

Phase III CSO Program

Design Management Plan (Version 2.0)

Technical Memorandum

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List of Abbreviations and Acronyms

AOS	Apparent Opening Size
ASHTO	Association of State Highway Transportation Officials
AWWA	American Water Works Association
Chair	Stage Gate Chair
CSO	Combined Sewer Overflow
DB	Design-Build
DBB	Design-Bid-Build
DC	Design Consultant
EEO	Equal Employment Opportunity
GSI	Green Stormwater Infrastructure
GSS	Gate and Screening Structure
M/WBE	Minority/Woman Business Enterprise
NBC	Narragansett Bay Commission
NTP	Notice to Proceed
O&M	Operation and Maintenance
OPCC	Opinion of Probable Construction Cost
OPCS	Opinion of Probable Construction Schedule
PDS	Project Delivery System
PM/CM	Program Manager/Construction Manager
PXP	Program Execution Plan
RFP	Request for Proposal
QMP	Quality Management Plan
RFQ	Request for Quotation
RIDEM	Rhode Island Department of Environmental Management
RIDOT	Rhode Island Department of Transportation
RIGL	Rhode Island General Law
RIVIP	Rhode Island Vendor Information Program
SOE	Support of Excavation
WBS	Work Breakdown Structure

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Executive Summary

The Narragansett Bay Commission (NBC) embarked on a three-phase Combined Sewer Overflow (CSO) control program in 1998, aimed at lowering annual CSO volumes and reducing annual shellfish bed closures in accordance with a 1992 Consent Agreement with the Rhode Island Department of Environmental Management (RIDEM). Phases I and II of this program, which focused on the Fields Point Service Area (FPSA) in Providence, were completed in 2008 and 2015, respectively. The program to date has succeeded in lowering annual CSO volumes and reducing annual shellfish bed closures to levels that are in keeping with the 1992 Consent Agreement.

Phase III of the CSO program, which began in 2016, is focused primarily on the Bucklin Point Service Area (BPSA) in the communities of Pawtucket and Central Falls. The final phase (i.e., Phase IIID) of the program addresses the outfalls in the BPSA and the remaining outfalls in the FPSA. Its projected completion date is 2041. The Phase III CSO Program has been subdivided into four sub-phases, as follows:

- Phase IIIA: Pawtucket Tunnel
- Phase IIIB: Upper BVI Relief Structure and OF-206 Sewer Separation
- Phase IIIC: Stub Tunnel to Control OF-220
- Phase IIID: West River Interceptor and OF-035 Sewer Separation

The Stantec/Pare Team is under contract with NBC to serve in the role as the Program Manager/Construction Manager (PM/CM) for Phase III CSO Program. The program is currently in the planning phase preparing a Design Criteria Report (DCR) for Phase IIIA and IIIB Facilities and transitioning into design. The PM/CM is implementing a procurement plan for soliciting qualifications and proposals from Design Consultants (DCs). The DCs will be responsible for design of identified project packages for Phases IIIA and IIIB, under contract to Stantec. DCs shall serve in the role as Engineer of Record on a given (i.e. assigned) project. As such, it shall be the responsibility of each DC to utilize licensed engineers, landscape architects, architects, surveyors, and other design professionals in accordance with Rhode Island General Law.

The purpose of this Design Management Plan (DMP) is to document the Program Design Standards and Guidelines in accordance with Task 16.2.1. The DMP will apply to all projects within the Phase III CSO Program. It integrates the Project Delivery System (PDS) to support delivery of consistent and complete design documents. Each design assignment will have a specific scope that defines the required design elements, schedule, deliverables, and budget to complete the work.

The DMP outlines the methodology to be used by project managers from the PM/CM Team to manage schedule, budget, and compliance with submittal requirements for each DC. The DMP also provides direction on how to review design submittals for completeness and compliance with the PDS and Stage Gate Governance Framework.

