Safety Management

Creating a Custom Approach for a Mega Infrastructure Project

By Todd B. Bjornsen, Stephen E. Nash and Carolyn Jones

San Francisco Public Utilities Commission (SFPUC) is an agency of the City and County of San Francisco; it is responsible for water, wastewater and municipal power services. The agency is implementing a $4.6 billion infrastructure program, known as the Water System Improvement Program (WSIP), to repair and seismically upgrade the local and regional water system. The program encompasses 86 separate construction projects including dams, tunnels, pipelines, treatment plants and special facilities.

The water system for the city and county has local Bay Area reservoirs, but most of the water comes from the Hetch Hetchy reservoir in Yosemite National Park. The water is transported approximately 160 miles via a system of pipelines and tun-

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Photo 1: Overview of the Hetch Hetchy Water Transmission System.

nels to the Bay Area to serve a regional population of 2.5 million customers. The Hetch Hetchy Water System crosses three active earthquake faults, which makes it vulnerable to damage and disruption of water delivery (SFPUC).

To improve system reliability in seismic events, San Francisco is taking steps to upgrade its water infrastructure, build new facilities with added operational flexibility to provide alternate routes for water supplies when the main transmission system fails, and to create interconnections with neighboring water systems to provide needed water supplies in an emergency. The program is expected to complete construction in 2016.

IN BRIEF

- **San Francisco Public Utilities Commission is implementing a $4.6 billion infrastructure program, known as the Water System Improvement Program, to repair and seismically upgrade the local and regional water system.**
- **It encompasses more than 86 separate construction projects including dams, tunnels, pipelines, treatment plants and special facilities.**
- **The agency has developed an innovative safety approach that clearly defines roles, responsibilities, policies and procedures for all program stakeholders to maximize control of foreseeable risk, and instill top-down support for an effective safety culture.**

The complexities of a construction program covering hundreds of square miles require management in a multitude of disciplines, including safety. Early on, SFPUC recognized the need for a collaborative and coordinated approach to achieving optimum safety performance, and set about developing the custom WSIP safety approach. The approach is the product of a concerted effort by SFPUC executive management and construction management working in consultation with safety experts and legal counsel. It was implemented in 2009 and has been the guiding document for all WSIP construction projects since its inception. To date, nearly 4 million hours have been worked with injury rates well below the national average.

Bay Tunnel & New Irvington Tunnel

Several larger projects are underway including two tunnel projects. The Bay Tunnel (Photos 2 and 3) project involves construction of nearly 5.5 miles of subaqueous 16-ft-diameter tunnel in soft ground under South San Francisco Bay. The tunnel will be mined using EPB machine with hyperbaric capability. Some Franciscan rock (approximately 700 linear ft) is expected to be encountered on the tunnel's east end. Slurry walls 140-ft deep were constructed for the approximately 51-ft-diameter construction access shaft before the 800-ft-long tunnel boring machine (TBM) and trailing gear were launched. To date, the TBM has advanced more than 3 miles. This is the first subaqueous tunnel in San Francisco.

The New Irvington Tunnel project (Photo 4, p. 46) involves construction of approximately 3.5 miles of 14-ft-diameter tunnel utilizing conventional methods (e.g., road header and drill and blast). Geology concerns include the potential for poor rock, gassy ground, high water table and seven fault zones at depths ranging from 150 to 700 ft below ground. Excavation is now more than half complete.

The safety record for these jobsites has been better than comparable BLS statistics, but the work has not been without challenges. For example, the program has heightened protective measures as a result of the New Irvington Tunnel project changing from a potentially gassy to a gassy environment, which requires continuous air monitoring for methane, carbon monoxide, hydrogen sulfide, nitrogen oxide and carbon dioxide. In addition, special precautions are followed to ensure that equipment used underground is intrinsically safe (Group 2, Category 1, Gas), and specific entry protocol guidelines are used to prevent potential ignition sources (e.g., cell phones, watches, cameras) from entering the environment. All monitoring events are confirmed manually each hour, with backup supportive data available within the monitoring and calibration equipment as well.

