, their lack of willingness to implement WSPs was because, '*… we've already got in a lot of different formats and in different contexts; we've got a lot if not all of this* [*WSPs*]. *It's just not succinctly tied into the umbrella of a water safety plan or what not*' (L2). In addition to WSPs' perceived duplication, L2 is concerned about workload, aging infrastructure, and budgets, *'We're just more worried about managing the work load … managing aging infrastructure is probably the single biggest work load driver for us in our organization … that's where our greatest priorities go.'* L2 suggested that smaller utilities might benefit from WSPs if they have the staff and resources, *'It may give them a vehicle and the motivation to develop a plan that they normally would not have.'*

In the three large utilities, current risk management practices ranged from 'established' to 'in need of assistance,' meaning revision or development of plans. For example, L2 has a, '*… very large and robust online database report catalogue system for any water supply in North Carolina with a public water supply ID number … That's actually done by the state and managed by the state, but we certainly can access that information and use it*' (L2). L2's water system management plan focuses more on management, financial, and administrative challenges rather than just water quality, '*… that's probably at a higher altitude look at the management of the water system. It would not probably get as detailed as this* [*WSP*] *type of program would …*' L3 has a written disaster preparedness plan, but it is difficult to use preventively instead of reactively due to high costs and too few staff:

> *'Well, you can't react to something until it happens … I wish we could check more often? Yeah, but can we afford it? No. I think I spent $37,000 last year on outside labs … [the] EPA says what method you will use to check for what parameter … I have one lab person. It takes four of us to run the company. It runs 24/7, 365, and working twelve-hour shifts it takes a minimum of four people to run it.'*

L1 noted that their management is reactive instead of preventive, '*… our* [*preventive*] *maintenance is pretty much nonexistent. We are strictly with the one supervisor and the four-line crews, we are strictly reactive maintenance …*' L1

Table 4 | Summary of large water utilities views on implementing WSPs

Large utilities Pop. served: 10,001–100,000	Willingness to implement WSP	Ability to implement WSP	Current risk management practices (water quality)	Perceived benefits of WSPs
Large 1 (L1)	No	No Too busy with urgent maintenance projects	Boil orders due to turbidity SCADA system that needs upgrading	Preventive instead of reactive Comprehensive mapping of distribution lines
Large 2 (L2)	No Perceived duplication of existing practices	Not clear, but did comment that in general, a utility may be more able to implement WSPs if they could identify how it naturally fit with existing practices	Uses online database of pollutants Has Water System Management Plan	Enhanced organization of information
Large 3 (L3)	Yes	No Initially participated in implementation but did not complete due to other obligations	Disaster Preparedness Plan	Improve water quality and costs savings

gave examples of their reactive activities during the summer and winter months:

> *'There's no time to do valve exercising, hydrant flush, flushing the system. We do flush on a regular schedule during the summer … During the winter, it's just by call basis when somebody has an issue, and most of the time, that's after we have a breakage and there are sediment and stuff in the lines'* (L1).

Formal documentation of processes that could be shared among teams within a utility does not exist for L1. They instead rely on memory of personnel, *'If we have a break over here, can we send water around it over here? We're having to rely on the guy's memory, so that's not a very good place to be'* (L1). The perceived benefit of WSPs was stated by L1 and L2 to be the potential for developing a library with the help of WSP structure. For example, L2 explained:

> *'I think it [WSPs] could certainly be something that could be of value and benefit to an organization. It could possibly be used more as a library for organizing all of this data in a centralized way so that everyone has access to it and understands how to, maybe has a little bit better way of extracting information from all of these documents and procedures'* (L2).