In general, the program goals have remained unchanged. The design criteria are focused on hydraulic performance of CSO facilities (i.e. reduction in overflow volume/frequency, design storm) to achieve the defined downstream water quality benefits. Provided below is a summary of the two key criteria which will continue to be used to evaluate the effectiveness of the CSO controls and facilities during design:

- No overflows for 3-month design storm
- No more than 4 overflows per year per outfall for the typical year (1951)

To ensure program goals are achieved, the PM/CM Team has developed standard program details and specifications to improve the efficiency and consistency in project delivery. The focus of the program specifications is procurement, general agreement, administrative requirements, schedule, and construction quality control. It will be the responsibility of the DCs to develop required technical specifications to support the design of a given project. It is acknowledged that technical specifications on common elements and/or materials may be provided to DCs as the program design elements evolve.

Standard program details will be incorporated into design drawings, as applicable, for consistency. Standard details from State and local agencies are referenced as part of the standard program details. The purpose of standard details is to facilitate efficient construction, material procurement, and bidding. It also promotes consistency in design deliverables, which promotes efficient review. Standard details will be made available on the Program SharePoint portal for reference in PDF for planning. Standard details will also be incorporated into standard CAD templates. It is acknowledged that standard program details are not applicable for all design projects.

The Program Design Guidelines and Standards, defined herein, outline the minimum design standards and best practices for all design work to be performed by either the PM/CM Team and/or DCs. The design guidelines describe the minimum standard technical requirements for the design(s) of individual projects (i.e. CAD/BIM standards, survey standards, pipe design standards, standard approved materials/products and/or manufacturers, etc.). Design standards consist of Phase III standard details and specifications.

The design guidelines and standards are used in conjunction with applicable codes, laws and ordinances of this jurisdiction, recognized industry standards, current engineering “best practices” and specific program needs. The goal is to define design elements necessary to meet the defined design criteria for the Program; while emphasizing efficiency, flexibility, safety, and reliability in an economic and environmentally responsible manner. It shall be the responsibility of the DCs to research applicable codes, laws and ordinances of this jurisdiction, recognized industry standards, current engineering “best practices” and specific, applicable project needs. Federal, State, and local codes shall be used in the event of a conflict with any Program guidelines.

Section 1.0

Introduction and Purpose

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1.0 Introduction and Purpose

1.1 Introduction

The Narragansett Bay Commission (NBC) embarked on a three-phase Combined Sewer Overflow (CSO) control program in 1998, aimed at lowering annual CSO volumes and reducing annual shellfish bed closures in accordance with a 1992 Consent Agreement with the Rhode Island Department of Environmental Management (RIDEM). Phases I and II of this program, which focused on the Fields Point Service Area (FPSA) in Providence, were completed in 2008 and 2015, respectively. The program to date has succeeded in lowering annual CSO volumes and reducing annual shellfish bed closures to levels that are in keeping with a 1992 Consent Agreement between NBC and RIDEM.

Phase III of the CSO Program, which began in 2016, is focused primarily on the Bucklin Point Service Area (BPSA) in the communities of Pawtucket and Central Falls. The final phase (i.e., Phase IIID) of the program addresses the remaining outfalls in the FPSA. Its projected completion date is 2041. The Phase III CSO Program has been subdivided into four sub-phases, as follows:

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DCs shall serve in the role as Engineer of Record on a given (i.e. assigned) project. As such, it shall be the responsibility of each DC to utilize licensed engineers, landscape architects, architects, surveyors, and other design professionals in accordance with Rhode Island General Law.

1.2 Purpose

The purpose of this Design Management Plan (DMP) is to document the Program Design Standards and Guidelines in accordance with Task 16.2.1. The DMP will apply to all projects within the Phase III CSO Program. It integrates the Project Delivery System (PDS) to support delivery of consistent and complete design documents. Each design assignment will have a specific scope that defines the required design elements, schedule, deliverables, and budget to complete the work.

The DMP outlines the methodology to be used by project managers from the PM/CM Team to manage schedule, budget, and compliance with submittal requirements for each DC. The DMP also provides direction on how to review design submittals for completeness and compliance with the PDS and Stage Gate Governance Framework.

The Program Design Guidelines and Standards, defined herein, outline the minimum design standards and best practices for all design work to be performed by the PM/CM Team and DCs. The design guidelines describe the minimum standard technical requirements for the design(s) of individual projects (i.e. CAD/BIM standards, pipe design standards, standard approved materials/products and/or manufacturers, etc.). Design standards consist of Phase III standard details and specifications.