In addition to ensuring that gas mitigation procedures are in place and strictly followed, the threat of working underground in various soil/rock conditions requires a continuous refinement process. Based on team discussions, the job hazard analysis (JHA) was modified to include engineering methods for placement of ground supportive structures, verification of such based on changing ground conditions (risk control checklist based on soil classification) and enforcement of no worker exposed to unsupported ground conditions.

In addition, the hazards of working around heavy equipment (e.g., tunnel boring machine, road header, loci) with blind spots and tight working spaces are unavoidable. To address these, the projects implement fundamental risk control methods to verify that power transmission exposures on equipment are guarded; that alarms are operative before any movements; and that equipment is deenergized during maintenance or adjustments. Additionally, the projects have safe zones along the tunnel path and a refuge chamber at 5,000 ft from the portal entry.

Lastly, mining through constantly changing and various geological formations can present health hazards to workers due to dusts that may contain silica or amphibole. Industrial hygiene sampling analysis, work zone control (during mining operations), wet methods engineering at tunnel face/conveyor and use of appropriate PPE have been effective controls.

Shutdown of Coast Range Tunnel

The Alameda Siphons (Sunol) and Tesla Treatment Plant (Tracy) (Photos 5 and 6, p. 47) projects are unique in that they are at opposite ends of the 25-mile-long Coast Range Tunnel (CRT). A shutdown completed in January 2010 necessitated

the unwatering of the tunnel and installation of adequate forced ventilation to control buildup of methane in the drained CRT. To accomplish this, two large ventilation fans with capacity of 80,000 cfm were installed at the Alameda end of the CRT (Photo 5, p. 47). A detailed shutdown and safety plan was developed prior to the shutdown. Gas levels and ignition sources were strictly controlled at both project sites during the shutdown, which was accomplished on schedule and gas buildup was adequately controlled.

Calaveras Dam Replacement Project

The Calaveras Dam Replacement Project is the largest WSIP project (Photo 7, p. 48). The Calaveras Reservoir, which is on the Alameda-Santa Clara county line, drains 100 sq miles of watershed, including much of the southern sections of the East Bay and the southern slopes of Mount Diablo. Due to seismic concerns about dam stability, reservoir use has been limited to less than half its design capacity since 2001.

The project will eliminate the current dam's structural problems and "restore the reservoir to its historic capacity of 96,850 acre-ft, or 31 billion gallons. In all, 7 million cubic yards will be excavated, the equivalent of two Great Pyramids. The amount of dirt and rock removed would bury 1,200 football fields under one yard of dirt" (Fimrite, 2011).

The WSIP Safety Approach

At one point, SFPUC had an owner-controlled insurance program (OCIP), whereby contracts, including construction management (CM), contractors and subcontractors, were insured under a single insurance policy for general liability and workers' compensation (otherwise known as a wrap-up). During this time, SFPUC was proactive with contractor safety in order to control premiums. In 2005, the agency terminated future activity in an OCIP. In an effort to reduce liability to the SFPUC, a revised safety strategy was initiated whereby construction safety was left to the contractor with minimal oversight by SFPUC.

During 2007, when the WSIP program was being developed, the issue of construction safety responsibility was revisited with the city attorney. The goal was to clarify the city's concerns and develop a proactive approach regarding construction safety and risk allocation. Over several months, a team of city and SFPUC professionals assessed the potential for the city to assume additional liability for contractor construction safety by performing safety audits, and employing safety specialists for the sole purpose of overseeing contractors' daily safety practices. The team included project management, CM, safety and health, and representatives of the city attorney.

The SFPUC goal was to find a balance between an owner-driven safety program, which could lead to greater than desired potential city liability as the owner, and a contractor-controlled program that could leave the city without a mechanism to hold the contractor accountable. In addition, the agency wanted to make clear that responsibility for construction safety rested solely with the contractor.

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Photo 2: Tunnel boring machine (TBM) cutter in the Bay Tunnel.

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Photo 3: Water System Improvement Program (WSIP) Bay Tunnel shaft.

