SWIFT CREEK PUMP STATION SEWAGE SPILL ASSESSMENT

Prepared for

Town of Cary

October 6, 2006

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BROWN AND CALDWELL

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

*Figure follows page number noted.

EXECUTIVE SUMMARY

On June 23, 2006, the discharge pipeline from the Town of Cary (Town) Swift Creek Pump Station failed. Over the next several days, the Town (the project's owner), the project design engineer Black & Veatch International (Engineer of Record, or EOR), and the project construction contractor Laughlin-Sutton Construction Company (Contractor) worked around the clock to effectuate a solution. On June 28, a temporary bypass around the failed pipe section was completed and bypass pumping commenced. On July 20, repairs to the pipeline were completed and the pump station was returned to service. As a consequence of the failed pipe, an estimated 8 million gallons (mg) of raw wastewater spilled from manholes along the Swift Creek Interceptor, eventually flowing into Lake Wheeler, and some portion on into Lake Benson.

The failure that resulted in the spill was due to the separation of an existing pipe joint between the 36-inch tee and 36x30 reducing fitting on the discharge line from the Swift Creek Pump Station. The assessment team determined that the separation resulted from removal of soil in the vicinity of the force main without providing adequate restraint of the force main during the excavation. There were engineering, geotechnical, organizational and institutional factors that contributed to the pipe failure and consequent spill of untreated wastewater.

The contract documents prepared by the EOR for construction of the expansion to the Swift Creek Pump Station required safeguards for the protection of the existing pipeline and other existing facilities during construction including a detailed note specific to the pipeline on the drawings, a requirement for an Excavation Support System (ESS) for the lowest part of the pumping station foundation, and installation of movement monitors to be installed on the pipeline prior to and during excavation. Prior to the spill the excavation of the lower footing proceeded in general accord with the ESS, except that the specified movement monitors were not installed.

In the days immediately prior to the spill the Contractor excavated for and constructed a set of footings between the pipe and the lower foundation that was protected by the specified ESS. The slope of the excavation adjacent to the failed pipe was steepened to near vertical without any special restraint or monitoring of the pipeline. A geotechnical investigation performed by the investigation team through a review of soils reports, project drawings and the photographic record showed that the excavation was unstable and on the brink of failure in the days immediately prior to the actual event.

During construction of the project, the staff from the three organizations who were on the project site regularly reportedly believed that restraint of the existing piping system was not needed except during the actual connection of a new pipe from the expanded facility to the existing pipe. Following significant storm events preceding the spill, the EOR's representative notified the Contractor, both orally and in writing, with copies to Contractor's site office and to the Town, of concerns regarding slope stability of the entire excavation but apparently without specific note of the danger to the existing pipeline. Concern for assumption of additional liability may have overshadowed the duty to act on readily available information (steep side slopes, proximity of the excavation to the buried thrust block, and saturated soil,) and protection of the pipeline was left to the Contractor as part of the Contractor's responsibility for the means and methods to be used in constructing the project.

Following the failure, the Town, the EOR, and the Contractor took immediate action to repair the failed pipe using materials and equipment on hand. Although well-intentioned and collaborative among the three parties, the initial repair effort was principally reactive, did not involve engineering, and failed soon after implementation. Several days later, the temporary bypass was completed, followed some time later by the permanent repair. The investigation team reviewed the incident and response of the parties in each of four stages: Prevention, Preparation, Response, and Recovery. The assessment team has made recommendations for organizational and institutional improvements in each of these four areas. The Town is presently incorporating a National Incident Management System (NIMS) into its Emergency Response Program (ERP) which should significantly improve performance in these four areas.

> “The assessment team performed an evaluation of potential short-term and long-term impacts on water quality in the Swift Creek basin and downstream in Lake Wheeler and Lake Benson. As a first step, the assessment team determined that the previous estimate of the spill volume of approximately 8 million gallons appears reasonable, but gave it a range of 6 million to 9 million for the purpose of estimating pollutant loads. There are several pollutants of concern that could further be addressed now and in the future. These include pathogens; nitrogen and other nutrients that might lead to eutrophication in the lakes; pharmaceuticals, endocrine disrupting compounds, and personal care products. There remain some questions regarding deposition of solids that would require visual inspection, and / or sampling of the Lake bottom and further study to quantify, but this is not considered to be a high priority. The working assumption that groundwater transport is from the water table to the stream valley should be scrutinized on a local scale with hydraulic gradient studies to be protective of wells that are close to the Lakeshore.
>
> Any program to restore public confidence in the watershed resources should include the development of a regionally coordinated program of monitoring and watershed management, because in the long-term watershed loads cause more significant impacts than this single event. Monitoring and management should target eutrophication and improved water clarity as endpoints. This not only has direct benefits for dissolved oxygen, aesthetics, and taste and odor, but can also reduce bacteria counts by accelerating ultraviolet disinfection. Mercury impacts were evaluated and considered to be low; it is recommended that the community continue to implement a regionally coordinated strategy of monitoring mercury in fish and communicating fish consumption advice. "

1. INTRODUCTION

This report presents the findings, conclusions and recommendations of Brown and Caldwell's assessment of the wastewater spill.

1.1 Sewage Spill Assessment Team

The wastewater spill assessment team consisted of engineers, operations specialists, and water quality specialists from various Brown and Caldwell offices, principally in North Carolina, California, and Minnesota. The principal members of the assessment team are:

Table 1-1. Assessment Team

Individual	Specialty
Denis O'Malley, Assessment Team Leader	Construction Management
Rick Carrier, P.E., Project Manager	Design Engineering
Garr Jones, P.E.	Quality Assurance
Rick Arbour, Certified Operator	Operations and Business Practices
Chris Hardin, P.E.	Geotechnical Engineering
Khalil Abusaba, Ph.D.	Water Quality
Marshall Taylor, P.E.	Water Quality
Frank Stephenson, P.E., Carolina Operations Manager	Quality Assurance

1.2 Interviews Conducted with Project Participants

As part of our assessment, we interviewed personnel from the three project participants (Town of Cary, the project owner; Black & Veatch, the project design engineer and Engineer of Record; and Laughlin-Sutton, the general contractor constructing the project) as well as other engineers, subcontractors, and other project stakeholders such as regulatory agencies, property owners, and other governmental bodies. Those interviewed are listed in two tables in Appendix A, the first sorted by organization and the second sorted by individual. Follow-up interviews and observations were conducted at the Operations Center.

1.3 Documents Reviewed

A bibliography of many of the documents provided to the assessment team is included in Appendix B. The bibliography is fundamentally a list of documents to which the authors or assessment team referred during the work. The singular exception is e-mail. Because e-mail are prolific and, because of their convenience, often contain non sequiturs, we have included only discrete e-mails in the bibliography and cited them as references when necessary.

Not all items in the bibliography are necessarily cited in the report. Those that are cited are listed as references at the end of the report.

2. TIMELINE OF EVENTS

A report[1] was prepared by Black & Veatch following the event that provides a summary of the events leading up to the breach of the pipeline at the Swift Creek Pump Station and a detailed description of the response activities subsequent to the breech. Town personnel prepared a summary of personnel and activities in an Excel spreadsheet.[2] Our review of these documents indicates an excellent correlation of the two. Further, the interviews with personnel from the three project participant organizations also corroborate the validity of those two documents. Therefore, and in the interest of brevity, a summary is presented here.

2.1 Sequence of Events Leading Up To the Spill

Rainfall at the Swift Creek Pump Station site was unofficially recorded at 3-1/2 inches and 4 inches on June 5 and June 12, respectively. Tropical Storm Alberto, the first tropical storm of the 2006 hurricane season, formed on June 10 in the Caribbean Sea as a tropical depression. The storm moved north, making landfall in Florida on June 13.

Alberto produced heavy rain across Florida, North Carolina, and Virginia. On Wednesday, June 14, the Town of Cary unofficially recorded over 8 inches of rain at the Swift Creek Pump Station construction site. Swift Creek itself rose to approximately elevation 309, submerging the existing wet well and the new wet well excavation.

Following clean-up and dewatering of the pumping station excavation, the Contractor resumed work on the project and excavation in the vicinity of the existing force main. On Friday, June 23, the Contractor placed the concrete footings closest to the force main and left the site for the weekend. That evening a high intensity, short duration storm event occurred beginning about 4:30 p.m. after all personnel had left the construction site for the day.

Shortly after 5 p.m., the Town received an alarm indicating the Swift Creek Force Main had lost pressure. Town Utilities Services Maintenance personnel dispatched to the site observed a breach of the pipeline releasing raw wastewater.

2.2 Sequence of Events Following the Spill

Senior personnel from the Town were advised and they, in turn, notified Black & Veatch and Laughlin-Sutton personnel. After overcoming personal and communications challenges, representatives from each of the project participant organizations coordinated and worked collaboratively and continuously through the night to acquire equipment and materials to mitigate and control the spill until the evening of Saturday, June 24.

Initial efforts to mitigate and control the spill, and return the pump station to service, utilized materials and equipment readily available at the site. Unfortunately, the repair efforts were unsuccessful. At about 6:30 Saturday evening, the Town initiated a pump and haul operation to transport wastewater in tankers to another drainage basin to mitigate further discharge from the pump station. At approximately 8 p.m., in the interest of safety and concern for the well-being of those working at the site, all personnel were directed to stand down and return the next morning.

On Sunday, June 25, the project participants met at the site and agreed to spend the day formulating a plan, rather than continue to attempt to make repairs with materials and equipment on hand. A plan was developed and, during a meeting that evening, the project participants agreed upon it.

Beginning early Monday morning, June 26, the participants worked continuously and collaboratively through early Wednesday morning June 28, to construct a permanent bypass connection on the existing failed pipeline. The bypass was completed early Wednesday morning and the town initiated bypass pumping. Repair of the failed pipeline commenced.

On Thursday, July 20, repair of the pipeline was completed and the town placed the Swift Creek Pump Station and its reconstructed pipeline back into operation.

3. POTENTIAL REASONS AND INFLUENCING FACTORS FOR THE SPILL

There are technical, organizational, and institutional reasons and influencing factors for the wastewater spill. The technical issues are presented in this section while the organizational and institutional issues are discussed later.

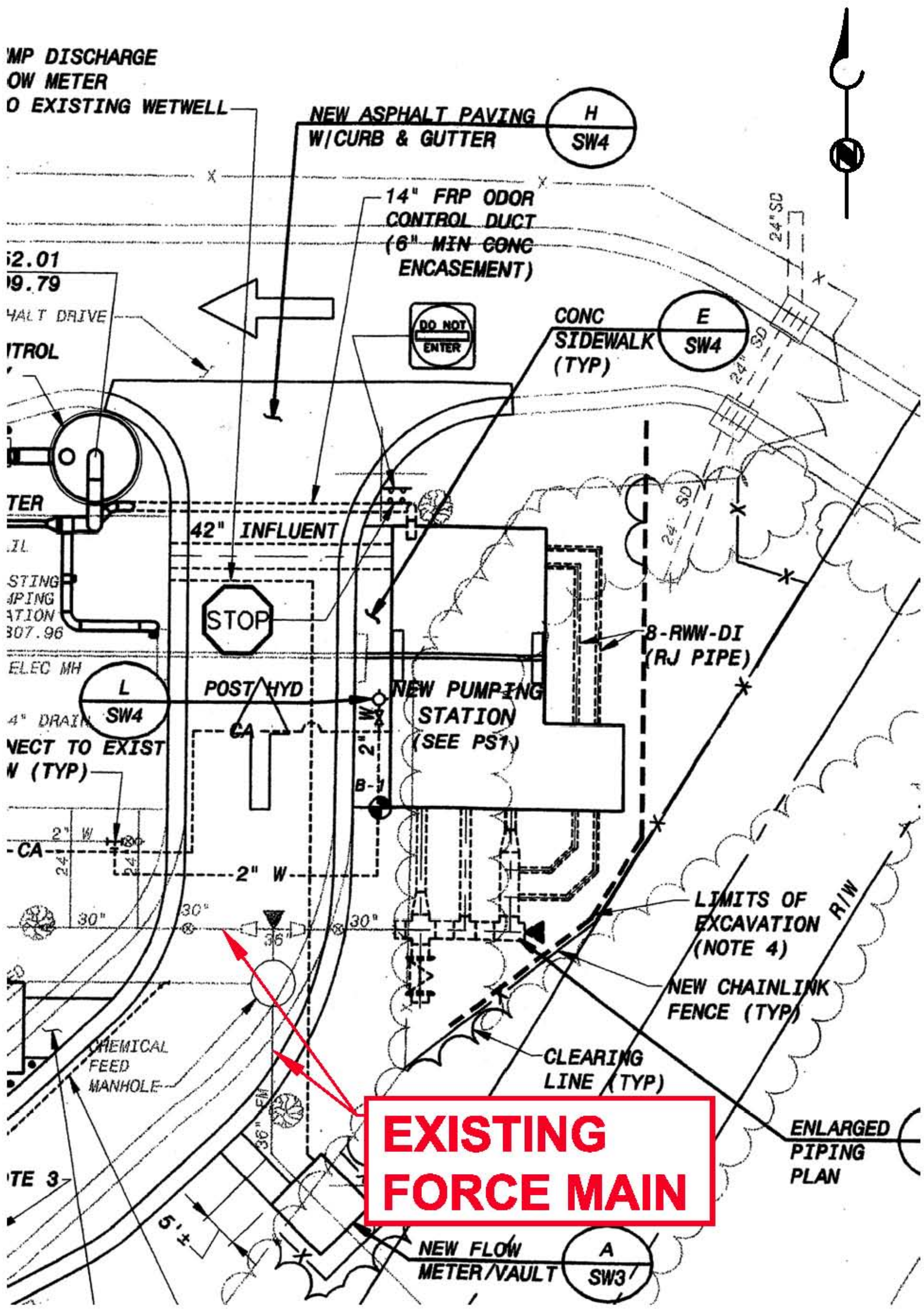
3.1 Engineering and Geotechnical Evaluation of Failure

An engineering evaluation of the design, in-place construction, and sequence of events was performed. In general, it was found that the spill was caused by the removal of soil in the vicinity of the force main without providing adequate restraint of the force main during the excavation.

Engineering Evaluation. The assessment team reviewed the EOR's design development reports, the documentation of the force main failure, and initial construction documents with regard to the cause of the spill. An excerpt from drawing SW2, from the Contract Documents prepared by the EOR, showing the proposed pumping station construction, is presented on Figure 3-1. A new pumping station was to be constructed adjacent to the existing Swift Creek Pump Station, which was to remain in service without interruption during the construction.

The existing Swift Creek pumping system conveys wastewater from the gravity sewer system in Swift Creek basin to the Cary South Wastewater Treatment Plant where it is treated and discharged. The existing Swift Creek pumping station includes three submersible pumps that deliver the wastewater via a pressurized piping system or force main.

All the wastewater conveyed by the existing Swift Creek pumping station is delivered through this 36-inch force main system, which is shown with a single-line depiction on the design drawing (see annotation on Figure 3-1). The pipeline is located less than twenty feet from the proposed pumping station. The failure of this pipeline during construction of the new pumping station is the subject of this investigation.



NOT TO SCALE

FIGURE 3-1
PLAN VIEW OF NEW PUMPING STATION FROM CONTRACT DRAWINGS

A clearer illustration of the force main and the constructed elements at the time of the failure is provided on Figures 3-2 and 3-3. In general, the Contract Documents prepared by the EOR required the Contractor to install the new pumping station and connect it to the existing force main while maintaining the existing pumping station in operation. Section 02200 of the Contract Documents required the Contractor to install an Excavation Support System (ESS) as part of the lowest part of the pumping station foundation. The specifications prescribed that the ESS be designed by a registered engineer and was reviewed and approved by the EOR. The specifications did not specifically require the design of the ESS to address the stability of the excavation sides slopes above the lower part of the excavation and in the vicinity of the force main. A specific requirement to monitor the location of the force main during excavation of the installation of the ESS and during the excavation of the lower footing at elevation 264 was included in the ESS specification page 02200-12: "The CONTRACTOR shall monitor the existing 30-inch pipe south of the excavation for movement during installation and use of the ESS …." A note is included on drawing SW2 of the Contract Documents that requires the Contractor to restrain the existing force main:

> "CONTRACTOR SHALL TEMPORARILY RESTRAIN THE EXISTING ISOLATION VALVE PRIOR TO DISTURBING THRUST BLOCK OR SOIL IN THIS AREA. AFTER VALVE IS RESTRAINED TO SATISFACTION OF ENGINEER, CONTRACTOR SHALL REMOVE EXISTING THRUST BLOCK AND PLUG AND INSTALL NEW PIPING AS INDICATED. TIE TO EXISTING 30" SHALL BE MJ BELL."