The design guidelines and standards are used in conjunction with applicable codes, laws and ordinances of this jurisdiction, recognized industry standards, current engineering "best practices" and specific program needs. The goal is to define design elements necessary to meet the defined design criteria for the Program; while emphasizing efficiency, flexibility, safety, and reliability in an economic and environmentally responsible manner. It shall be the responsibility of the DCs to research applicable codes, laws and ordinances of this jurisdiction, recognized industry standards, current engineering "best practices" and specific, applicable project needs.

The organization of the DMP is as follows:

- ***Section 1.0 Introduction and Purpose***: Define purpose and objective of incorporating design guidelines and standards into the Program.
- ***Section 2.0 Program Design Criteria:*** Define design criteria at program level to establish key objectives of the program to meet program system operational and regulatory requirements.
- ***Section 3.0 Program Design Guidelines:*** Define minimum design procedural elements to be incorporated into DC statements of work for all design projects in the Program.
- ***Section 4.0 Project Delivery System:*** Define project governance to establish the framework for consistent project delivery.
- ***Section 5.0 Standard Program Details:*** Define program details to be incorporated into design projects.
- ***Section 6.0 Standard Program Specifications:*** Define program specifications to be incorporated into design projects.

Section 2.0

Program Design Criteria

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2.0 Program Design Criteria

2.1 Introduction

The purpose of this section is to highlight design criteria, which was utilized by NBC, to define the effectiveness of the long-term CSO abatement control program. The criteria were first defined in the 1998 Conceptual Design Report Amendment as attaining the following program goals:

- 98% reduction annual CSO volumes
- 98% reduction fecal coliform loading
- 95% reduction in number of annual overflows
- < 4 overflows per year
- 75% and 80% reduction in TSS and BOD loadings, respectively
- 80% reduction in shellfish bed closures

In general, the program goals have remained unchanged. The design criteria are focused on hydraulic performance of CSO facilities (i.e. reduction in overflow volume/frequency, design storm) to achieve the defined downstream water quality benefits. The PM/CM Team will continue to use the criteria to evaluate the effectiveness of the CSO controls and facilities during design in order to ensure program goals are achieved.

As stated in Section 1.0, the design criteria, guidelines and standards are used in conjunction with applicable codes, laws and ordinances of this jurisdiction, recognized industry standards, current engineering “best practices” and specific program needs. The goal is to define design elements necessary to meet the defined design criteria for the Program; while emphasizing efficiency, flexibility, safety, and reliability in an economic and environmentally responsible manner. To reiterate, it shall be the responsibility of the DCs to research applicable codes, laws and ordinances of this jurisdiction, recognized industry standards, current engineering “best practices” and specific, applicable project needs.

2.2 Hydraulic Design Criteria

The primary element of the Phase III CSO Program is the Pawtucket Tunnel and stub tunnel. The tunnels are designed to have sufficient volume to store the 3-month storm for all contributing overflows during a storm event for subsequent pump-out and treatment at the BPWWTF following an event. The remaining technologies (e.g. sewer separation, GSI, regulator modifications, consolidation conduits) are designed to either convey flow to the tunnel and/or divert wet weather flow from the combined system.

Provided below is a summary of the two key criteria used to evaluate the effectiveness of the CSO controls:

- No overflows for 3-month design storm
- <4 overflows per year per outfall for the typical year (1951)

2.2.1 Hydraulic Design Criteria – Consolidation Conduits

Consolidation conduits are relief sewers designed to convey wet weather flow from upstream diversion structures to downstream gate and screening structures (GSS) and drop shafts. The drop shafts bring the flow from the surface to the tunnel for storage.

Consolidation conduits are designed to fully drain to the tunnel following storm events. As such, the pipe material does not require special consideration for protection against long-term hydrogen sulfide corrosion. Decisions on pipe materials shall be based upon diameter, depth, slope, installation method, loading condition, surcharge potential, and anticipated flow velocities.