These concerns were addressed in the development of the WSIP safety approach. A concise document outlining responsibilities of each party, owner, construction manager and contractors, was finally agreed on; it attempted to balance and clearly allocate the inherent risks. Implementing a safe construction workplace requires an appropriate balance between acceptable efficiency (production) and thoroughness (quality-safety). Hollnagel (2009) states:

> [I]t is necessary for an organization to be both efficient and thorough. It is necessary to be efficient as resources are always limited . . . and thorough to assure things are done in the right way to achieve goals and avoid adverse consequences—incidents and accidents.

The following excerpts illustrate how the approach is crafted to achieve this balance.

> The goal of the WSIP safety approach is to establish superior safety performance on WSIP projects and to define roles, responsibilities, programs, policies and procedures to accomplish this goal. All parties to this approach shall implement measures to develop an acute awareness that shall promote error-free performance (efficiency/thoroughness) at the project worksites and facilitate achiev-

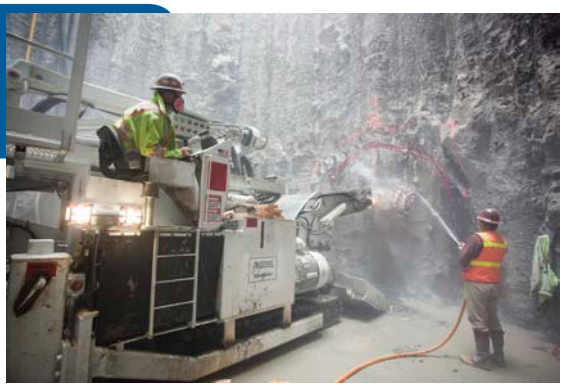

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Photo 4: WSIP Irvington Tunnel roadheader.

ing contract objectives in the safest manner possible. Error-free performance, in vision, is the ultimate intersection of construction management quality while effectively controlling risk for worker injury, shortfalls and or damage to property or environment.

All WSIP participants (from the owner to subcontractors) execute risk mitigation standards and principals with forethought and collective unity. The primary objective is to construct each project with ZERO incidents, totally free from accidents. Measureable safety goals are developed within specific site contract partnership forums, to obtain management ownership and commitment for error-free performance. The commitment to achieve this goal will result in increased productivity and the prevention of job-related losses.

The successful implementation of this safety approach involves safety awareness at all levels of program/project management teams. The emphasis of top-down support is key to the development of a safety culture within the WSIP projects. The primary participants in this safety approach are the construction general contractors including their subcontractors (collectively GCs), the project CM firms, the program, project, preconstruction manager (PPPCM) and the program construction manager (PCM).

A core requirement of this approach was a revised standard safety specification for all projects that outlined an upgraded set of comprehensive contractual requirements for the contractor. A revised safety specification was drafted, reviewed and agreed on with the city attorney. Under this specification, contractors must prepare a comprehensive, project-specific health and safety plan (HASP); the specification also contains enhanced documentation and reporting requirements, and requires incorporation of a qualified safety manager on a contractor's staff.

As the entity directly and totally responsible for construction safety, each contractor must engage a qualified, full-time site safety representative for each project. This individual is responsible for daily inspection and monitoring of project construction safety for conformance to all applicable standards and requirements.

Typically, the CM would have a full-time safety professional to monitor the project and the contractor. However, since this safety oversight was transferred to the program management staff, the WSIP safety approach modified this and directs the CM team to assist in monitoring safety compliance through use of staff in regular (nonsafety) positions. These staff, such as quality assurance inspectors, are not safety specialists but they are experienced with construction and knowledgeable of the contractor's project-specific HASP and Cal/OSHA obligations. As usual, all project personnel are authorized to stop work in an imminent hazard situation.

The WSIP approach is different from many common approaches used by project CM teams in that it does not require staff safety specialists whose sole duty is to monitor contractor safety compliance. Instead, CM staff have experience with construction safety and monitor construction activities for general conformance with the approved HASP and Cal/OSHA requirements; finally, independent oversight for general consistency and conformance with the approach is performed by program-level regional safety managers who are employed by the PCM (AECOM).