The excavation of the lower footing proceeded in general according to the ESS, except that the specified movement monitors were not installed. An ESS was not specifically required by the Contract Documents for the construction of a series of footings between the lower foundation work and the force main. The specifications and drawings also did not require that the Contractor address excavation stability during the installation of the footings in the vicinity of the force main.

A more detailed drawing of the failed pipe section is shown on Figure 3-4. Figure 3-4 was compiled from reports and photographs of the spill and from record drawings of the initial construction. The original design and construction of the force main relied on a concrete thrust block and frictional earth pressure to restrain the piping system. The general failure that resulted in the spill was due to the separation of an existing pipe joint between the 36-inch tee and 36x30 reducing fitting. The failure appears to be have been caused mainly by the reduced capacity of the thrust block system resulting from removal of soil immediately adjacent to and around the existing pipe and thrust block. The separation at the first 36-inch pipe joint rather than one of the 30-inch pipe joints is to be expected as the force necessary to restrain a joint is proportional to the area of the joint (i.e., the force on the 36-inch section is 1.44 times the force on the 30-inch section). It appears that the entire section of 30-inch pipe and the thrust block to the east of the failure remained intact following the initial failure.

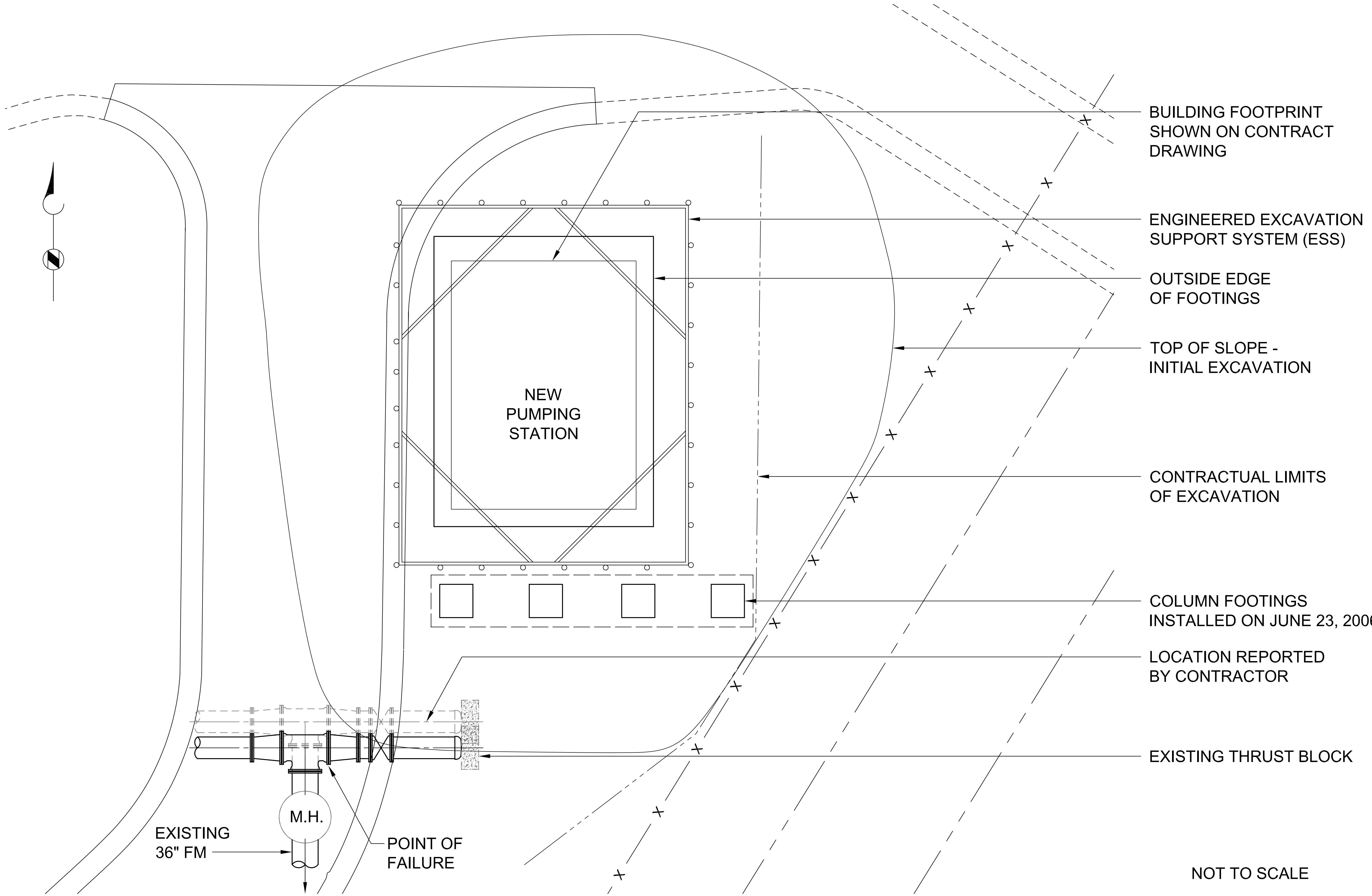
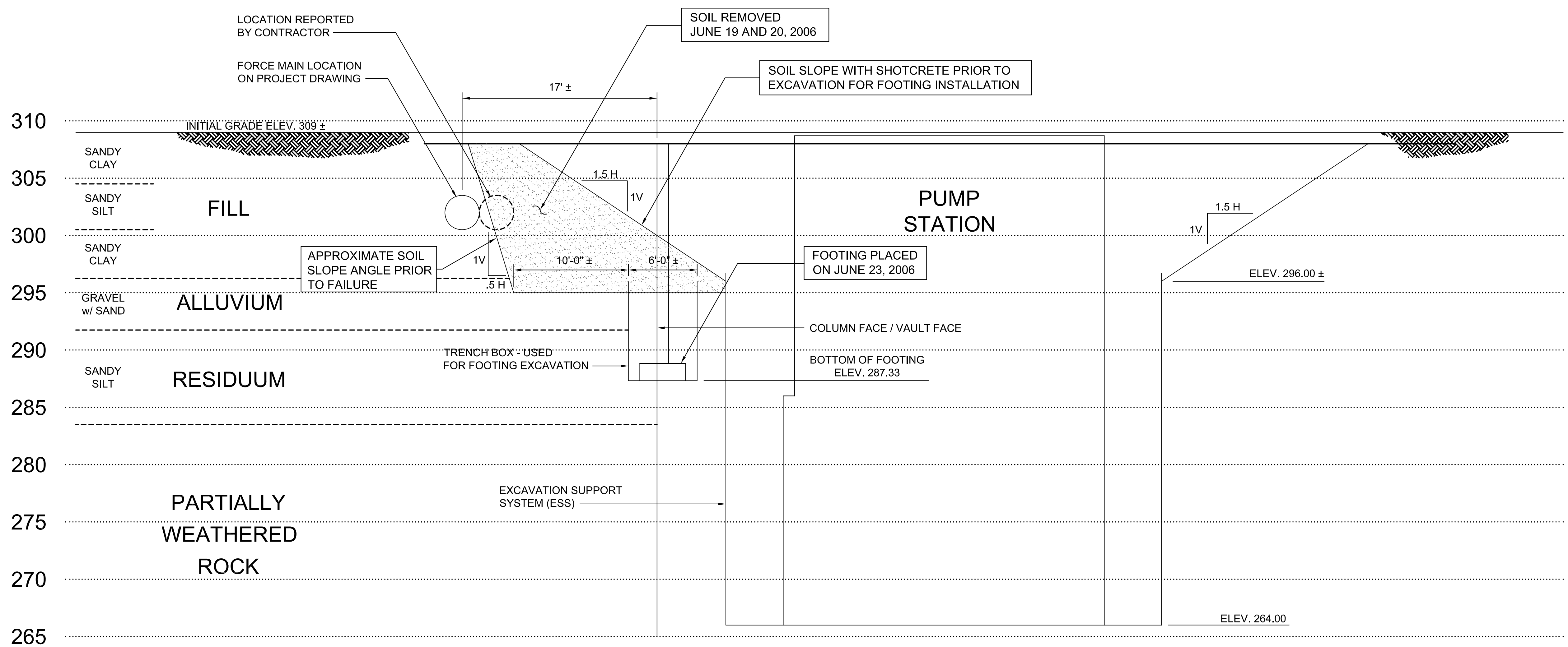


FIGURE 3-2
ENHANCED PLAN VIEW
OF EXCAVATION



NOT TO SCALE

NOTE:

SOIL CLASSIFICATIONS ARE FROM THE GEOTECHNICAL SUBSURFACE INVESTIGATION REPORT, DATED FEBRUARY 28, 2003

FIGURE 3-3
SECTION THROUGH PUMP STATION EXCAVATION

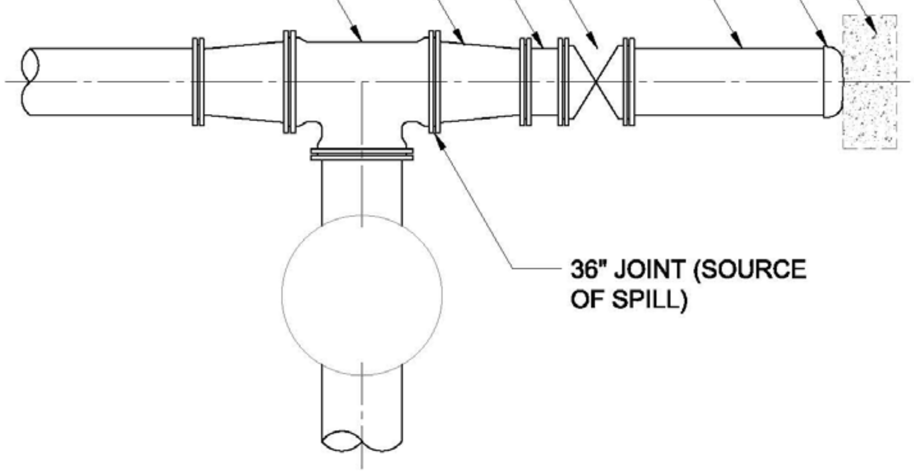


FIGURE 3-4
DETAIL OF FAILED PIPE SECTION

Geotechnical Evaluation. A geotechnical slope stability evaluation was performed to establish the reasons for the failure (often referred to as the "mode of failure") of the soil system that resulted in the failure of the pipeline. To evaluate the geotechnical conditions and slope stability that influenced and/or caused the failure of the subsoils beneath the thrust block and force main, the assessment team considered the following:

1. Influence on soil conditions/slope stability caused by the excavation of the soil to a side slope of 0.5 horizontal (H) to 1.0 vertical (V) to install the building footings in the near vicinity of the existing thrust block. Figure 3-5 is a photograph that indicates that the pipeline was either very close to being exposed or actually exposed by the steep excavation.
2. Potential failure scenarios that may have been present as the soils supporting the force main and thrust block transferred from passive to active earth pressure coefficients.
3. Influence on slope stability of saturated near surface soils and a rise (increase in elevation) of the water table resulting from the frequent rain events in the weeks and days prior to the pipeline failure.

Figure 3-5. Excavation for Placements of Concrete, June 22, 2006

To understand the results of the slope stability evaluation, it is necessary to provide some background on the factor of safety that is accepted by geotechnical engineers and the construction industry for this type of evaluation. The factor of safety represents a ratio of the driving forces to the resisting forces in the soil/groundwater matrix using a limiting equilibrium evaluation method. The minimum factor of safety for slope design typically ranges from 1.25 to 1.5 depending on the critical nature of the facility that is being supported. A factor of safety of 1.0 or less indicates an imminent or pending failure condition. A factor of safety of less than 1.0 indicates that failure would occur before the slope reaches the configuration evaluated, e.g, depth of excavation.

The slope stability analysis conducted by the assessment team considered both the total and the effective stress conditions that would be present in the soil and groundwater matrix. Total stress is the soil pressure per unit area experienced by the soil and groundwater matrix. Effective stress is the total stress minus the porewater pressure present in the soil and groundwater matrix. The geotechnical evaluation of the excavation and slope stability adjacent to the force main included determining the factor of safety for both total and effective stress conditions.

The assessment team developed cross sections for the slope stability analysis from the site photos before and after the force main failure, information in the Black & Veatch report[1], geotechnical information and data about the in-situ soils from the Tierra report[4]. The slope stability evaluation in the vicinity of the force main included evaluation of the factor of safety against rotational slope failure before and after the soil was excavated to install the building footings. The slope stability evaluation included evaluation of potential failure scenarios with both saturated and unsaturated groundwater conditions and slope sidewalls at 0.5H to 1V and 1.5H to 1V. An explanation of the various failure scenarios that were evaluated is included in the report from Schnabel Engineering in Appendix C.

The results of the slope stability evaluation indicated the following:

1. The short-term, total stress factor of safety is 1.0 for the cut slope 0.5H to 1V without the influence of groundwater. This indicates imminent failure in a static, non-saturated condition.
2. The long-term, effective stress factor of safety is 0.8 with the groundwater level at an Elevation 290 or less. This indicates immediate failure as the slope transitions toward the long-term condition.
3. The long-term, effective stress factor of safety is 0.8 with the groundwater level at the toe of slope at Elevation 296. This indicates immediate failure and virtually no difference from the factor of safety when the groundwater level is significantly below the surface.

Based on the results of the slope stability evaluation and a review of the pertinent project information, the assessment team concluded that the slope was at failure conditions after the slope was cut to 0.5H to 1V and could stay up only for a short time (i.e. several hours to several days). However, the long-term, effective stress factor of safety typically rules for cut slopes that are excavated to a slope angle steeper than the soil's effective stress friction angle. This means that the unsupported and partially saturated soil slope adjacent to and/or beneath the force main/thrust block was already in the process of failure (more driving forces than resisting) as soon as the slope was cut was cut to 0.5H to 1V. Based upon the slope stability evaluation, the assessment team concluded that, after the soil was removed from the slope to make room for the footing excavation, it was only a matter of time until the evidence of slope failure and movement of the thrust block occurred.

The slope stability evaluation indicated the top of the failure surface to be 8 ½ to 10 feet from the top of the slope at 0.5H to 1V. It is interesting to note that the location of the failure surface from the slope stability evaluation is very similar to failure conditions identified in site photographs taken after failure, but before the force main was repaired (see Figure 3-6). The soil properties for the slope stability analysis were estimated from the test boring logs and soil index properties in the Tierra report[4]. A sensitivity evaluation of the unit weight, cohesion and internal friction angle was conducted to ensure a representative evaluation of the slope stability at the time of the force main failure. A back calculation analysis was also performed to confirm the validity of the estimated soil properties.

Figure 3-6. Soil Failure Surface, Approximately 10 feet into Slope, June 2006

Although the primary cause of the failure appears to have been the removal of soils near the pipe and thrust block system, there are a number of other factors that may have contributed indirectly to the failure:

1. The existing piping system appears to have had two defective construction elements. The existing thrust block, which would be considered the primary source of restraint for the system, was approximately 1/3 the size that was indicated on the 1987 record drawings prepared by Diehl and Phillips[5] and about 1/5 the size of the replacement block depicted on the Black & Veatch Contract Documents. Visual inspection of the thrust block concrete found it to be in sound condition. In addition, when the existing piping was uncovered following the spill, the bolts on the failed pipe joint were reportedly smaller than customary and were found to be loose. Although the bolts are not a significant element in the restraint system, the mechanical joint may have leaked more following the initial failure than would have been expected thereby accelerating the ultimate failure through loss of soil caused by the leakage.
2. The record drawings for the original construction[5] appear to show the existing force main 14 feet away from the existing structure. The drawings in the Contract Documents showed the existing pipe was approximately 17 feet away. The Contractor reported the existing pipe was approximately 14 feet from the outside of the new pumping station structure.
3. The rainfall may have contributed by softening the exposed soils.