Very large water utility

One 'very large water utility' (VL1) was interviewed, which has 60 staff members and serves over 250,000 people (Table 5). VL1 appreciated the process of WSPs but did not verbalize willingness to implement it in their work processes because they perceived their current risk management practices to be the same as or to surpass WSPs. However, VL1 did have suggestions on what makes for a successful water provider in the context of preventive risk management, *'… you've got to be collaborative, you really do, and you've got some that that's internal, but you've got collaboration … I think we need to go across boundaries.'* As for what VL1 would change in their risk management, and possibly where WSPs could assist, they would like to have more exercises, *'We've got a very, very good plan in writing, but we don't have enough exercises to actually practice that plan … We don't practice enough.'* It is useful to note VL1's approach to legally required rules and voluntary rules. For example, regarding the disinfection byproduct rule, *'… driving most of what you see as far as optimization of the plant, [water source] management, building raw chemical storage towers, piloting new chemicals or different chemicals to help optimize the plants.'* VL1 has chosen to voluntarily test for unregulated disinfection byproducts because, *'We're actually more proactive here, progressive. I think it's more of the people we hire, the way we hire them, the type of credentials that we want in the hiring process. We've got some very, very good operators now.'* VL1 did not explicitly state that their staff are able to implement WSPs, however they have a larger number of staff that could potentially do so.

Of the current risk management practices, VL1 focuses on water source safety in the sense of human security, referring to threats to human safety from deliberate contamination of a water supply, *'I don't think there's many systems out there that have adequate ways of knowing what's coming into their plant. If they decide to poison the*

Table 5 | Summary of very large utility's views on implementing WSPs

Very large utility, pop. served: 100,001 +	Willingness to implement WSPs	Ability to implement WSPs	Current risk management practices (water quality)	Perceived benefits of WSPs
Very Large 1 (VL1)	No Current utility activities are perceived to be similar to WSPs	Not stated Potentially has sufficient staff, and has training programs for various operations	Focus on source water safety and security in relation to human security Comprehensive in-house training for new operators Emergency Response Plan, Operations Response Plan	None stated

water or do whatever, how do we know until it's too late? So we've stepped up monitoring …' Several of VL1's existing processes are somewhat similar to the WSP process such as an emergency response plan, chemical spill response plan, and operations response plan, all coordinated with the county. For example, if one water plant of VL1 could not pump or could not treat water, another plant would take over. With regard to control of operations, everything would move to another location and the entire water system would be run from another plant. VL1 also has in place various emergency response and operation response plans, '*… We also have the operations response plan partnered with* [*a nearby county*], *more resources to us with all emergency services, so we're all tied in together.*' VL1 has a training program, an emergency response plan, and an operations response plan. These activities are consistent with WSP processes and could be an entry point for further enhancement by WSPs. Duplication of existing practices was a concern of VL1. VL1 expressed that training of operators is a key activity in their utility, and training is encouraged across disciplines to create understanding of what is needed across teams:

> *'We've got an extensive training program for operators…. The goal is for us to take someone that knows nothing about water and we can train [them] within eighteen months or less, we can have them fully functional. Cross-training takes place so that a lab staff member can go to a particular level of operator's school that creates better understanding for what each team needs*' [VL1].

DISCUSSION

The results show that four of the eleven utilities were willing to adopt and implement WSPs, although they stated a lack of ability to do so. Seven of eleven utilities expressed they were not willing to implement WSPs. Such findings are useful for determining if and how WSPs would be used in North Carolina, and how to integrate new risk management related programs in water utilities in general. Primary reasons that utilities were not willing to use WSPs are lack of staff time for integrating WSPs and lack of significant evidence that WSPs decrease operating costs. Perceived benefits of WSPs included improved organization of record keeping and communication between utility and city administration.

Many utility managers feared that WSPs would encroach on staff time and duplicate existing risk management practices. This finding is consistent with Mayr *et al.* (2012) who found a similar view with small utilities (up to 2,000 households for each supplier) in Austria in that lack of time and potential duplication of WSPs with existing practices were issues. To address this, a WSP implementation tool, a spreadsheet that translates utility information to WSP goals for small water utilities was developed (Mayr *et al.* 2012). Furthermore, WHO published a step-by-step WSP implementation guide for small water suppliers (WHO 2012). A barrier to WSP uptake in New Zealand was cited as lack of staff time due to other more urgent priorities (Kot *et al.* 2015). Kot *et al.* (2015) note that a broader stakeholder view may help with WSP implementation, that is, community readiness in which knowledge of the issue, attitudes toward change, and resources could assist with preparing a community to use a WSP.