Accountability Hierarchy: Methods, Means & Techniques

The following summarizes the responsibilities of each participating entity and provides the basis for implementing and monitoring key program elements.

WSIP Contractors

General contractors will have full and total responsibility for the construction means, methods, techniques and all construction site safety on the project. This is demonstrated on a daily basis through the implementation of fundamental, contractually specified safety activities.

WSIP Project CM Firms

Project CM firms will be responsible for monitoring contractors' compliance with the WSIP safety approach as it relates to their projects.

WSIP PCM

The PCM will be responsible for the implementation and monitoring of the safety approach by all program/project participants.

SFPUC WSIP Staff

As the program owner, SFPUC WSIP staff will determine the overall approach to safety; approve the overall approach to safety management; authorize the resources necessary to effectively implement the safety approach; and ensure that contract documents define the requirements for conformance to the safety approach.

Contractual Safety

Clear definition of primary accountability and responsibility is the underlying tenet in the contractual and administrative requirements of WSIP. It is written and communicated that the contractor

"shall be solely and fully responsible for compliance with all laws, rules and regulations applicable to safety and health of persons during the performance of the work." This language is based on the understanding that the contractor exercises authority over the successful implementation of safety risk mitigation with full control over methods, means and techniques for construction of all WSIP-related activities.

Categorically, the document addresses safety specifics for general safety requirements; staff organization; substance abuse; training; meetings; JHAs; contractor HASPs; inspections; incident reporting/investigations; PPE; emergency equipment; logs; reports and remedial action. To achieve the necessary levels of compliance with these contract requirements, the construction contract specifications typically provide for a full-time contractor site safety representative who must meet several mimimum requirements, including 5 years' experience as a full-time safety representative with requisite experience in the associated tasks of the contract, satisfactory completion of an OSHA 30-hour course as well as other pertinent training.

These contractual items, along with pertinent local and state safety regulations, are used as minimum standards for the delivery of construction safety performance on WSIP jobsites.

Application in the Field: Achieving a Safety Culture

Program success is realized through the uniform implementation of field activities:

- bidder awareness of contractual requirements;
- prebid meetings;
- preconstruction meetings;
- site-specific HASP content review;
- CM orientation;
- contractor orientation;
- progress meetings;
- operational shutdown meetings;
- JHAs and incident reviews;
- partnering.

Specifications

Potential bidders must be aware of the stringent requirements of the program, as well as the detailed requirements of the SFPUC safety and health specification before submitting a bid. These specific requirements are, therefore, included in the contract specifications. In turn, the WSIP CM plans, procedures and contracts are coordinated with the contract specifications and work together as a whole to implement the approach.

Prebid Meeting

Specification requirements are discussed in detail at prebid meetings and it is communicated that the winning bidder will be required to meet such requirements. This may be a somewhat foreign concept to contractors with no prior experience in a stringent owner-developed safety program, so it is important to clearly stipulate these requirements at the outset and make clear that they will be enforced. These prebid meetings also allow for discussion of special conditions that contractors must address (e.g., potential for gassy tunnel, confined space entries, blasting requirements).

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Photo 5: WSIP Alameda Siphons Ventilation.

Photo 6: WSIP Tesla UV treatment piping.

Preconstruction Meeting

Before construction begins, the project CM and contractor meet to discuss, once again, contract requirements, including the WSIP safety approach, special conditions, specific safety exposures and contract specifications. This meeting allows for further clarification of project expectations.

Site-Specific HASP Content Reviews

Contractors as well as CMs must submit, for approval, site-specific HASPs prior to starting work. These accepted HASPs are the guiding documents for the CMs and contractors in achieving the parameters of the WSIP safety approach.

CM Orientation

The CM teams must attend an orientation that provides detailed training in SFPUC policies for safety as well as for quality assurance and control, scheduling, environmental training and similar areas. During these orientations, the safety approach is presented in detail. These meetings allow for specific discussion about responsibilities and the active role in the coordination of overall project safety.