The following criteria will be considered in the design of consolidation conduits:

- Capacity: >2-year peak hourly flow without surcharging
- Velocity: maximum velocity < 10 fps based on 2-yr peak hourly flow (Note: pipe reaches, bends, and MH's having velocity > 8 fps shall be further evaluated to determine if special design consideration are required.)
- Slopes: Minimum slopes as defined in TR-16 Guides for the Design of Wastewater Treatment Works
- Pipe materials: pipes exposed to sanitary flow and/or daily combined flow shall be rated to resist impacts from hydrogen sulfide (Note: As defined above, consolidation conduits are designed to be fully drained between storm events.)
- MHs: 0.1' elevation difference at every bench (i.e. sloped at minimum 0.5-inch per foot)
- MH Spacing: MH placement at changes in alignment and every 350-ft to 500-ft based on diameter, flow conditions, type of service, and installation method. (Note: Large diameter consolidation conduits, which are designed to be fully drained following storm events, installed using micro-tunneling can have increased MH spacing to reduce jacking/receiving pits.)

2.2.2 Hydraulic Design Criteria – GSI

The overall intent of Green Stormwater Infrastructure (GSI) is to utilize green technologies to reduce the volume and frequency of overflows within a given drainage area. GSI has not been selected as a technology to fully comply with the goals of the program (i.e. reducing overflows to less than four times per year). It has been selected as a viable technology to improve the performance of the approved abatement plan. The goal is to reduce the flow during storm events by incorporating infiltration and surface storage. It also provides an effective partnering, outreach opportunity to work with community stakeholders to embrace the objectives of the program.

The design criteria for specific GSI best management practices (BMPs) shall comply with the most recent update to the RIDEM Stormwater Design Manual. The defined GSI opportunities are interpreted as retrofit projects. As such, there may be circumstances where not all of the requirements in the RIDEM Design Manual are attainable. The design should comply with the standards to the maximum extent practical.

GSI opportunities have been identified by the PM/CM team with a focus on improvements within the public right of way or publicly owned parcels. Private parcels and areas in the FPSA may be considered in the future. The primary design criteria for GSI is to reduce the volume of overflow associated with the 3-month storm, using infiltration and/or storage. Flow estimates shall be calculated using the 3-month storm with an estimate of percent reduction for the contributing drainage area for a given outfall. The percent reduction should not be limited to the specific study area.

For regulatory compliance, the design will be required to address the requirements for groundwater re-charge, storage of the water quality volume, and separation with seasonal high groundwater table. The guidelines in the RIDEM design manual shall be followed to the maximum extent practical.

2.2.3 Hydraulic Design Criteria – Regulator Modifications and Relief Structures

Regulator modifications and interceptor relief structures have been identified during the optimization effort to reduce the capital cost of the program. The specific design criteria for these structures is to meet the overall key criteria for impacted outfalls:

- No overflows for 3-month design storm
- <4 overflows per year per outfall for the typical year (1951)

It is the responsibility of the hydraulic modeling team to define require adjustments to regulators (i.e. weir elevation, weir length, diameter of underflow pipe) to achieve the desired program goals. The modeling team has also defined minimum structure dimensions of the two interceptor relief structures. Replaced underflows and combined sewers shall comply with the following design criteria:

- Velocity: maximum velocity < 10 fps based on 2-yr peak hourly flow (Note: pipe reaches, bends, and MH's having velocity > 8 fps shall be further evaluated to determine if special design consideration are required.)
- Slopes: Minimum slopes as defined in TR-16 Guides for the Design of Wastewater Treatment Works
- Pipe materials: pipes exposed to sanitary flow and/or daily combined flow shall be rated to resist impacts from hydrogen sulfide
- MHs: 0.1' elevation difference at every bench (i.e. sloped at minimum 0.5-inch per foot)
- MH Spacing: MH placement at changes in alignment and every 350-ft to 500-ft based on diameter, flow conditions, type of service, and installation method.

2.2.4 Hydraulic Design Criteria – Sewer Separation

The design objective of sewer separation is to design and construct a separate storm sewer system. RIDEM requires 100% separation. The existing combined system would be transformed into a separate sanitary sewer system. The design shall focus on providing drainage for the public right of way and include parcels within the drainage area of the proposed storm sewer system.

It should be noted that the sewer separation may meet the regulatory definition of a re-development, requiring compliance with RIDEM stormwater regulations. As such, sewer separation design may need to include elements of GSI to address water quality.
Separate storm system may utilize the existing CSO outfall, if it can be connected downstream of regulator and not impact compliance. A level meter is required at regulator to be used for long-term compliance monitoring.