3.2 Engineering Considerations During Response to the Sewage Spill

Review of the records and recollections of those interviewed indicate that the initial repair was performed largely through the use of Contractor and operational experience to best use materials and equipment on hand. It was principally reactive and largely did not involve engineering.

The repaired and reconstructed facilities, including the revised pipe location and installation of the bypass pumping connection, were engineered solutions. That construction is now out of the way of the Contractor. A surge (water hammer) analysis has not been completed on the new configuration.

There are organizational and institutional perspectives on the response to the wastewater spill. Those are discussed later.

3.3 Measures that Could Have Eliminated or Mitigated the Cause and Consequences of the Spill

The assessment team reviewed the EOR's design documents as well as previous design development reports and initial construction documents to answer the question of how the causes and consequences of the spill could have been eliminated or mitigated. This section addresses the engineering and geotechnical considerations while organizational and institutional issues are discussed later.

Elements of the engineering design and construction process that could have mitigated or eliminated the failure include:

1. The field staff from the three project participant organizations apparently believed that restraint of the piping system was not needed except during the actual tie-in to the pipe. Development and inclusion in the contract documents of a specific sequence of construction and plan for maintenance of operations during construction would likely have ensured at least temporary restraint of the pipe prior to any excavation. Installation of a temporary restraint system might have revealed that the thrust blocks were inadequately constructed in the original construction.
2. Both the as-constructed location and size of the existing thrust block could have been detailed better on the record drawings and in the contract documents. This would have necessitated exploratory excavation during the design period, either by the designer or the owner.
3. More frequent communication and intervention by the EOR during construction may have eliminated the problem. The project participants, including the EOR, Contractor, and Town, had individual knowledge of the pipe location and proximity to the excavation and had the opportunity to intervene. Clear communication of the critical and dangerous nature of the piping arrangement through the contract documents to the field personnel might have eliminated the failure.
4. Involvement of experienced construction engineers from the Town and other engineering and contractor resources could have better responded to the spill and helped in the development of the solution more quickly.
5. Engaging Tierra or another geotechnical engineer for geotechnical service during construction, rather than only as an independent testing laboratory, could have heightened the awareness of field staff to the dangerous condition caused by excavation in the vicinity of the force main.
6. The role of the representative from North Carolina, Department of Labor, Consultative Services was apparently misunderstood by the Contractor and others on the site. Roles and responsibilities of such personnel need to be clearly defined and understood by all. The representative's responsibilities were limited to safety and health concerns and did not include geotechnical issues. His comments

that addressed confined space entry were apparently misunderstood to include adequacy of shoring and slope stability.

7. When evidence of changing groundwater and/or soil conditions was observed, an experienced geotechnical engineer consulted by the Contractor would have readily identified the instability of the side slopes.

3.4 Preventive Actions to Avoid a Pump Station Failure and Spill

There are engineering actions that are recommended to help prevent future spills from the Swift Creek force main system, or from other pump stations.

1. Undertake a new surge analysis both to reflect the current configuration and the configuration that will be in place following tie-in of the new pumping station. The surge (water hammer) analysis upon which the design was based was developed during preliminary engineering; it does not reflect the piping configuration installed in response to the spill.
2. Perform a condition assessment for the existing force main particularly in the area of existing air/vacuum valves and the discharge location. The force main reportedly partially drains upon each pump off/on cycle thereby creating favorable conditions for hydrogen sulfide corrosion. If corrosion has progressed to the point of potential failure, immediate corrective actions should be taken. If significant corrosion is evident, consider accelerating design and construction of the future parallel force main planned for 2007 to allow the existing force main to be taken out of service for refurbishment.
3. For modifications to existing facilities, confirm that record drawings for subsurface conditions, at a minimum, are accurate. For projects in construction, emphasize the importance of accurate record drawings to the designers and contractors.
4. Protect critical systems with jointly-developed contingency plans for construction activities in and around operating facilities.
5. Provide geotechnical engineering services to designers and contractors during construction to assure proper assessment of in situ subsurface conditions.
6. Consider protection of critical facilities in the flood prone areas. Although the flooding associated with tropical storm Alberto does not appear to have had a significant role in the failure, the flood waters were reportedly within inches of major electrical components and could have seriously damaged the pumping system thereby resulting in a similarly catastrophic spill.
7. The Town ultimately installed a temporary bypass pumping connection to allow the use of portable pumping equipment to deliver wastewater via the existing force main system. Installation of similar connections at critical wastewater pumping stations could help speed installation of temporary pumping systems to remove a pumping station from service, in response to either a planned outage or one resulting from an emergency. The use of this bypass can be facilitated by the purchase of one or more trailer-mounted, engine-driven, self-priming pumping systems.

4. ORGANIZATIONAL AND INSTITUTIONAL FACTORS

During the evaluation of the Swift Creek Pump Station failure, the assessment team considered organization and institutional factors that may have been partially the cause or an influencing factor in the failure and subsequent sewer system overflows (SSO).

Organizational factors or issues tend to be short term issues in an organization that are specific to different departments. Institutional factors and issues are business practices that are embedded within an entire organization that may have not kept pace with growth as the organization has evolved over time. The assessment team identified the organizational and institutional issues during the document review, the on-site interviews and on-site observations at the Operations Center. They are also derived from knowledge, experience and application of Emergency Response Planning (ERP) in the utilities industry as well as industry-wide best business practices for pumping stations, force mains and gravity sewers in wastewater collection systems. This section describes the four phases of emergency management and presents our findings and recommendations within the framework of these four phases.

4.1 Four Phases of Emergency Management

There are four phases of emergency management commonly recognized by the utility industry and the Federal Emergency Management Agency (FEMA).

Prevention. What business practices, policies and procedures are used during the design and construction of capital projects to prevent emergencies, during construction? Once constructed, how are preventive and corrective maintenance business practices used to increase asset reliability and availability that in turn, reduces the risk of future emergencies due to asset failure and loss of function?

Preparation. This phase recognizes the fact that emergencies will always occur in public utilities even when the prevention phase is effective. Hurricanes cannot be prevented, nor can manmade events always be controlled. A contractor "digging" up a force main is a case in point. This phase prepares for the emergency by identifying and preparing for emergencies caused by natural events as well as for manmade emergencies. The preparation phase is both system and asset specific for normal and extraordinary emergency events. Development of an Emergency Response Plan (ERP) is completed in this phase to be implemented in the next phase, Response. Examples of information that would be included in the ERP are provided in Table 4-1.

Table 4-1. Example Information Included in an Emergency Response Plan	
Emergency Numbers (an emergency can be cross-jurisdictional or have more than one provider of services)	Electric, gas, water, cable, telephone, locators Key personnel that have decision making authority to respond Police, Fire Medical
Notification Procedure – Internal Divisions and Departments	Safety, Loss Control, Industrial waste, Finance, Public Information
Notification Procedure – External	Police, Fire, Regulatory, Community, Media, Other Jurisdictions
Other Sections	Site Security, Mutual Aid Agreements
Emergency Resources, Equipment, and Systems	Pre-approved list of contractors and contacts General Electrical & Mechanical
	Equipment and materials suppliers Local Industry Other utilities Other communities
	Engine Driven Generator Sets Portable - match to pump stations and inventory applicability to specific stations Logistics Tow vehicles& drivers, Fuel, Operators, Cables & hookups Load tested, preventive maintenance performed, & ready for use
	Onsite Load test Transfer switch operation Fuel availability and quality Supervisory Control and Data Acquisition (SCADA)
	Supervisory Control and Data Acquisition (SCADA)
Example Hose, Piping, Fittings Inventory	4, 6, 8, & 10, inch flexible hose with quick connect fittings stored on pallets and staged appropriately Aluminum irrigation pipe Irrigation contractors Fittings and valves needed for bypassing Suction hose
Example of Electrical Control and Pump Information	Submersible Pumps Power, Motor Control, Cables, Floats, Lights Operating Characteristics Head and capacity Suction lift Physical size for access Types Engine Driven Electric Submersible Hydraulic Trailer-mounted, engine-driven, self priming pumps

The Preparation Phase is a major component of the National Incident Management System (NIMS; described later in this section) protocol and must be incorporated as the program is developed.

Response. This phase is primarily the implementation of the established Emergency Response Plan. Depending on the severity of the emergency, the Incident Command System (ICS) may also be implemented. Under normal emergencies, the Town's Public Works Utilities (PWUT) would typically respond, while extraordinary emergencies, which might be broader, would likely involve other departments, and potentially other local jurisdictions, state, and/or and federal resources.

Recovery. The fourth phase is restoring the system to normal operation and remediating the effects and impacts of the emergency. Depending on the nature of the emergency, Recovery can begin at any time once the situation is stabilized or the event has passed. The Recovery Phase focuses on maintaining and/or restoring public health and safety concerns, and restoring the functionality of the asset or facilities beyond the temporary measures taken during the Response Phase. This phase generally would require the completion of a Failure Mode Effect Analysis (FMEA) to determine cause(s) of failure and the steps to be taken to prevent a reoccurrence. The FMEA would be included in the prescribed final reporting requirements. These would also include assessment of impacts, for example, calculating and varying flow volumes.

4.2 National Incident Management System

The National Incident Management System (NIMS) is a FEMA program that provides for a structured protocol for the four phases of Emergency Management. Most emergency situations or events are addressed locally with local resources, as was the case with the incident under review. When there is a major incident, help may be needed from other jurisdictions, the state, and/or the federal government. NIMS was developed so responders from different jurisdictions and disciplines can work together better to respond to natural disasters and emergencies, including acts of terrorism. NIMS benefits include a unified approach to incident management; standard command and management structures; and emphasis on preparedness, mutual aid and resource management

The Town staff is currently undergoing NIMS on-line training and will complete that in the near future. Following the training, staff will develop and implement a NIMS specific to the Town, which will become a key piece in an expanded Emergency Response Program for the Town.

4.3 Sewage Spill Assessment within the Framework of Emergency Management

As noted previously, there are four phases of emergency management commonly recognized by the utility industry and FEMA. The assessment team evaluated the organizational and institutional issues related to the wastewater spill within the framework and context of these four phases. The objective was to identify areas that may have contributed to the incident and, perhaps more importantly, to identify potential modifications to the Town's business practices to minimize the probability of future events and, when they do occur, assure effective, efficient response and service restoration.

4.3.1 Prevention Phase

The Town Engineering did not have direct responsibility for the Swift Creek Pump Station expansion project. While there was collaboration between Engineering and PWUT during the design, the project management during construction was assigned to the Utility System Maintenance (USM) Division, whose representative had frequent on-site contact with the EOR and Contractor. During project construction, USM was concerned with maintaining the operational capability of the pump station. It appears they may not have had the technical background or the necessary charge regarding engineering or construction. Instead they relied on the EOR to take care of construction related issues. They may also have been time limited depending on other daily priorities. On projects affecting critical assets, the appropriate level of expertise should be used to best protect the interests of Town. This institutional issue has reportedly been addressed as larger capital improvement construction projects are now managed by Town Engineering. It should be documented as a Standard Procedure so the interdepartmental roles and responsibilities are clearly defined and understood.

Prevention and Mitigation Actions. During the design phase, the Town needs to ensure that the construction contract documents incorporate language necessary to maintain the functionality of critical assets during the construction and have a contingency Emergency Response Plan in the event of failure. This should reflect the NIMS framework being developed.

Once an asset is designed and constructed, Preventive Maintenance (PM) is necessary to maintain the desired function of the asset. PM is a proactive activity. PM procedures are developed and executed as part of the Preventive Phase. Corrective Maintenance (CM) is maintenance that is performed to restore asset functionality after a failure has occurred. If the failure consequences are severe, it becomes high priority Emergency Maintenance (EM). CM is a reactive activity. EM procedures are developed in the Preparation Phase and executed in the Response and Recovery Phases.

The Public Works Utilities Department (PWUT) has well developed Preventive and Corrective Maintenance programs that they use to perform programmed PM and CM on the wastewater collection system. PM and CM activity is tracked using a Computerized Maintenance Management System that generates work orders and records historical data when completed. Preventive maintenance at the pump stations is structured so more critical stations receive a higher level of preventive maintenance. Gravity sewers are cleaned on a programmed basis and inspection/condition assessment is performed using Closed Circuit Television (CCTV) and/or other methods. Defects identified during the inspection/condition assessment are then scheduled for; increased PM, spot repair, rehabilitation or replacement. Preventive maintenance activity is tracked and reported. The Town also ensures that the maintenance program complies with North Carolina Department of Environment and Natural Resources (NCDENR) permit. Of particular note in assessing the town's level of professionalism, NCDENR has adopted some of the Town SSO Response Procedures for state wide use. The Town developed a Fats, Oils, and Grease (FOG) program that is recognized nationally. The staff responsible for the program has participated in the development of workshops and FOG Program documents for the Water Environment Federation as well as for the U.S. Environmental Protection Agency. A Right of Way/Easement Maintenance program maintains access to Town field assets.

PWUT has an inventory of emergency response materials that includes pumps, hose and fittings, portable engine driven generators and other equipment. This inventory is being added to this year with the procurement of high density polyethylene (HDPE) pipe, generators and other equipment as it is identified.

Other Issues and Concerns. The assessment team identified other assets that may be at risk.

1. The Swift Creek Force Main should be evaluated for potential failure due to corrosion based on observations of existing piping during recovery.
2. The Walnut Creek Pump Station and Force Main may also be at risk and should be evaluated.

On a broader scale, a formal condition assessment program should be developed and implemented for Town pump stations and pressure pipe.

During the interviews and field observations at the Operations Center, some concern was expressed for the future sustainability of the preventive maintenance program due to the number of vacancies in staff positions and the growing backlog of priority work. Growth of the system has also added to the workload. The Town needs to evaluate resources available versus the resources needed to sustain the high performance levels established.

4.3.2 Response Phase

The Town has an Emergency Response Plan in place. That plan relies, in part and somewhat indirectly, upon the real time monitoring of the field operating conditions of the Swift Creek Pump Station (all pump stations use SCADA) and upon the availability of standby crews to respond to alarms and customer service requests after normal work hours.

Prevention and Mitigation. The SCADA system first recorded the loss of pressure in the force main and, subsequently, the high wet well condition caused by the pumps shutting down and the force main failure. The alarm was sent immediately to the primary standby crew who then responded to evaluate the alarm within 30 minutes of receiving the alarm. The crew's knowledge and experience allowed them to rapidly assess the situation and began immediate mobilization of the appropriate Town staff.

Town staff decided to divert approximately 1 million gallons per day (mgd) of flow from the Swift Creek Pump Station influent line to the Walnut Creek Pump Station, and from there to the North Water Reclamation Facility. The decision to divert was made at 1845 or 1 ½ hours after the loss of pressure alarm. This action mitigated the amount of the SSO to surface waters.

By 1900, key PWUT staff members were at the Operations Center evaluating the information from the field staff and began mobilizing the external and internal resources needed to respond, including the Contractor and the EOR. Staff also began mobilizing a local contractor in the event the Contractor could not be contacted. The Contractor was successfully contacted and responded immediately so the local contractor was recalled.

The response to the incident was very rapid because of the real time SCADA information, because staff was already responding to other alarms in the field, and because key staff had remained at the Operations Center because of the wet weather event that preceded the Swift Creek Pump Station pipe failure.

The dedication and professionalism of the Town staff was illustrated by several staff returning from vacation and other staff calling in to assist in the response.

Other Issues and Concerns. During the response, organizational and institutional issues became evident that may have had a slight impact on the incident but need to be evaluated further in the context of avoidance of future catastrophic system failures. As noted previously, the full implementation of the NIMS structure will address these issues.

Once on site, representatives from the Town, EOR and Contractor focused on an immediate repair that would return the station to operation as soon as possible. While there was a high level of confidence this repair would be effective, some time was lost in initiating contingency alternatives to the repair; such as the pump and haul operation and the temporary bypass. Ideally, the decision to implement one or both of those plans could have been initiated Friday evening, June 23 as the condition assessment developed. This might have saved a few hours for the implementation of the pump and haul operation and up to two days for the bypass pumping. The NIMS framework should include identification of failure modes for critical facilities and develop pre-planned contingencies such as pump and haul and bypass. Resources then need to be identified to execute the contingency plans.