Contractor Orientation

Once a project receives notice to proceed and within 10 days of mobilization, the program-level regional safety managers conduct a site orientation with the CM and contractor supervisors, to once again present the WSIP safety approach, and related safety and health requirements.

In addition, the HASP is reviewed as are upcoming work and associated hazards. As required by the contract, the contractor develops and implements hazard control methods and means to mitigate worker exposures.

Progress Meetings

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Photo 7: WSIP Calaveras Dam preretro.

The continued implementation of the safety approach along with other safety and health requirements is stressed at weekly progress meetings as well as field visits by regional safety managers who work directly with the CM for any needed corrective action. All means and methods for corrective action are the contractor's responsibility. Field audits determine adherence to the policies and identify any areas needing attention. The project CM and PCM do not prescribe specific responses or solutions to identified safety concerns. Such measures are always proposed by the contractor.

Shutdown Meetings

To complete tie-ins to existing (operating) lines, a carefully coordinated series of shutdowns is required throughout this program. The planning and execution of these shutdowns must include coordination of the contractor, CM and SFPUC operations from the planning stage to completion of the lockout/tagout. Periodic shutdown meetings are held at the project level to ensure that appropriate actions are taken for each specific shutdown plan. A monthly high-level management meeting is held to discuss progress of current shutdowns as well as to update planning status for future shutdowns. A lessons-learned summary also is provided to facilitate and improve the completion of upcoming shutdowns.

The effectiveness of this coordinated effort was tested early on when the 25-mile CRT, which is the main arterial water tunnel from Tracy (east) to Sunol (west), needed to be shut down in early 2010 to accommodate tie-in connections at each end. The short shutdown duration (45 days) combined with the known presence of methane, indigenous to the geology, while the tunnel was dewatered, required that ventilation fans be installed to dilute the gas buildup that accumulated while the tunnel was in a dry state. A real-time series of gas monitoring instruments that could be monitored remotely also was installed. The careful planning, design, scheduling, coordination and execution of the work resulted in a successful shutdown with early completion.

JHAs & Incident Analyses

Even when an accepted HASP has been developed, the contractor must augment it with a detailed JHA for hazardous work such as crane picks and confined space entry. JHA development and use may not be familiar to all contractors, so some may have a learning curve with respect to content, task control, surrounding hazards and their control.

While the WSIP injury rate remains below national average, some lost-time incidents have occurred since the program's inception, but none of them resulted in major or life-threatening injury. Strains and sprains have caused the highest number of lost workdays.

When an injury, property damage or near-miss occurs, a detailed accident report must be submitted within 72 hours, followed by a root-cause analysis to provide further detail about the causes and needed corrective action. By contract, a contractor must report all incidents (near-misses, first aid, property damage) to the CM and regional safety managers in a timely matter (24 hours), and any member of the CM team who observes unsafe conditions or behaviors has a contractual obligation to intercede and stop exposure to the hazard.

Unacceptable at-risk behaviors or physical conditions, in violation of the WSIP contract, can result in a noncompliance notice submitted by the CM to the contractor—who must then submit a formal response within 24 hours of receipt. An imminent uncontrolled hazard can result in the immediate stoppage of work by anyone at any time. Actions taken against workers as well as supervisors have included removal from the project, mandatory days off without pay and formal written warnings.

All incidents are followed by a full investigation by the contractor, submitted to the PCM and project CM for comments, and a final root-cause analysis.

All site incidents are reviewed at the weekly site progress meetings and monitored to ensure the care of the injured worker, mitigation of immediate exposures and potential operational modifications to reduce risk within a given task (e.g., change in structural support installation sequence within the tunnel to reduce overhead rock fall exposures).

Partnering

Partnering also has yielded positive results. These sessions are held periodically with the CM, contractor and regional safety teams; the meetings provide a forum to discuss any compelling site issues and consider remedies on the local project level, thus eliminating the need to elevate to higher authorities. These meetings are overseen by an independent moderator or ombudsman to ensure a free and fair exchange of ideas. Partnering sessions allow the contractor, CM and owner to meet each other face-to-face on a periodic basis in a neutral, off-site forum.