Unclear financial benefits of WSPs discouraged its use by North Carolina water utilities. The preference for financial benefits is contrary to recommendations that public health priorities be emphasized in order to motivate implementation, over financial, political, or other administrative gains (Summerill *et al.* 2010b). The primary purpose of a WSP is to protect public health (Bartram *et al.* 2009). Potential impacts include financial benefits (Gelting *et al.* 2012), but are not central. For the North Carolina case, this focus on cost savings implies that utilities' current priority is financial. The water utilities believe that efforts toward implementing WSPs in North Carolina would require additional funds and human resources. However, the source of funds such as federal government tax revenues or the utility's own funds, or other sources, were not made specific.

Several of the utilities perceived communication and coordination between utility and town management, organizing utility records and documents, and promoting risk prevention as potential benefits of implementing WSPs. Similar to these findings, small water utilities in Alberta, Canada also expected improved organization and communication (Perrier *et al.* 2014). Consistent with another study, potential outcomes of implementing WSPs include increased communication and collaboration, improved knowledge and

attitudes, increased training, improved operations and procedures, cost recovery and investment (Gelting *et al.* 2012).

Lack of staff time and of evidence for decreased operating costs are not surprising barriers to implementation of WSPs. In an industry where environmental and health regulations, and to some extent reputation among the community, and basic public health goals are important, it is difficult to expect utility personnel to add a voluntary measure that is untested in the US context. The utilities viewed WSPs as a way to organize their records and clarify communication within the utility, across municipal departments, and with their customers. This finding was unexpected because organization and communication are not primary goals of WSPs. A WSP's primary goals are preventive controls to protect water safety for public health, which may include enhancing organization and communication. Small and medium utilities commented on their more immediate need for improved organization of internal records and communication with the communities they serve regarding water safety emergencies and preventive actions, so that they are able to better safeguard the quality of drinking water. These small and medium utilities voiced that they are not prepared to add yet another plan such as a WSP to their existing activities that need enhanced organization. Available staff time is focused on priorities such as infrastructure maintenance, so less urgent, but necessary, processes of organizing their records and existing risk management plans may be neglected.

Findings also show that the majority of the utility leaders believe that their organizational culture is reactive instead of preventive, with few opportunities for exploration and experimentation with new risk management methods. The utility leaders are aware of their reactive instead of preventive organizational culture, as explicitly stated in interviews, with the exception of VL1. Stricter regulations and fewer financial resources facilitate the conditions for reaction instead of prevention. While an incentive for prevention is public health, it is difficult to identify the factors that contribute to a lack of public health incidents, and therefore investment in risk prevention is overlooked. Furthermore, water infrastructure faces under-invest challenges (ASCE 2013) that facilitates a reactive culture in which money goes toward temporary maintenance fixes. The lesson from the North Carolina case is that utilities would not voluntarily adopt a new or adjusted way of managing risks without evidence of benefits for North Carolina utilities, such as decreases in operational costs. Examples of benefits resulting from studies in other countries were not convincing to the utilities.

Future research on bridges and barriers for WSP uptake and implementation in North Carolina should focus on assessing the potential benefits of WSPs, such as evaluating possible cost saving outcomes, and organizing records and communication within utilities and between utilities and town management. Examining policy and institutional relationships of various stakeholders in water service delivery such as the state environmental regulator, customer protection organizations, and public health organizations would also reveal motivations and limitations of implementing WSPs. A community's influence on the drinking water system is a future area of analysis for implementing WSPs in North Carolina and the USA. We also recommend further examining one of the study's findings regarding reaction vs. prevention: To what extent do North Carolina water utilities have a reactive instead of a preventive organizational culture to public health, and how are environmental and public health regulations influencing such culture?

CONCLUSIONS

Bridges to adopting and implementing WSPs in North Carolina water utilities include the perceived benefit of increased organization of information and communication, improved risk management, and decreased operations and maintenance costs. A few utilities showed interest in developing a library of documents and protection of source water. Another potential bridge toward implementing WSPs, though not explicit in the interviews, is a perceived need for improvement of existing water quality delivery. Barriers to adopting and implementing WSPs in North Carolina water utilities are clear: insufficient staff time and perceived duplication of existing practices. Findings show that lack of time and sufficient resources discouraged using WSP principles alongside utilities' existing risk management practices. Perceived duplication of existing practices, that WSPs are not legally required in the USA, and that there are no examples from North Carolina or the USA were also reasons given for the lack of willingness and ability to implement WSPs.

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