Some critical activities relied on the experience and knowledge of the Town staff. This experience and knowledge, often called institutional knowledge, must be captured as soon as possible. The reality is that many key staff will be approaching retirement within the next ten years. This information can be used immediately to begin succession planning and also incorporated into the structured NIMS system the Town is implementing.

Acknowledgement of the institutional knowledge thus leads to acknowledgement of the need for a formal succession planning strategy to be developed and implemented. As part of that planning strategy, the Town can continue to obtain and collect system attribute information and to populate GIS and other information system databases with that data. Examples are:

- Manhole location
- Invert elevation
- Rim elevation
- Low points in upstream gravity sewers
- Storage capacity in upstream gravity sewers at different flow conditions
- By-pass capability

A SCADA upgrade project is currently underway. Elements of the new SCADA system need to be included in the NIMS implementation

Communications was also mentioned as sometimes confusing and frustrating during the initial response period, for example, multiple staff performing the same task. Based on internal and external interview comments, communications plan and/or protocols for both internal and external notification need to be more clearly defined. Using these protocols, the Town will maximize the use of available resources internally across the organization, (for example, among PWUT, Engineering, and Public Information Officer) and externally to the public and those affected by a catastrophic event. This communication plan should be developed and documented as part of the NIMS implementation.

One practice in reasonably common use among agencies is to request users in the affected service area to reduce water consumption during an incident such as the pipe failure. Potentially, this could reduce the volume of overflows. Practices such as these should be included in the communication plan developed in the NIMS framework.

4.3.3 Recovery Phase

Once the bypass system was functional, staff began the Recovery Phase which included:

- Design and construction for the permanent repair of the failure
- Remediation of SSO site soil
- Evaluation of water quality issues
- Post incident critiques and root cause failure analysis
- Quantification of bypass and SSO volumes
- Final reporting
- Other activities as necessary to execute the Recovery Phase

The post incident analysis focused on the technical issues, the effectiveness of the Town ERP and identified needs in several organizational and institutional areas such as internal and external communications, optimizing Departmental/Divisional resources, and policy procedure documentation. The Town has already implemented changes in several areas as a result of the on-going internal collaborations. They have also initiated changes to improve technical issues identified.

It is important to note here that each failure of this type has its unique aspects. The experience gained in dealing with each event will include lessons learned. These must be incorporated into the Response Plan and other documents to improve the quality of the Response Plan. It is also of paramount importance, continually emphasized, that these documents not be treated as archival monuments but rather should be living documents subject to frequent review and revision.

5. ANTICIPATED SHORT-TERM AND LONG-TERM WATER QUALITY AND ENVIRONMENTAL IMPACTS

This section summarizes the water quality impacts of the June 23 to June 28, 2006 wastewater spill into Swift Creek in Wake County, North Carolina. Background information on the watershed characteristics, previous receiving water monitoring data, post-spill monitoring data, wastewater flow and influent characteristics, other spills in the region, and other relevant information was gathered and reviewed. Data gaps were identified by interviewing stakeholders and seeking additional input or available information. Stakeholder interviews also helped assure that the scope of the investigation would address the issues of all interested parties.

A simple box model/residence time approach was used to describe the fate and transport of dissolved and solid constituents of the discharge, and estimates of constituent loads were used to characterize the potential for impacts to water quality. Using simple conceptual models of pollutant effects, a prioritized list of issues and next steps was developed, including recommendations for monitoring needs and a conceptual level analysis of potential remedial actions. The results of the impacts analysis are summarized below:

- The water quality resource
- The nature of pollutants of concern present in raw wastewater
- Characterizing impacts due to the spill
- Monitoring needs and next steps to restore public confidence in the use of the resources

5.1 The Water Quality Resource

The Swift Creek Watershed is classified by the North Carolina Division of Water Quality (NCDWQ) as a Class-III Water Supply Watershed. This means that it has the potential to serve as a potable water supply and is a low to moderately developed watershed. WS-III watersheds also support the beneficial uses of water contact recreation, fishing, wildlife habitat, fish and aquatic life propagation and survival, and agriculture. The Swift Creek watershed is also classified as a Nutrient Sensitive Watershed (NSW) by the NCDWQ, meaning that it needs additional nutrient management because it is subject to excessive growth of microscopic and macroscopic vegetation. Swift Creek is located within the upper Neuse River Basin, and as such is subject to the Neuse River NSW Rules.

The Swift Creek Watershed includes two lakes owned by the City of Raleigh that serve as recreation and auxiliary water supply. Lake Wheeler provides boating, water skiing, inner tubing, and fishing recreation, while Lake Benson recreation is limited to surface boating and fishing. Stakeholder interviews, including with the City of Raleigh Parks and Recreation Director, confirm that water contact recreation is extremely popular among residents. Recreational trails planned by the City of Raleigh for the Swift Creek Watershed will form a continuous loop connecting Lake Johnston to the north with Lake Wheeler and Lake Benson. Because of the high recreational value of this watershed, maintaining public confidence in the safety of water contact recreation is one of the highest watershed management priorities. Recommendations are provided later in this report regarding reestablishing and maintaining public confidence in the safety and aesthetic quality of Lakes Wheeler and Benson.

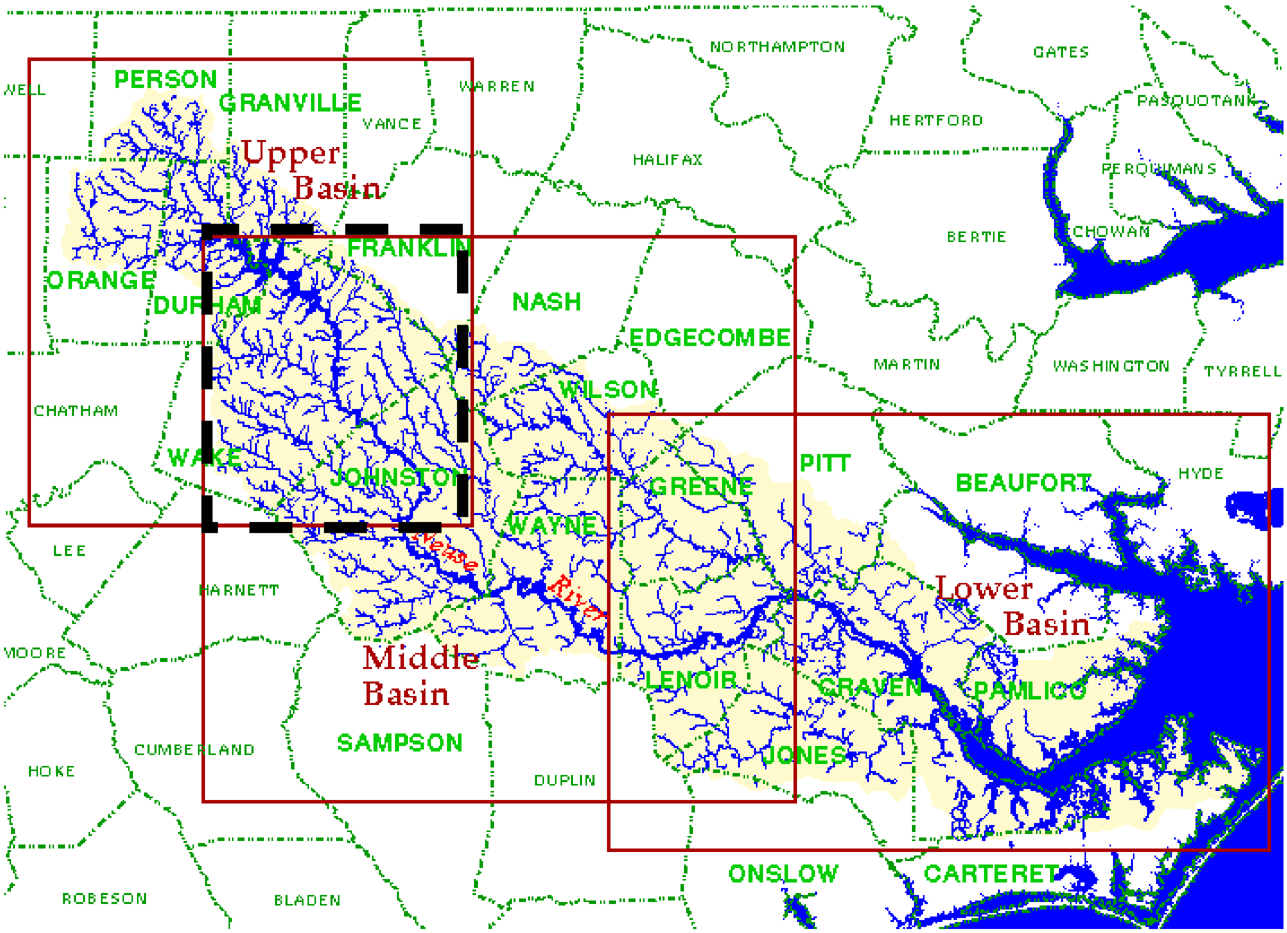


Figure 5-1. Neuse River Basin. (Dashed line details area around Swift Creek Watershed)

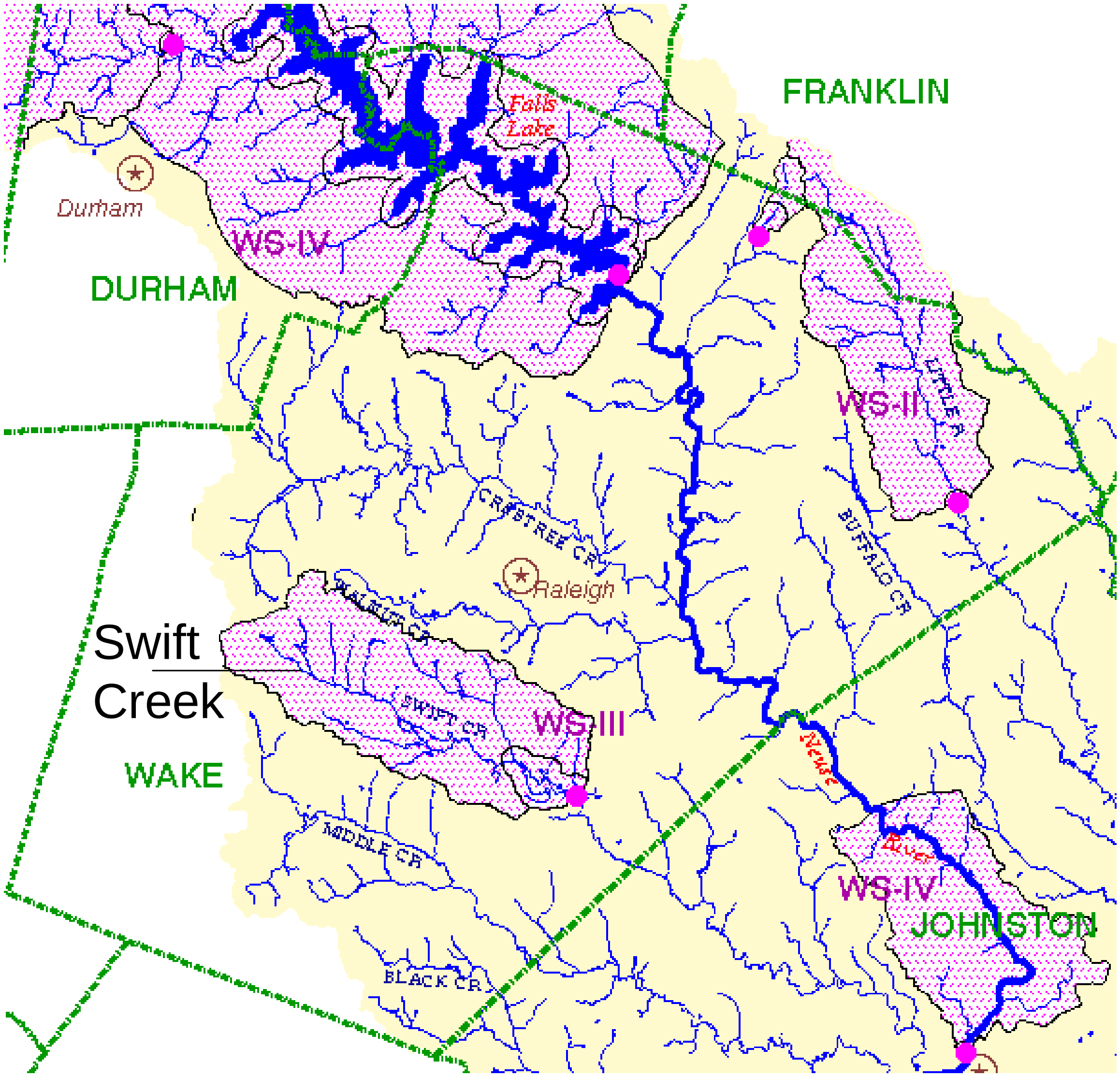


Figure 5-2. Neuse River Basin in Wake County, North Carolina

Lake Benson was used as a water supply reservoir for Raleigh until the mid 1980s. The City of Raleigh's Public Utilities Commission is planning to resume use of Lake Benson for water supply, and therefore has a direct interest in the protection of potable water quality. Because of its protected status, the Swift Creek watershed is subject to the Swift Creek Land Management Plan, which specifies buffer zones around critical watershed areas and other zoning measure intended to resolve the competing interests of water quality protection and logical urban growth and development. About 2/3 of the land area in the watershed is characterized as developed.[6] Because potable water is not currently being produced at the Lake Benson Water Treatment Plant, the Cary spill produced no short-term impact upon this use category. Although detrimental long-term impacts are not expected, there are recommendations presented later in this section that address continued monitoring of the potential impacts.

There are a number of homes served by private wells in the vicinity of Lake Wheeler. Therefore, protection of groundwater quality is also important to the community. The Arcadis preliminary report[6] on Water Quality Impacts concluded that the spill caused "negligible, if any" impacts to private groundwater wells. That finding was based on the general flow of groundwater from the water table into the stream valley, and the measurement of bacteria in surrounding wells. This review generally supports that conclusion, but recommendations are provided for follow-up studies that could provide additional verification of the safety of local groundwater supplies.

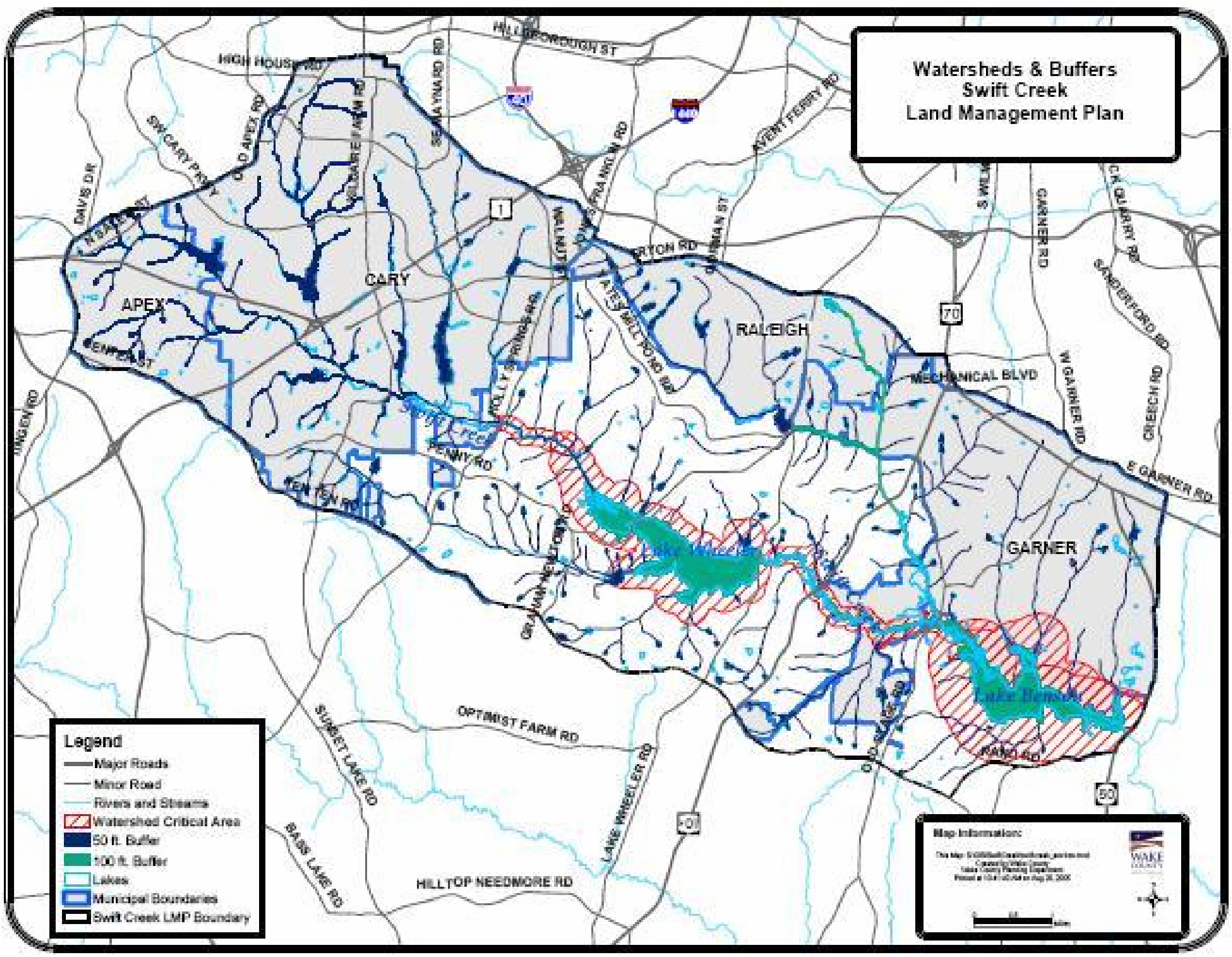


Figure 5-3. Swift Creek Land Management Plan
(Source://www.wakegov.com/planning/landuse/SwiftCreekLMP.htm.)