Lessons Learned

When a large public agency such as SFPUC solicits bids for major infrastructure renovation projects, numerous bidders typically respond. These diverse bidders have unique corporate risk management cultures with an array of safety practices. That said, some trends have emerged.

The Relationship Curve

The relationship curve has three progressive stages—honeymoon, frictional and relationship maturity. As the contract begins, during the mandatory meetings, submittal reviews and partnering sessions, a spirit of cooperation and a willingness to meet the contractual requirements is displayed, no questions asked.

However, about 3 to 6 months into the contract, when specific safety refinements are suggested or

mandated, push back (frictional) or even avoidance may arise. Some studies refer to such behavior as the optimism bias, the belief that negative events are less likely to happen to oneself than to others (Caponecchia & Sheils, 2011). This is to be expected, realizing that contractors will be challenged to balance quality or safety assurance with contract efficiency (e.g., schedule, costs). This is where the PCM teams can use the continuity, knowledge, leadership and management skills of the regional safety managers (as independent parties) to identify inefficiencies and tactfully and collectively influence the CM to take proactive measures to mitigate risk.

Around 1 year into the specific contract, a level of cooperative safety maturity seems to prevail. This will start showing up from the project CM or the designated site safety representative in various ways. They may start calling with questions about specific safety hazards, or they may communicate in a progress meeting that they took proactive measures by developing a thorough JHA or sent a worker foreman or even a superintendent home without pay for safety infractions.

These can be difficult lessons for some contractors to learn initially, especially if they require a change in culture. However, most contractors have come to appreciate that it is a mature investment to take action on expectations previously communicated.

Morale Hazards

Achieving accurate understanding, transparency, communication timeliness and innovation is a daily challenge on any large multidiscipline construction project. The weekly progress meetings held with key professional members verify that accurate knowledge of at-risk tasks is shared and controls are reviewed. Due to the culture and experience variations between the project sites, drawing out accurate understanding and transparency of field safety challenges can require skillful and tactful questioning within these dynamic group meetings. Professional demeanor, persistence and follow-up are essential to confirm the scope of potential hazards, controls in place and adherence to WSIP expectations.

Detail Paradigms

In developing safety protocols for high-hazard tasks, appreciation for details is relative to the person accountable for completing the paperwork. As the relationship between contractor, CM and PCM develops, it is necessary to carefully assess the level of detail provided in these important documents. Since many in the CM hierarchy are not trained in hazard awareness or safety task analysis principles, the high-hazard analysis may be viewed as a superficial yet necessary program requirement. Therefore, during the project's honeymoon phase, contractors need to be made aware of the need to focus on details.

Conclusion

Since its initial application in the field in early 2009, the WSIP safety approach has been found to be an effective model for jobsite and overall program safety. Typically, CMs field safety specialists responsible for oversight and enforcement of construction site safety. This model carries inherent risks and potential liabilities for the CM and owner, and may not always foster a strong safety culture among contractors. The WSIP approach mitigates such risks.

However, continued effectiveness will depend on the full participation of all entities. It is equally important that no party oversteps its prescribed role or encroaches upon or limits the responsibilities of any other party. Although the program has been successful to date, some CMs and contractors took longer than others to learn and embrace the requirements. So, patience and persistence in early project stages are key. Experience with a diverse group of contractors and CMs indicates that once this initial learning curve is met, the resulting response has been positive and self-sustaining. Therefore, effective and continuous oversight and enforcement is necessary to sustain success.

Another essential ingredient is the absolute commitment and support of the owner at all levels of the WSIP organization. In this respect, SFPUC have been exemplary, unrelenting and unflinching in its support for and enforcement of absolute compliance with requirements by all parties.

The results of perseverance are measurable since the WSIP program has now reached the midpoint. At this time, the project is on schedule and unblemished by a major injury occurrence. This is attributed to a continued application of a coordinated, effective, clearly defined safety approach in the field from prebid to job completion. While it can be said that the learning curve is longer and more arduous for some, the aphorism that "all ships rise on a rising tide" applies based on results and the continued cooperation of all parties. **PS**

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