Downstream from Lake Benson, Swift Creek provides habitat for the Dwarf Wedge Mussel (*Alasmidonta heterodon*). Interviews with United States Fish and Wildlife Services (USFWS) staff confirm that this is the only federally listed endangered species likely to be affected by water quality impacts in this watershed. The City of Raleigh is discussing appropriate mitigation and monitoring for the Dwarf Wedge Mussel in relation to potential habitat loss due to resumption of water supply use of Lake Benson. There is little reason for concern for the impact of the spill upon the aquatic habitat and species in Lakes Wheeler and Benson with the possible exception of habitat in the upstream section of Lake Wheeler above Penny Road. Monitoring and potential remediation are discussed later in this report.

In summary, the primary uses of water that needed assessment for water quality impacts are:

- Water contact recreation

- Water supply
- Groundwater recharge
- Fishing
- Aquatic life habitat

This list of uses was developed and vetted with Town staff, Wake County Department of Environmental Health, Raleigh Parks and Recreation Department, Raleigh Public Utilities Commission, NCDWQ, the USFWS, and the Neuse River Foundation's Riverkeeper.

5.2 Prevention and Response

This section discusses both prevention, that is, knowing the pollutants of concern and applicable standards, and response, monitoring impacts as a basis for making the recommendations summarized at the end of this section. Water quality standards and pollutants of concern that needed assessment were discussed with stakeholders during interviews. Table 1 shows a list of probable impacts for standards and pollutants based on information gathered in the interviews and subsequent analysis. The standards, pollutant concerns, and rationale for each of these findings are discussed below, organized by standard or pollutant.

Table 5-1. Summary Of Probable Impacts For Water Quality Standards And Key Pollutants Of Concern, September 2006

Standard or pollutant	Probable short term impact	Probable long term impact
No discharge of untreated waste	High – The discharge occurred thus violating the standard	Low – The discharge has been stopped and future probabilities of discharge of similar or greater magnitude are low, particularly after implementing management and infrastructure improvements
Lost Use	Water Contact – High Water Supply – Low Aquatic Life – Low Wildlife Habitat - Low	Low, after implementing regionally coordinated monitoring, communication, and pollution prevention
Bacteria and pathogens	High – particularly in the upstream reaches of Lake Wheeler above Penny Road. Medium to Low elsewhere directly attributable to the spill but there are continuing concerns that require monitoring.	Low
Biosolids	Uncertain	Low
Nutrients	Low – nutrient loading is a small fraction of reasonable estimates of watershed loading. Potential for significant localized impacts existed but adverse conditions were not observed.	Low – localized impacts in upper reaches of Lake Wheeler still a significant concern.
Non-biodegradable solids	Uncertain	Low
Pharmaceuticals / Endocrine Disrupting Compounds (EDCs)	Uncertain	Low
Mercury	Low	Low

5.3 Discharge prohibition

As a WS-III watershed, discharge of wastewater is prohibited according to 15A-NCAC-02B.0215(3)(a):

> "Sewage, industrial wastes, non-process industrial wastes, or other wastes: none except for those specified in Item (2) of this Rule and Rule .0104 of this Subchapter; and none which shall have an adverse effect on human health or which are not effectively treated to the satisfaction of the Commission and in accordance with the requirements of the Division of Environmental Health, North Carolina Department of Environment and Natural Resources; any discharger may be required by the Commission to disclose all chemical constituents present or potentially present in their wastes and chemicals which could be spilled or be present in runoff from their facility which may have an adverse impact on downstream water quality; these facilities may be required to have spill and treatment failure control plans as well as perform special monitoring for toxic substances."

NCDWQ staff stated in that this standard and the loss of use standard, discussed below, are the primary bases for their evaluation of the severity of the incident.

For evaluating impacts, the spill volume that exceeded this standard is estimated to be between 6 and 9 million gallons (Mg), with a best estimate of 8 Mg used for the purpose of calculating pollutant loads discharged. This range accounts for three scenario's of discharges and the estimated volumes include the estimates of inflow and infiltration of rain water that diluted the volume of raw wastewater discharged.

The short term impact of this exceedance is high – this was the third largest spill in the region in recent history. The long-term impact, that is, the likelihood of recurrence, can be significantly diminished by improved managerial and infrastructural changes. The analysis in this report describes the factors that led to the discharge and makes recommendations for improvements that are expected to lead to prevention of future violations of this standard.

5.4 Loss of Use

15A-NCAC-02B.0211(2) states that Class C watersheds shall be suitable for aquatic life propagation and maintenance of biological integrity, wildlife, secondary recreation, and agriculture. Discharges that preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard. With reference to water contact recreation, NCDWQ staff stated that the lost use standard applied regardless of whether the lost use was based on real or perceived risk.

The primary lost use at least partly contributable to the spill appears to be water contact recreation. A key indicator for lost use discussed by the Raleigh Parks and Recreation director is the days of lake closures for general recreation and cancellation of planned activities such as camps and other organized activities. The director strongly believes that his customers deserved some means of assuring restoration of public confidence in the use of the recreational resources of the Lake. No summary of lost days and cancellations has been provided. Some of that lost use was due to closing of Lake Wheeler for recreational activity and additional lost use may have occurred due to public perception of risks. Due to development in the watershed, and due to the wildlife (waterfowl) use of Lake Wheeler, it is extremely difficult to confirm that recreational closures in the days following the spill were fully contributable to the spill.

In the long term, restoration of public confidence would be enhanced by a regionally coordinated program of water quality monitoring and effective public outreach and communication. This requires the cooperation of a number of interested parties, including:

- Wake County Environmental Services
- Raleigh Public Utilities Commission
- Raleigh Parks and Recreation Department
- Town of Cary Public Utilities Commission
- Town of Garner Parks and Recreation Department

A watershed management initiative directed at monitoring, pollution prevention, and public education implemented by interested parties would also need to coordinate with:

- United States Fish and Wildlife Service, (USFWS)
- North Carolina Wildlife Resources Commission (NCWRC)
- North Carolina Division of Water Quality (NCDWQ)
- North Carolina Division of Land Resources (NCDLR)
- United States Environmental Protection Agency (USEPA).
- Neuse River Foundation
- Research Institutions such as the United States Geological Survey (USGS), Duke University, North Carolina State University, and the University of North Carolina.

USFWS and other environmental stakeholders did not express direct concerns about lost wildlife uses, but referred to the more general regional issue of habitat quality monitoring for the Dwarf Wedge Mussel related to planned water supply diversions from Lake Benson. Raleigh Public Utilities Commission questioned the potential for some constituents to impact the quality of potable water. This is discussed in more detail in section 2.7 (Pharmaceuticals, endocrine disrupting compounds, and personal care products). The potential for short term impacts is low, due to the slow transfer of water from Lake Wheeler to Lake Benson, and the fact that Lake Benson is not currently in use as a water supply. The potential for long term impacts to lost water supply use is low so long as appropriate monitoring measures are in place.

Groundwater wells do not appear to be threatened, based on the general principle of the regional groundwater movement from the water table towards the stream valley, in addition to preliminary well tests conducted by Wake County. Gradient studies conducted near water supply wells that are within 500 feet of the lake, especially near the deeper eastern shoreline, would confirm that the stated assumptions about groundwater flow are correct in all situations. As a first step toward this, the Town of Cary has begun a GIS search to identify and communicate with residents with houses located near the lake shore. Further monitoring and analysis of those wells within 500 feet of Lake Wheeler will confirm the prior analyses and build confidence that the potential problem has been fully addressed.

5.5 Bacteria and other pathogens

Raw wastewater contains fecal coliforms, enterococci, shigella, and other harmful bacteria that can lead to disease outbreaks through water contact recreation. Bacteria can lead to the disease symptoms directly, as with shigella and cholera outbreaks that cause diarrhea, or indirectly by carrying human viruses that cause diseases such as gastroenteritis. Abundance of enterococci has been correlated with swimming-related outbreaks of gastroenteritis.[7]

Fecal coliforms are indicators of environmental risk due to water contact exposure to pathogens. The following water quality criterion applies to protection of human health by water contact recreation as specified in 15A-NCAC-02B.0211(3)(e):

> "Organisms of the coliform group: fecal coliforms shall not exceed a geometric mean of 200/100 ml (MF count) based upon at least five consecutive samples examined during any 30 day period, nor exceed 400/100 ml in more than 20 percent of the samples examined during such period; violations of the fecal coliform standard are expected during rainfall events and, in some cases, this violation is expected to be caused by uncontrollable nonpoint source pollution; all coliform concentrations are to be analyzed using the membrane filter technique unless high turbidity or other adverse conditions necessitate the tube dilution method; in case of controversy over results, the MPN 5-tube dilution technique shall be used as the reference method."

Protozoans such as giardia and cryptosporidia are also of concern. They occur in raw wastewater, but also can be transported from watershed sources of animal fecal matter [8,9] Both protozoans can cause diarrhea and abdominal cramping, though giardia infections are often asymptomatic. These pathogens exist in water as cysts that are transmitted to people through the oral route, for example water inadvertently ingested while swimming or water skiing. Cysts can persist in water for up to a year before they die.

The City of Raleigh has a monthly monitoring program that includes pathogens. Enterococcus has been measured monthly since 2001. Giardia and cryptosporidium cysts have been measured quarterly since 2001. Fecal coliforms have been measured monthly from 2001 to 2004. Monitoring data provided by the City of Raleigh replaced fecal coliforms with total coliforms and E. Coli for the period 2005 to present. Additional post-spill monitoring data, shown in Table 5-2, were provided by the City of Raleigh PUC, the Town of Cary, and the Wake County Department of Environmental Health. These data help understand short term and long term impacts of bacteria, and identify uncertainties that can be resolved through monitoring.

Short term impacts of the spill are demonstrated by the substantial exceedances of the 400 counts/100 ml standard immediately after the spill particularly in the western arm of Lake Wheeler. The time distribution of the data suggests that it takes about a day for bacteria from the spill and other storm water sources entering from Swift Creek to reach the eastern side of the lake.

Table 5-2. Post-spill monitoring data supplied by the City of Raleigh and the Town of Cary helps characterize short term water quality impacts on pathogens criteria.

Date	Marsh Fecal #/100ml	LW1 Fecal #/100ml	LW2 Fecal #/100ml	LW3 Fecal #/100ml	LW4 Fecal #/100ml	LW5 Fecal #/100ml	LW6 Fecal #/100ml	LW7 Fecal #/100ml	Spillway Fecal #/100ml
6/24/2006	20000 a	8300	2100	3367	<10	2	<2	6	- b
6/25/2006	-	8100	1130	190	110	110	365	305	625
6/26/2006	2500	610		280	420	30	-	20	10
6/27/2006	1010	590	650	210	150	100	-	80	10
6/28/2006	-	-	-	-	-	-	-	-	-
6/29/2006	145	170	165	105	110	10	-	<10	<10
6/30/2006	60	50	<10	<10	<10	<10	-	<10	<10
7/1/2006	-	20	-	-	-	-	-	-	-
7/2/2006	-	50	-	-	-	-	-	-	-
7/3/2006	-	5	-	-	-	-	-	-	-

[a] - Bold and italicized values exceed the 400 count / 100 ml standard, which is not to be exceeded more than 20% of the time.

[b] - Indicates no data

This observation is consistent with residence time calculations for the lake. During peak flows observed in storm events, the entire water volume of Lake Wheeler west of Penny Road is replaced in about a day by inflowing storm water. In contrast, the volume of the main recreational lake is replaced much more slowly, so the transport of bacteria by the spill takes a day or more by wind-driven mixing and lake circulation.

Attenuating factors that help explain the short term impacts characterized in Table 5.2 include dilution, settling, and bacteria die-off. The volume of Lake Wheeler, about 7,200 Acre-feet or 2.3 billion gallons, is about 300 times greater than the volume of spill, about 8 Mg. So it makes sense that the initial upstream bacteria counts of 1,000 - 20,000 / 100 ml are much lower when diluted into the entire volume of the lake. Fecal coliform bacteria do not generally survive very long in the ambient environment, so once a bacteria source is shut off the bacteria count would be expected to drop, especially in the surface waters where ultraviolet light speeds up die off rates. Bacteria also attach to particles, so as suspended solids coagulate and settle bacteria counts are removed from surface waters. While in some circumstances these bacteria will survive and reproduce in sediments, such conditions are not characteristic of Lake Wheeler.

The time distribution of the bacteria counts shown suggest that the majority of the short-term impacts occurred during the first day of the spill, and that subsequent interim measures diminished pollutant loads. This should be kept in mind for load estimates based on days of the spill – the majority of the uncontrolled discharge may have occurred during the first two days following the pipe separation at the pump station.

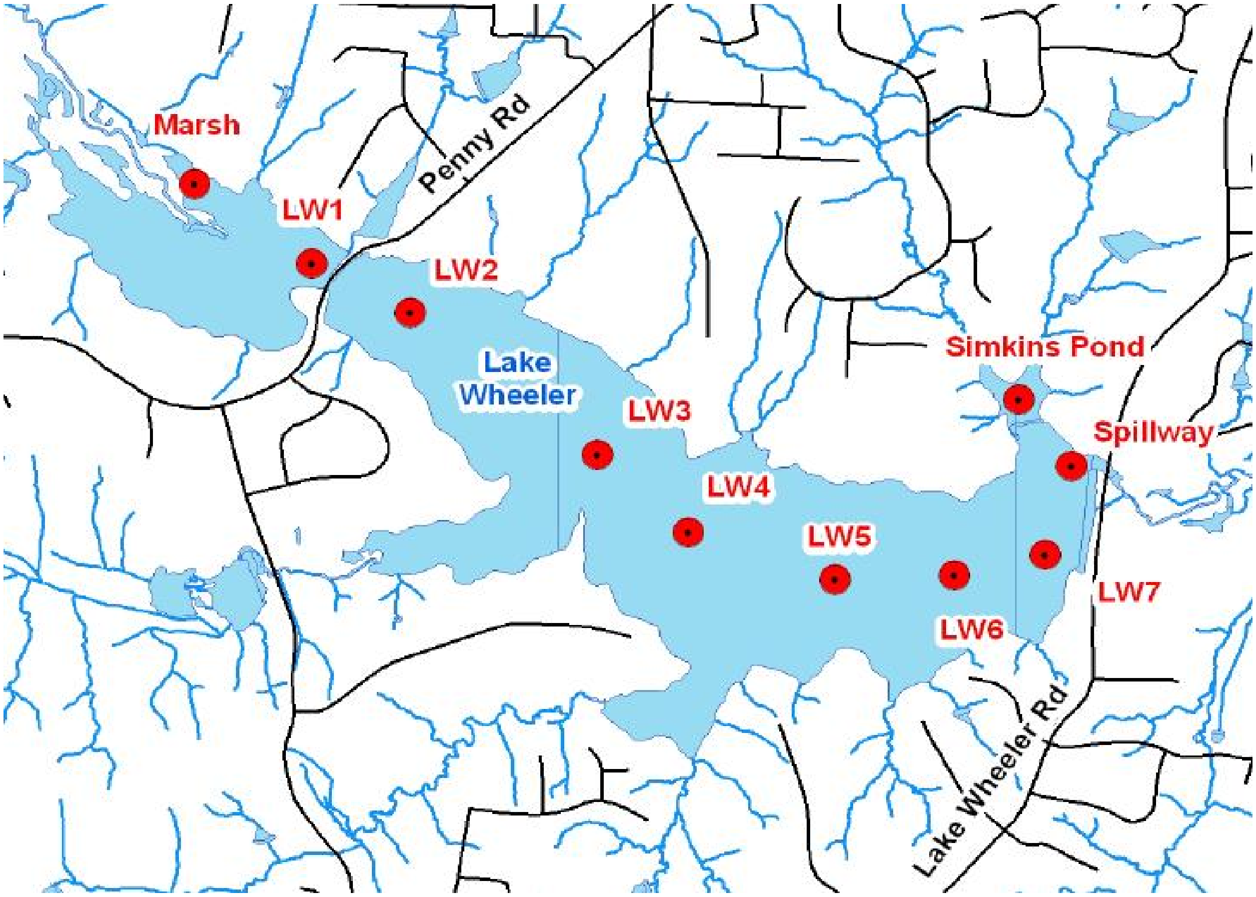


Figure 5-4: Locations of post-spill monitoring data collection points. Map source: City of Raleigh Public Utilities Commission.

The potential for long-term impacts can be put into perspective by examining post-spill monitoring data in the context of monthly monitoring for fecal coliform. West of Penny Rd., on June 24 and 25, the exceedances of the standard were the largest in the monitoring data set provided (Figure 5-5). East of Penny Rd., in the downstream (eastern) reach of the lake, the exceedance of the standard was comparable in magnitude to previous occurrences of runoff during which wastewater spills did not occur (Figure 5-6). In both segments, the frequency of exceedances is about the same, five to six over the past five years of data. While the data are not adequate to evaluate long-term attainment of the 20 percent threshold, it is clear that pre-spill events can also influence attainment of bacteria standards.

Preliminary data were provided by the City of Raleigh on giardia and cryptosporidium monitoring from historic and post-spill monitoring. The historic data are best interpreted as presence / absence findings, and so frequency over time is more meaningful than point data. Giardia cysts have been detected eight out of nineteen times in the past five years west of Penny Rd., and downstream two out of nineteen times in Lake Wheeler. Cryptosporidia cysts have been detected three out of sixteen times in both segments. There is not sufficient information to tell whether frequency of detection has increased post-spill, but is does appear that under pre-spill conditions giardia is detected more frequently west of Penny Rd. The possible existence of spatial gradients in the Lake that pre-dated the spill should be looked into more carefully.

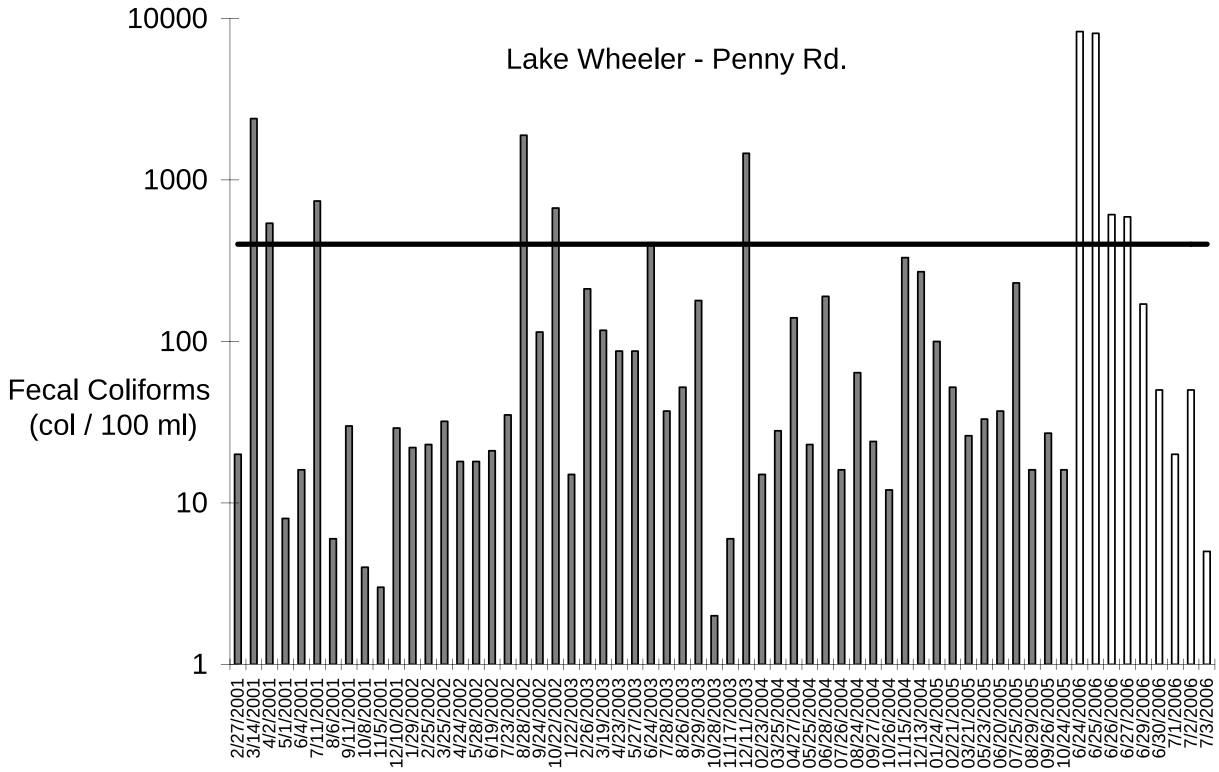


Figure 5-5: Long term data set showing fecal coliform counts in the west side of Lake Wheeler. Data source: City of Raleigh. Light colored bars indicate post-spill data, dark bars indicate monthly monitoring conducted by the City of Raleigh.

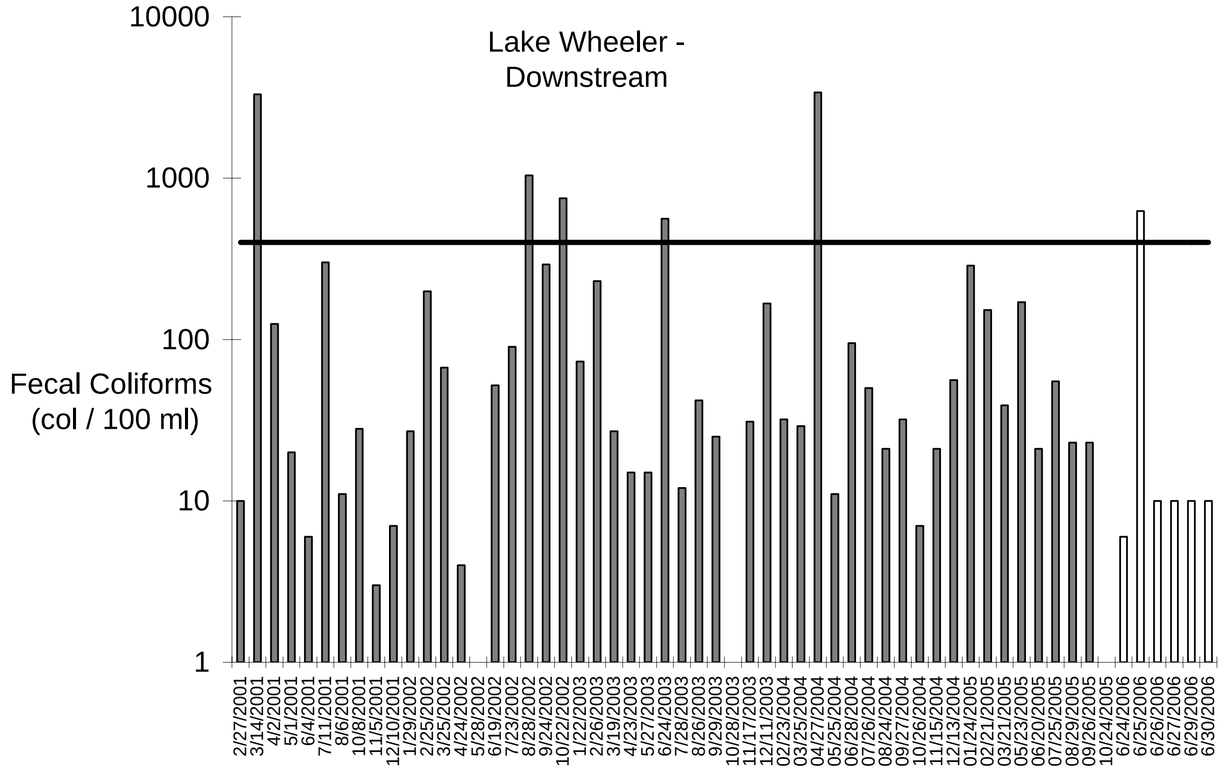


Figure 5-6: Long term trends in fecal coliform counts in the eastern side of Lake Wheeler based on data supplied by the City of Raleigh. Light colored bars indicate post-spill data, dark bars indicate monthly monitoring conducted by the City of Raleigh

Bacteria die off over time, so once a source is shut off the impact is attenuated. In the long term, actions to attain water quality standards for bacteria should focus on source assessment and reduction in the watershed, monitoring in the lake and communication of the results, and as discussed in the next section, nutrient management strategies to maintain water clarity. With this approach, long term impacts from pathogens due to the spill are likely to be low.

5.6 Nutrients

Nitrogen and phosphorous loadings to surface waters can stimulate the growth of unwanted algae and other vegetation, a process known as eutrophication. Excessive algal blooms can have the direct effect of impairing aesthetic appearances, and indirectly can lead to depressed dissolved oxygen and associated odors and degraded habitat value because of microbial decomposition of decaying plant matter. As noted above, Swift Creek is listed as a Nutrient Sensitive Watershed, and is subject to the Neuse River Rules for nutrient management (15-NCAC-02B.0232-0242).

Nutrient impacts should be considered at both the basin-wide and local watershed scale. Estimated loads of nutrients released from the spill into Lake Wheeler can be compared to estimated watershed loads into Lake Wheeler. However, at the basin-wide scale, relating nitrogen discharged from the spill to loads at the Neuse River Mouth is difficult because transport through the Swift Creek watershed through the Neuse River is slow relative to biological uptake and transformation processes. Because of this, recommendations for recovery focus on practical watershed management approaches to nutrient management based on the Neuse River Rules and the Swift Creek Land Management Plan and regional strategies to monitor and reduce nutrient impacts in the long term.

For WS-III watersheds the applicable numeric water quality standard for nitrogen as defined in 15A-NCAC-02B.0215(3)(h)(i)(E) is nitrate nitrogen (10 mg/L). However, this is a drinking water standard, rather than an ecosystem protection endpoint. Target concentrations to avoid nuisance algal blooms may be lower and involve both other forms of nitrogen and other nutrients.

Preliminary estimates of nitrogen loads discharged can be made based on influent nitrogen concentrations (41 to 45 mg/L) and an estimated range of 6 to 9 Mg of wastewater discharged. The best estimate of nitrogen load discharged from the spill event is 1300 kg, with a likely range of 900 to 1500 kg. For perspective, if all of the 8,371 developed acres of the Swift Creek watershed above Holly Springs Rd. attained the Neuse River Rule goal of 3.6 pounds per acre per year for new development[10] , the annual nitrogen load would be about 14,000 kg, about 10 times more than the nitrogen introduced into the system by the spill..

1,300 kg of nitrogen is a potentially significant short term impact, in particular if the source of nitrogen is readily available to stimulate algal growth. Because of the relatively long residence time of Lake Wheeler, nitrogen impacts would likely be focused on that Lake, and may be delayed until springtime bloom conditions or later. Monitoring of chlorophyll, focused studies of nutrient cycling dynamics, and potential mitigations for lake eutrophication such as aeration may be appropriate if short term impacts become apparent. In the longer term, watershed management to attain goals set by the Neuse River Rules is a more significant factor affecting nutrient loads to Swift Creek watershed.

5.7 Biosolids

Biosolids are a concern because they carry bacteria and other pathogens, and because they provide a ready source of carbon, nitrogen, and other nutrients that can put biochemical oxygen demand on a system. One of the key questions about biosolids in this system is their settling rate and fate. It is important to know whether the biosolids discharged were distributed over the entire lake, or whether they settled in the western arm of Lake Wheeler. This is explained later in this section with a simple residence time conceptual model, which leads to some of the monitoring recommendations presented later.

Biosolids and non-biodegradable solids (Section 5.8, below) are subject to the Standard for solids, 15A-NCAC-02B.0211(3)(c):

> Floating solids; settleable solids; sludge deposits: only such amounts attributable to wastewater, industrial wastes or other wastes as shall not make the water unsafe or unsuitable for aquatic life and wildlife or impair the waters for any designated uses.

Similar to the nitrogen load, the load of suspended solids can be calculated from the Total Suspended Solids (TSS) of wastewater influent (220 to 250 mg/L) and the same range of estimated discharge volumes (6 to 9 Mg). The best estimate is 7,000 kg biosolids discharged, with a possible range of 5,000 to 9,000 kg. For comparison, 5600 cubic meters of sediment accumulate in Lake Wheeler every year on average, corresponding to 15,000,000 kg of sediment, roughly 2,000 times the biosolids load discharged from the event. Just as the volume of the lake substantially diluted the volume of the spill, the mass of sediment involved in watershed sediment transport processes may make it difficult to discern the presence of any biosolids, particularly after sufficient time has elapsed for microbial digestion, degradation, and re-working of colloidal matter to occur.

5.8 Non-biodegradable solids

Urban areas often have non-biodegradable solids mixed into influent streams as a result of people disposing of consumer products in their household toilets. Inadvertent discharge of such matter into surface waters is a concern if residual deposits later are mobilized into swimming and boating areas. Rough estimates of common consumer products, such as cigarette butts, latex prophylactics, and sanitary napkins can be made based on population and consumption rates, and noting that the bulk of the raw wastewater spill may have occurred over the first two days of the spill, before pump and haul operations commenced. Based on normal consumption patterns and estimates of disposal rates, it is likely that the number of non-biodegradable solids attributable to the spill is at least in the hundreds, more likely in the thousands, and probably less than ten thousand. Most of that material should be in the deposits in Lake Wheeler upstream of Penny Road. This can be refined by visual inspection using remote cameras or collection of sediment samples from the Lake bottom. Note that above surface visual inspections of Lake Wheeler upstream of Penny Road have been made and no increased density was observed of non-biodegradable solids above that usually observed around piedmont North Carolina lakes.

5.9 Pharmaceuticals, endocrine disrupting compounds, personal care products, and other human-originating chemicals

Raleigh Public Utilities Commission (PUC) staff expressed an interest in the approach to assessing loads of pharmaceuticals, endocrine disrupting compounds, personal care products, and other human-originating organic wastewater contaminant (OWCs). This is an emerging class of compounds known to be present in wastewater and residential wastewater. Because of the potential use of Lake Benson as a water supply, the PUC question was posed in the context of assessing long term risks to potable water quality. Little is known about risk assessment for many of these compounds, and they are not typically monitored in routine programs administered by the City of Raleigh or other agencies. Because of this lack of background information, the impacts are uncertain, and the recommendations are largely focused on reducing uncertainty.

A national reconnaissance of OWCs[11] provides some background on expected OWC concentrations in surface waters. Measurement methods are reviewed and concentrations are summarized for 95 compounds, including antibiotics, prescription drugs, non-prescription drugs, steroids, hormones, detergents, antimicrobials, and other wastewater-related compounds. One of the better characterized compounds is caffeine, which is a good tracer of human wastewater, because of its low natural background concentrations and prevalence in residential and commercial service areas[12].

Caffeine remains predominantly in the dissolved state, and so can be used to approximate the fate of other soluble OWCs. Estimated concentrations for a small subset of these compounds are summarized below, and they lead to monitoring and risk assessment recommendations. This ratio approach is not predictive in any quantitative sense. It is a useful conceptual method to estimate order of magnitude concentrations, and describe where soluble pollutant loads from the spill are today. It helps to inform preliminary risk assessment questions for future water use and design of monitoring studies.

The preliminary results of mass transport modeling suggest that most of the dissolved constituents of the spill are still in Lake Wheeler, only a small fraction has been transported downstream to Lake Benson thus far. This modeled prediction can be verified or refuted by measuring the caffeine concentrations in Lake Wheeler and Lake Benson. The modeling results predict caffeine concentrations in Lake Wheeler will be 3 to four times those of Lake Benson, about 0.1 μg/L compared to 0.03 μg/L. These concentrations may be overestimated, because of many simplifying assumptions made in the model, but the relative difference between the lakes is very likely accurate, just based on the lake volumes and flow rates out of Lake Wheeler.

Table 5-3. Concentrations of other human derived compounds found by the USGS (2002) in surface waters, and the resulting estimated concentrations in Lake Wheeler and Lake Benson based on the ratio to caffeine.

Compound	Type	Median from USGS (2002), µg/L	Estimated concentration in Lake Wheeler, µg/L	Estimated concentration in Lake Benson, µg/L
Caffeine	Drug	0.08	0.1	0.03
Acetaminophen	Drug	0.1	0.2	0.04
Ibuprofen	Drug	0.2	0.3	0.08
Cholesterol	Plant/animal steroid	0.8	1	0.3
Coprostanol	Fecal steroid	0.09	0.1	0.03
Testosterone	Reproductive hormone	0.12	0.2	0.04
Progesterone	Reproductive hormone	0.1	0.2	0.04
Sulfamethoxazole	Antibiotic	0.07	0.1	0.03

This gives Raleigh PUC staff a simple approach to estimate concentrations of other OWCs. If a more refined estimate of OWCs is desired, measuring caffeine in the Lakes is a cost effective place to start. However, this is likely a lower priority compared to pathogens and nutrient monitoring needs.

5.10 Mercury and Other Metals

Mercury and other metals are known to be present in wastewater. Mercury is present because of direct inputs from dental facilities that use mercury amalgam, and indirect inputs from human body-burdens of mercury because of diet and use of mercury fillings. There are approximately 14 dental offices in the service area of the Swift Creek pumping station. Accounting for the number of dental offices and the population of the service area, the total mercury load discharged would range from a few tenths of a gram to a few grams. As with nitrogen and solids, this is small compared to expected watershed loads. Other metals are not likely an issue because of the lack of heavy industry in the service area. The recommended action for mercury is to continue monitoring mercury in fish and posting consumption guidance consistent with regional mercury management strategies. Conversion of ambient mercury to the more toxic form of methylmercury within the lake may be an issue, as it is with most lakes and reservoirs. If so, this would be a watershed management issue, rather than a spill-related issue.

5.11 Monitoring and Next Steps

One of the key lessons learned from the interviews was the need for improved planning and communication as part of this process. Those interviewed believed that the Town of Cary should have done a better job communicating to affected parties immediately after the spill, reflecting a more general need for improved engagement and communication with the surrounding communities that share watershed resources. Strengthening working relationships through watershed planning efforts can improve communications, a key area for dealing with any emergency situation.

Based on the findings of this assessment, the recommended next steps are:

1) **Develop and implement a regionally coordinated monitoring program.** Essentially all of the planning to avoid long-term impacts requires some monitoring to make decisions and reduce uncertainties. This can be done in a way that shares responsibilities among all users of the watershed resources.

2) **Develop and implement a regionally coordinated eutrophication management plan.** As noted in the nitrogen impact analysis, the long term watershed activities will play a far more important role in lake eutrophication than loads from the spill event. Therefore, watershed load reductions will be the best way to prevent unwanted algal blooms and associated low dissolved oxygen. In addition to watershed management to reduce loads, engineered solutions to manage eutrophication could be considered, such as aeration or sediment removal projects. This is important because it addresses

multiple issues: low dissolved oxygen and unsightly algal blooms can be problematic on their own for recreational aesthetics and taste and odor. But low dissolved oxygen can also accelerate the accumulation of mercury in the food web, and decreased water clarity slows down the die-off rate of light-sensitive bacteria. While managing water clarity is a challenge in North Carolina lakes, it is a high priority for Lake Wheeler and Lake Benson because of their current and potential uses.

3) **Conduct a spatial survey of Lake Wheeler bottom sediments.** A spatial survey will help determine whether the west side of Lake Wheeler is an ongoing source of pathogens or if it contains very high concentrations of objectionable materials that could be mobilized in the future and moved into the lower reaches of the lake. It appears that historically giardia may be observed more frequently west of Penny Rd., but this needs to be confirmed, and it may simply be because of higher suspended sediments in that side of the Lake. Recommended monitoring parameters include pathogens and bacterial source tracking techniques using RNA/DNA fingerprinting. Visual inspection using a remote camera will also help determine if non-biodegradable solids are a concern.

4) **Conduct a hydraulic gradient study of groundwater wells near Lake Wheeler.** The working assumption that groundwater moves away from the water table towards the stream valley should be confirmed for deep wells that are within 500 feet of the lake. This is recommended to be precautionary and respectful of community concerns expressed about the long-term protection of groundwater supplies.

6. RECOMMENDATIONS TO AVOID SIMILAR EVENTS IN THE FUTURE

The following is a summary of the recommendations from the assessment team to minimize and/or eliminate the likelihood and impact of similar events in the future:

1. Require involvement of the Town Engineering Department, working in collaboration with USM, in planning, design, and construction of projects involving critical operating facilities.
2. Perform a criticality review of facilities and then an engineering inspection and assessment of critical facilities to determine if there are facilities that may be at risk due to condition or environment.
3. Require a Sequence of Construction, a Maintenance of Facility Operations plan, and an Emergency Plan to be prepared and in place by engineer and contractor before construction work on critical operating facilities commences.
4. For critical operating facilities, conduct necessary excavation and exposure of subsurface facilities during the design period to assess condition and confirm location and constraints on construction.
5. For projects in construction, emphasize the importance of accurate record drawings to the designers and contractors.
6. For modifications to existing facilities, confirm that record drawings for subsurface conditions, at a minimum, are accurate.
7. For projects in construction, emphasize the importance of accurate record drawings to the designers and contractors. Clearly tie acceptability of record drawings to payment; consider line item for payment of acceptable record drawings.
8. Clearly communicate through design documents and construction documents the criticality and constraints for construction.
9. Define roles and responsibilities, including areas of overlap, for participants in construction project. Consider facilitated partnering (during planning, design, and construction) to enhance formal communications and to solicit personal commitments to maintaining critical operations.
10. Provide contracting mechanism to ensure geotechnical engineering resources are available to the Town and its consultants and contractors throughout the construction project. Require that apparent changes in groundwater and/or soil conditions be referred to the geotechnical resource for assessment.
11. Conduct a surge analysis for the Swift Creek Pump Station for both the repaired facility as well as for the final configuration of the existing and expanded facilities. Provide for peer review of the surge analysis.
12. Perform a condition assessment for the existing force main, particularly in the area of existing air/vacuum valves and the discharge location to determine if there is evidence of corrosion.
13. Continue and complete NIMS-based training and implement NIMS specific to the Town's needs.
14. Document procedures for interdepartmental collaboration on project, delineating roles, responsibilities, and expectations for team members.
15. Construct protection improvements at flood-prone critical facilities.
16. Install pumping connections for temporary bypassing at existing critical pumping stations.
17. Purchase one or more trailer-mounted, engine-driven, self-priming pumping systems for use with temporary bypassing connections at critical pumping stations

18. Develop and implement a regionally coordinated management plan to mitigate eutrophication.
19. Conduct a spatial survey of Lake Wheeler bottom sediments to determine whether the west side of Lake Wheeler is an ongoing source of pathogens or if it contains very high concentrations of objectionable materials.
20. Conduct a hydraulic gradient study of groundwater wells near Lake Wheeler to confirm the working assumption that groundwater moves away from the water table towards the stream valley deep wells within 500 feet of the lake.

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APPENDIX A

INTERVIEWS CONDUCTED BY PROJECT TEAM

Table A-1 Cary — Swift Creek Sewer Spill Assessment Project List of People Interviewed, September 2006, Sorted by Organization and Last Name

Organization	Last Name	First Name	Title
Black & Veatch	Foulke	Randy	Project Director/Manager
Black & Veatch	Lavallee	Christian	Project Engineer
Black & Veatch	Osburn	Pat	Construction Observer/Engineer's Representative
Black & Veatch	Willett	Bob	Senior Design Engineer, Engineer of Record
Diehl & Phillips	Hughes	Frank	Inspector
Diehl & Phillips	Phillips	John	Principal
Hayward-Baker	Heckman	Bill	Shoring System Designer
Laughlin-Sutton	Felts	Stevie	Superintendent
Laughlin-Sutton	Pollock	Lance	Vice President
Laughlin-Sutton	Spangler	Tim	Vice President
Neuse River Foundation, Inc.	Naujoks	Dean	Upper Neuse Riverkeeper

Table A-1 Cary — Swift Creek Sewer Spill Assessment Project List of People Interviewed, September 2006, Sorted by Organization and Last Name (Continued)			
Organization	Last Name	First Name	Title
North Carolina Department of Environment and Natural Resources, Division of Land Resources	Idol	Tami	Assistant State Dam Safety Engineer
North Carolina Department of Labor	Wilce	Rod	OSHA Consultant
North Carolina Department of Environment and Natural Resources, NC Division of Water Quality	Langley	Shannon	Environmental Specialist
North Carolina Department of Environment and Natural Resources, NC Division of Water Quality	Wakild	Charles	Regional Supervisor
Raleigh Parks and Recreation Department	Duncan	Jack	Director
Raleigh Public Utilities	Barnes	Vanessa	Senior Chemist
Raleigh Public Utilities	Johnson	Betty	Microbiologist
Raleigh Public Utilities	McMillan	Larry	Laboratory Supervisor
Town of Cary	Coleman	William	Town Manager
Town of Cary, Administration	Moran	Susan	Public Information Officer
Town of Cary, Engineering	Babuin, PhD	Michael	Environmental Specialist

Continued Table A-1 Cary — Swift Creek Sewer Spill Assessment Project List of People Interviewed, September 2006, Sorted by Organization and Last Name (Continued)			
Organization	Last Name	First Name	Title
Town of Cary, Engineering	Bailey	Tim	Director of Engineering
Town of Cary, Engineering	Brown	Steve	Associate Director of Engineering
Town of Cary, Public Works, Utilities	Allen	Tim	Inflow/Infiltration Technician
Town of Cary, Public Works, Utilities	Bajorek	Mike	Public Works Director
Town of Cary, Public Works, Utilities	Bilodeau	Bob	Operations Division Manager
Town of Cary, Public Works, Utilities	Bonné	Robert (Rob)	Utilities Director
Town of Cary, Public Works, Utilities	Campbell	Paul	Wastewater Collection Field Supervisor
Town of Cary, Public Works, Utilities	Fisher	Robert K. (Kim)	Director of Public Works, Utilities
Town of Cary, Public Works, Utilities	Gilbert	Jake	Operations Coordinator
Town of Cary, Public Works, Utilities	Holloway	John	Operations Analyst
Town of Cary, Public Works, Utilities	Lauderman	Ken	Utility Systems Maintenance Supervisor

Continued Table A-1 Cary — Swift Creek Sewer Spill Assessment Project List of People Interviewed, September 2006, Sorted by Organization and Last Name (Continued)

Organization	Last Name	First Name	Title
Town of Cary, Public Works, Utilities	Mills	James	Wastewater Collection System Operator
Town of Cary, Public Works, Utilities	Parisher	Chris	North Plant Superintendent
Town of Cary, Public Works, Utilities	Tingler	Sam	Utility Systems Maintenance Division Manager
United States Fish and Wildlife Service	Suiter	Dale	Fish and Wildlife Biologist
Wake County Environmental Services	Richardson	Rob	Environmental Health Spec. and Environmental Services Team Leader
_____	Blackwell	Carroll	Private Resident adjacent to Swift Creek
_____	Ginn	Fred	Private Resident adjacent to Swift Creek
_____	Kaydos	Wilfred	Private Resident adjacent to Swift Creek
_____	Schreiner	Anton	Private Resident adjacent to Swift Creek

Table A-2 Cary — Swift Creek Sewer Spill Assessment Project List of People Interviewed, September 2006, Sorted by Last Name			
Last Name	First Name	Title	Organization
Allen	Tim	Inflow/Infiltration Technician	Town of Cary, Public Works, Utilities
Babuin, PhD	Michael	Environmental Specialist	Town of Cary, Engineering
Bailey	Tim	Director of Engineering	Town of Cary, Engineering
Bajorek	Mike	Public Works Director	Town of Cary, Public Works, Utilities
Barnes	Vanessa	Senior Chemist	Raleigh Public Utilities
Bilodeau	Bob	Operations Division Manager	Town of Cary, Public Works, Utilities
Blackwell	Carroll	Private Resident adjacent to Swift Creek	_____
Bonné	Robert (Rob)	Utilities Director	Town of Cary, Public Works, Utilities
Brown	Steve	Associate Director of Engineering	Town of Cary, Engineering
Campbell	Paul	Wastewater Collection Field Supervisor	Town of Cary, Public Works, Utilities
Coleman	William	Town Manager	Town of Cary

Table A-2 Cary — Swift Creek Sewer Spill Assessment Project List of People Interviewed, September 2006, Sorted by Last Name (Continued)			
Last Name	First Name	Title	Organization
Duncan	Jack	Director	Raleigh Parks and Recreation Department
Felts	Stevie	Foreman	Laughlin-Sutton
Fisher	Robert K. (Kim)	Director of Public Works, Utilities	Town of Cary, Public Works, Utilities
Foulke	Randy	Project Director/Manager	Black & Veatch
Gilbert	Jake	Operations Coordinator	Town of Cary, Public Works, Utilities
Ginn	Fred	Private Resident adjacent to Swift Creek	_____
Heckman	Bill	Shoring System Designer	Hayward-Baker
Holloway	John	Operations Analyst	Town of Cary, Public Works, Utilities
Hughes	Frank	Inspector	Diehl & Phillips
Idol	Tami	Assistant State Dam Safety Engineer	North Carolina Department of Environment and Natural Resources, Division of Land Resources
Johnson	Betty	Microbiologist	Raleigh Public Utilities

Table A-2 Cary — Swift Creek Sewer Spill Assessment Project List of People Interviewed, September 2006, Sorted by Last Name (Continued)

Last Name	First Name	Title	Organization
Kaydos	Wilfred	Private Resident adjacent to Swift Creek	_____
Langley	Shannon	Environmental Specialist	North Carolina Department of Water Quality
Lauderman	Ken	Utility Systems Maintenance Supervisor	Town of Cary, Public Works, Utilities
Lavallee	Christian	Project Engineer	Black & Veatch
McMillan	Larry	Laboratory Supervisor	Raleigh Public Utilities
Mills	James	Wastewater Collection System Operator	Town of Cary, Public Works, Utilities
Moran	Susan	Public Information Officer	Town of Cary, Administration
Naujoks	Dean	Upper Neuse Riverkeeper	Neuse River Foundation, Inc.
Osburn	Pat	Construction Observer/Engineer's Representative	Black & Veatch
Parisher	Chris	North Plant Superintendent	Town of Cary, Public Works, Utilities
Phillips	John	Principal	Diehl & Phillips

Table A-2 Cary — Swift Creek Sewer Spill Assessment Project List of People Interviewed, September 2006, Sorted by Last Name (Continued)

Last Name	First Name	Title	Organization
Pollock	Lance	Vice President	Laughlin-Sutton
Richardson	Rob	Environmental Health Spec. and Environmental Services Team Leader	Wake County Environmental Services
Schreiner	Anton	Private Resident adjacent to Swift Creek	_____
Spangler	Tim	Vice President	Laughlin-Sutton
Suiter	Dale	Fish and Wildlife Biologist	United States Fish and Wildlife Service
Tingler	Sam	Utility Systems Maintenance Division Manager	Town of Cary, Public Works, Utilities
Wakild	Charles	Regional Supervisor	North Carolina Department of Environment and Natural Resources, NC Division of Water Quality
Wilce	Rod	OSHA Consultant	North Carolina Department of Labor
Willett	Bob	Senior Design Engineer, Engineer of Record	Black & Veatch

APPENDIX B

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APPENDIX C

SCHNABEL REPORT

Schnabel Engineering South, P.C.

5104 Reagan Drive, Suite 8
Charlotte, NC 28206

Phone (704) 921-2706
Fax (704) 921-2707
www.schnabel-eng.com

September 29, 2006

Brown and Caldwell
309 East Morehead Street, Suite 160
Charlotte, NC 28202

Attn: Christopher Hardin

Subject: Swift Creek Pump Station Trench Excavation Slope Stability Analyses
Cary, North Carolina
Schnabel Project No. 06390062

Dear Mr. Hardin:

Schnabel Engineering South, P.C. (Schnabel) is pleased to provide geotechnical engineering services to assist your project. This letter report summarizes our evaluation of the slope stability at the referenced project site. These services are provided in accordance with our scope of services outlined in our proposal (Schnabel Proposal No. P6390072) dated September 26, 2006 and authorized by you on the same date.

We appreciate the opportunity to assist you on the project. Please contact us if you have questions regarding this report.

Very truly yours,
Schnabel Engineering South, P.C.

Richard H. Wargo, P.E.
Principal

Bon Lien, P.E., Ph.D.
Senior Associate

Attachment:
Figure 1 - Project Site Cross Section (Prepared by Brown and Caldwell on 9/19/2006)

INTRODUCTION

We understand that an approximately 50 LF section of slope failure occurred several days after a heavy rainfall at the referenced project site. The project site cross section utilized in our slope stability analyses was provided by your office on September 20, 2006 (see Figure 1 in Attachment). To evaluate the stability of the slopes and referring to Figure 1, we define the following two site slope configurations:

Site Condition A – Prior to Existing
Prior to the trench box excavation, the slope immediately behind the top of the soldier pile support system was about 1.5H:1.0V. The height of the slope was about 14 feet.

Site Condition B – Steep Slope
During the trench box excavation, an approximate 17-foot wide bench at EL. 295 was excavated behind the top of the soldier pile support system, followed by a steep, 0.5H:1.0V slope. The height of the slope was about 14 feet.

SOIL PROFILE AND SOIL SHEAR STRENGTH PARAMETERS

A Geotechnical Engineering Report prepared by Tierra, dated February 28, 2003, was provided by your office. Based on the subsurface information provided in the report, we used the soil profile as shown on Figure 1 for the stability analyses. It is our understanding that no additional laboratory testing is possible because the soils in the vicinity of the failure area were transported during the failure and/or removed to repair the leaking force main. Subsequently, the soil shear strength parameters used in our analyses are based upon correlation among the field testing data from Tierra, our database, and local experience.

A summary of the soil shear strength parameters used in our analyses are:

Soil Type	Top Elev.	SPT-N	Saturated Unit Wt. (pcf)	Total Stress		Effective Stress	
				C (psf)	Φ (º)	C' (psf)	Φ' (º)
Sandy LEAN CLAY (CL)	309.0	11	120	300	12	200	14
Sandy SILT (ML)	305.5	10	120	35	15	30	17
Sandy LEAN CLAY (CL)	301.5	12	120	300	12	200	14
GRAVEL w. Sand (GP)	296.0	40	125	0	38	0	38
Sandy SILT (ML)	291.0	60	120	200	25	80	27
PWR	283.0	>60	130	1000	40	200	45

* C, C': Cohesion, Φ and Φ': Internal Friction Angle. PWR: Partially Weathered Rock.

SLOPE STABILITY ANALYSES

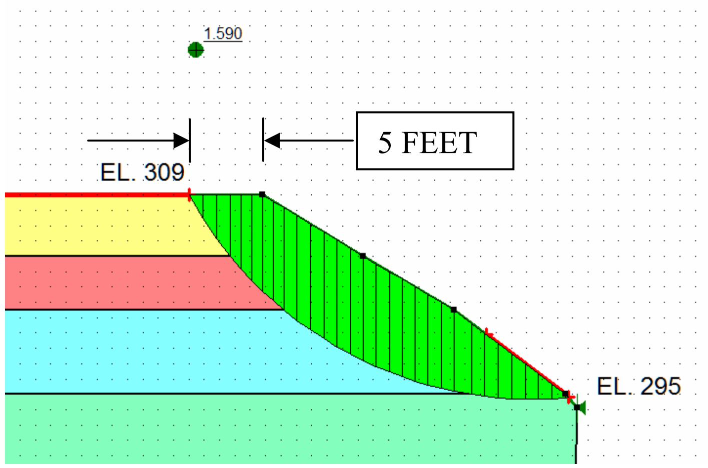
We used SLOPE/W, computer software developed by GEO-SLOPE International for the slope stability analyses, evaluating the location and shape of the potential failure slip surfaces, and the associated minimum factor of safety. Conditions and assumptions used in our stability analyses are:

- Assume the ground water elevation at EL. 295. (Note: Comments on this assumption will be provided at the end of this report.)
- We understand that the soldier pile support system was stable during construction of the proposed pump station. Accordingly, only the stability of potential slip surfaces passing through the toe of the slope (i.e., at top of the soldier pile support system) are evaluated.

To evaluate the stabilities of the two defined site slope condition, i.e., Site Condition A (Prior to Existing) and Site Condition B (Steep Slope), we performed the slope stability analyses for four different cases with the results as follows:

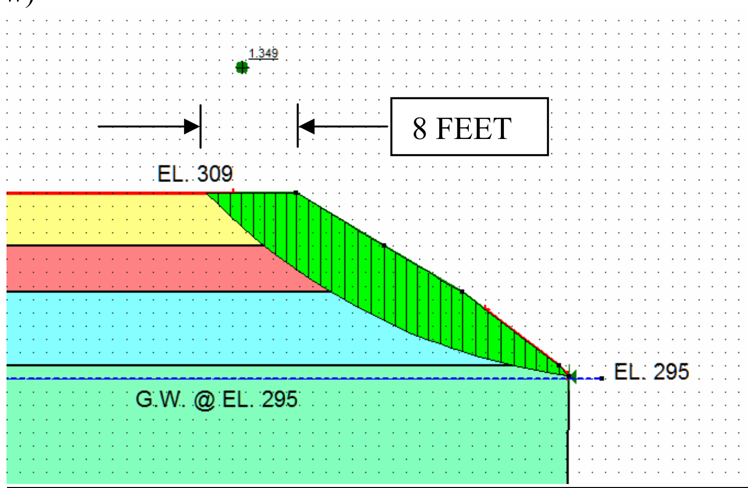
Case A.1 – Prior to Existing Site Condition, Total Stress Analysis

- Height of Slope = 14 feet; Slope @ 1.5H:1.0V
- **Calculated Minimum Factor of Safety (F.S.) = 1.59** (with a toe failure mode; see the critical slip surface below)



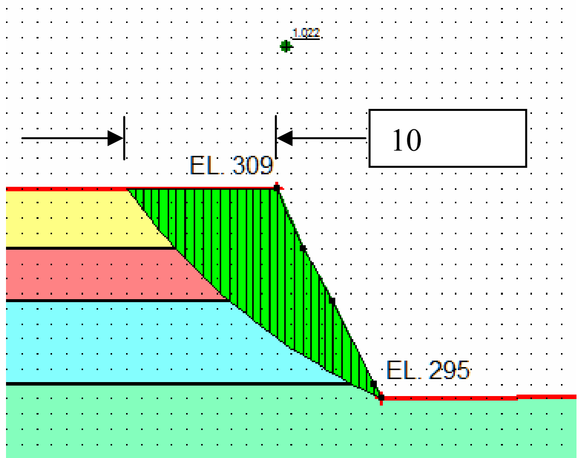
Case A.2 - Prior to Existing Site Condition, Effective Stress Analysis

- Height of Slope = 14 feet; Slope @ 1.5H:1.0V
- **Calculated Minimum Factor of Safety = 1.35** (with a toe failure mode; see the critical slip surface below)



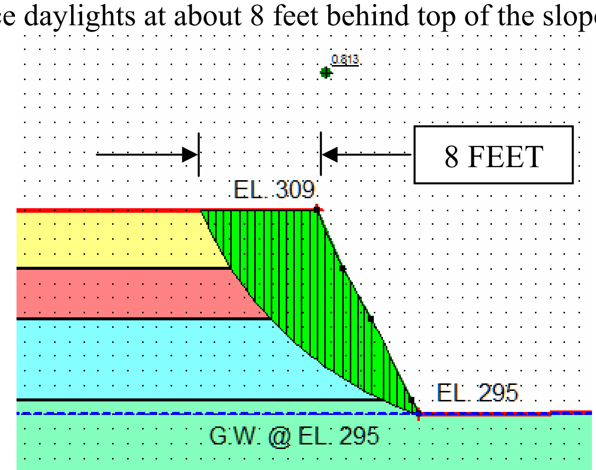
Case B.1 – Steep Slope Site Condition, Total Stress Analysis

- Height of Slope = 14 feet; Slope @ 0.5H:1.0V
- **Calculated Minimum Factor of Safety = 1.02** (with a toe failure mode; see the critical slip surface below).
- Critical slip surface daylights at about 10 feet behind top of the slope.



Case B.2 – Steep Slope Site Condition, Total Stress Analysis

- Height of Slope = 14 feet; Slope @ 1.5H:1.0V
- Assume ground water @ toe elevation (EL. 295)
- **Calculated Minimum Factor of Safety = 0.81** (with a toe failure mode; see the critical slip surface below). Note: For cases with ground water level lower than EL. 295, the calculated F.S. is the same.
- Critical slip surface daylights at about 8 feet behind top of the slope.



A back-calculation was performed to estimate the soil shear strength parameters that would yield a calculated minimum F.S. of 1.0. Results of the estimates are:

Soil Type	Top Elev.	Saturated Unit Wt. (pcf)	Effective Stress Back-Calculated w/ F.S.=1.0	
			C' (psf)	Φ' (º)
Sandy LEAN CLAY (CL)	309.0	120	200	22
Sandy SILT (ML)	305.5	120	75	25
Sandy LEAN CLAY (CL)	301.5	120	200	22
GRAVEL w. Sand (GP)	296.0	125	0	38
Sandy SILT (ML)	291.0	120	80	27
PWR	283.0	130	200	45

DISCUSSIONS AND COMMENTS

Based upon the results of the above slope stability analyses and evaluation, our comments are:

1. As general practice of geotechnical engineering, for similar types of project, the calculated minimum factor of safety should be a minimum of 1.25. It is our opinion that the stabilities of the cases evaluated in this report could be summarized as follows:

Case Evaluated		Mini. F.S.	Stability Assessment
A.1	Prior Exiting (1.5H:1V), Total Stress Analysis	1.59	Acceptable
A.2	Prior Exiting (1.5H:1V), Effective Stress Analysis	1.35	Acceptable
B.1	Steep Slope (0.5H:1V), Total Stress Analysis	1.02	Marginal/ Pending Failure
B.2	Steep Slope (0.5H:1V), Effective Stress Analysis	0.81	Unacceptable

   In general, the result of total stress analysis represents the short term, temporary construction conditions. However, for cut slope conditions, the stability is governed by long-term, effective stress conditions. Note that, for Case B.1 and Case B.2, the critical slip surfaces daylight at about eight (8) feet to ten (10) behind top of the slope.

2. A back-calculation with the Case B.2 site condition, assuming the steep slope was under a marginal/pending failure condition, was done to estimate the soil shear strength parameters. It is our opinion that the available subsurface information and data do not support the higher values of the soil shear strength parameters derived from the back-calculation.

3. We assume a ground water elevation of EL. 295 in our analyses. We understand that during the construction, dewatering measure was taken to lower the ground water to about EL. 265 at the trench box excavation location. Because results of our slope stability analyses indicate the critical slip surfaces exit at the toe of the slope (EL. 295), cases with ground water elevations lower than EL. 295 will not affect the results of the stability analyses.

LIMITATIONS

This report has been prepared to aid your evaluation of the project site conditions. It is intended for use concerning this specific project. The analyses and evaluation submitted herein are based on the information provided by your office and assumptions made in this report. We would appreciate an opportunity to review additional subsurface information, when available, to provide further evaluation.

We have endeavored to complete the services identified herein in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality and under similar conditions as this project. No other representation, expressed or implied, is included or intended, and no warranty or guarantee is included or intended in this report, or any other instrument of service.

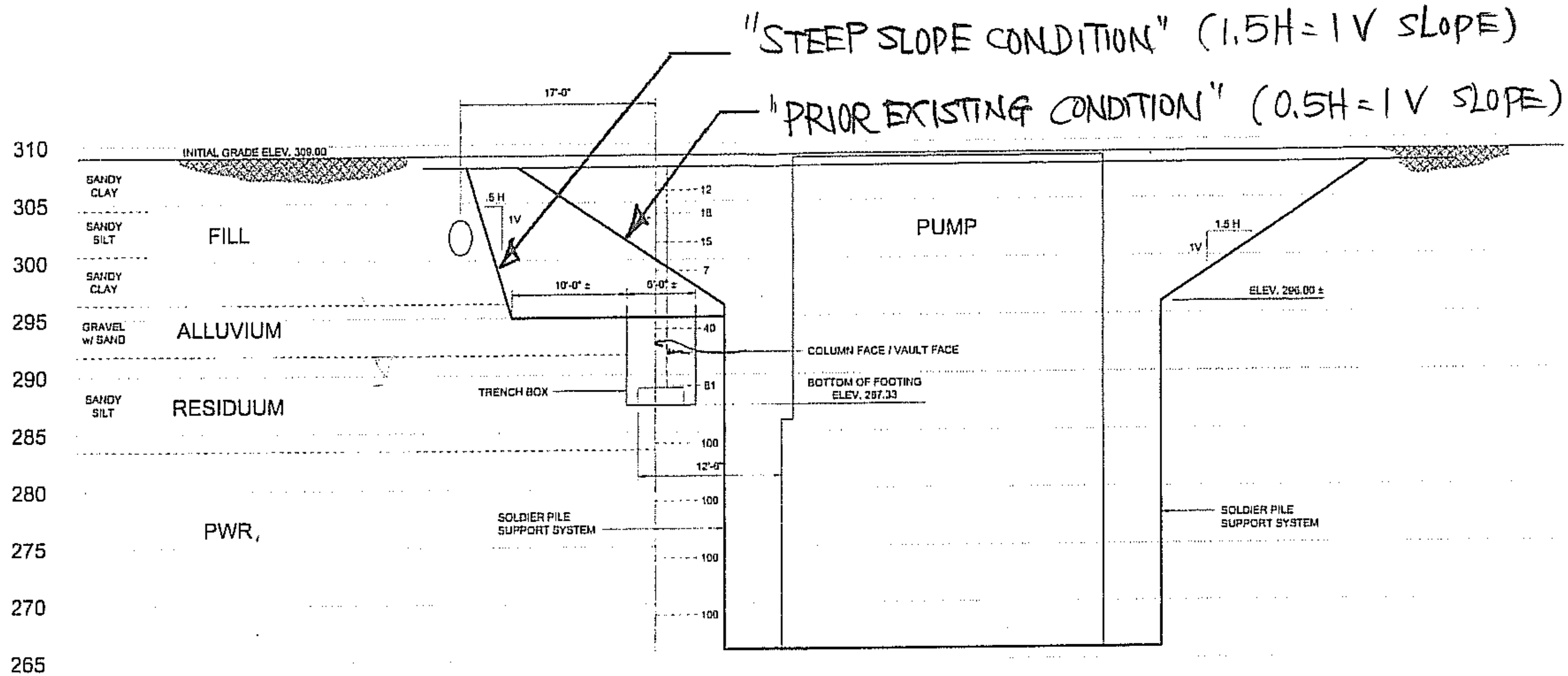


FIGURE 1. PROJECT SITE CROSS SECTION

Sep 19, 2006 - 9:32am Keistler

130580 Proj Border.dwg

H:\Swift Creek Profile.dwg

BROWN AND CALDWELL

SWIFT CREEK

Bon Lien
Schnabel Engineering 9/28/06