Provided below are key design criteria for sewer separation:

- AASHTO standards apply for defining design storms based on road rating (i.e. primary, secondary) and catch basin spacing
- Design storm: pipe capacity >25-yr, 24-hour, Type III design storm
- CB spacing: no flow in travel lane for 10-yr, 24-hr storm for secondary roads and no spread in travel lane for 25-yr, 24-hr storm for primary road

2.3 Design Criteria – Ancillary Facilities

Provided below is a brief summary of design features and required equipment at associated facilities:

- Gate and Screening Structures: flow meters (depth/velocity), slide gate for isolation (maintenance only), sluice gate (control), and trash rack (6-inch AOS)
- Regulator Modifications: level meter (compliance monitoring only) and floatables control (i.e. FRP bar rack 3-inch AOS)

Section 3.0

Program Design Guidelines

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3.0 Program Design Guidelines

3.1 Introduction

The purpose of this section is to outline program design guidelines to be used by DCs and incorporated into the statement of work for all design projects in the program. It shall be the responsibility of DCs to incorporate program design guidelines into a project specific design work plan. The guidelines are not intended to limit flexibility and/or responsibility for DCs to implement an effective, quality, and/or creative solution to a complex problem. The objective is to implement consistent platform/approach to quality designs and control risk.

3.2 Program CAD Standards

The purpose of the program CAD Standard is to develop consistency between all design deliverables, amongst the DCs. The CAD Standards, presented in Appendix A, are based upon the National CAD Standards (NCS). NCS is a collaborative effort among computer-aided design (CAD) and building information modeling (BIM) users. Its goal is to create a unified approach to the creation of building design data. The standards are comprised of The American Institute of Architect's CAD Layer Guidelines, the Construction Specification Institute's Uniform Drawing System (Modules 1-8), and the National Institute of Building Sciences BIM Implementation & Plotting Guidelines.

The CAD Standards (see Appendix A) have been organized into two sections: Drawing Elements and General Drawing Conventions and Symbols. Drawing Elements focuses on the border file of the sheet set. One border shall be used for all drawings to create a uniform presentation for all drawings. Each subsection of the Drawing Elements explains all aspects of the border file and for what each aspect is used. The second section explains the general drawing conventions and symbols. It is important to use these conventions to develop a uniform look for all texts, symbols, and leaders. Use of the conventions create a consistent, professional presentation for all proposed design projects. All conventions and symbols are found in the NBC_STYLES and NBC_COMMON files to be supplied on ProjectWise. No changes shall be made to these files to assure all drafters are using the same styles.

The PM/CM Team utilizes ProjectWise as a central database that shall house the program CAD Standards, such as NBC_STYLES and NBC_COMMON files. A Project Standard folder shall be provided on ProjectWise for plotstyle files. This plotstyle files shall be used to plot all sheet sets with a consistent line weight and color. All drawing sets shall be saved on ProjectWise under the corresponding discipline folder.

All general blocks, drawings and files for AutoCAD platforms presented in this guide are available on ProjectWise. DCs shall not add or modify the files. The files are replicated each evening; they will be overwritten.

3.3 Program Schedule Standards

3.3.1 Introduction

The purpose of Program Schedule Standards is to establish minimum requirements for DCs to follow in preparing project schedules for individual design packages. It is the responsibility of the PM/CM to maintain an overall program schedule. Therefore, it is imperative that schedules for individual design packages are structured and prepared using a consistent format. It is the responsibility of DCs to develop project specific schedules to align with the proposed scope of work and defined project milestones. The schedule shall be consistent with minimum WBS, defined herein. DCs can add activities, as appropriate, to align with project specific work elements.

All design project schedules shall be developed using the critical path method (CPM) and Oracle Primavera P6 Project Management software. A work breakdown structure (WBS) has been developed based on the PDS developed for the program. Design project schedules shall be structured using the following WBS, with additions and/or modifications subject to acceptance by the PM/CM Team:

1. Design
    a. 30% Design
        i. Perform Geotechnical Studies and Prepare Reports
            1. Activity
            2. Activity
        ii. Draft 30% Design Documents
        iii. Prepare Opinion of Probable Construction Costs
        iv. 30% Technical Review Meeting
        v. Submit 30% Design to RIDEM
    b. 60% Design
        i. Draft 60% Design Documents
        ii. Prepare Opinion of Probable Construction Costs
        iii. Value Engineering and Risk Management
        iv. 60% Technical Review Meeting
        v. Prepare, Submit Application for CRMC Assent
    c. 90% Design
        i. Draft 90% Design Documents
        ii. Prepare Opinion of Probable Construction Costs
        iii. 90% Technical Review Meeting
        iv. Prepare, Submit Application to RIDEM for Order of Approval
    d. Final Design
        i. Final Design (100%) Package
        ii. Prepare for Construction Procurement
        iii. Submit Design Documents to RIDEM for Certificate of Authorization
2. Bid & Award (PM/CM to provide milestones)
        i. Bid
        ii. Award

3. Construction (PM/CM to provide milestones)
    a. Preconstruction
    b. Construction
    c. Startup and Commissioning
4. Post-Construction (PM/CM to provide milestones)

3.3.2 Schedule Preparation and Format

Schedules shall show activities, activity durations, and activity relationships that reflect the manner in which the DC proposes to execute the work. The summaries of start and finish dates, durations and costs at each WBS level of the project schedule will be incorporated into the corresponding activities of the program schedule at the start of the project and updated monthly. Schedules shall also meet the requirements of the Defense Contract Management Agency's (DCMA) 14-Point Assessment. Activities shall be grouped under the appropriate WBS level listed above.

Schedules shall be developed by:

1. Identifying activities, milestones and constraints
2. Assigning each activity to the appropriate WBS grouping
3. Determining durations of activities
4. Determining relationships between activities
5. Identifying resources and unit costs
6. Assigning resources to each activity

Schedules shall contain the following columns of information:

- Activity ID
- Activity Name
- Original Duration
- Remaining Duration
- Start Date
- Finish Date
- Total Float
- Earned Value (Based on Physical Percent Complete)
- Actual Cost
- Cost Variance

Activities for project start and project finish, all interim and major milestones, and activities showing anticipated dates of no work shall be listed at the beginning of the schedule. The start date for the project shall be the project start date established in the Notice to Proceed (NTP). All activity durations shall be in workdays. Legal holidays observed by the Narragansett Bay Commission (NBC) shall be accounted for in the project schedule as non-working days. Deliverables requiring review and acceptance by the PM/CM and NBC shall provide for a minimum review time of ten (10) working days, unless a more extensive review timeframe is required based on project complexity and the anticipated content of the deliverable. Extended review durations will be coordinated with the DC in advance so that sufficient review times can be accounted for in project schedules. The DC shall also account for review times by regulators, based on published or otherwise previously agreed to review timeframes (or estimated review times based on past experience, where published requirements are absent) required of each agency.

Schedules shall be cost loaded in accordance with the rates and level of effort contained in the Contract. Labor and non-labor resources, with unit costs, shall be identified and assigned to corresponding activities. Unit costs for labor shall be in hours.

When requested, the DC shall provide the PM/CM with baseline, revised and updated schedules, prepared and submitted electronically, in the following formats:

- Primavera XER
- One complete Construction Schedule in Bar Chart format in Portable Document Format (PDF) file type, formatted to an 11"x17" page size for reproduction at a legible size and scale.

3.3.3 Baseline Schedule

The DC shall prepare a Baseline Schedule meeting the format requirements noted above. The Baseline Schedule will be the basis for monitoring project progress and measuring the DC's adherence to the overall project schedule. The Baseline Schedule shall be submitted for review within ten (10) working days of the contract start date.

Once accepted, the Baseline Schedule shall only be modified when contract amendments that impact schedule are authorized by NBC. A request for revision to the Baseline Schedule shall be made by submitting a narrative along with the revised schedule to the PM/CM for review. Schedule revisions shall account for the following:

1. When a delay in completion of any activity or group of activities (WBS level) indicates an overrun of the Contract Time or milestone dates by twenty (20) working days or 5 percent of the remaining duration, whichever is less.
2. When delays in submittals are encountered, making it necessary to re-plan or reschedule activities. This excludes scheduling of the construction phase and pertains only to delays during design (e.g., schedule impacts caused by a delay in receiving a survey baseplan from a subconsultant).
3. When the schedule does not represent the actual progress of activities.
4. When any change to the sequence of activities, the completion date for major portions of the work, or when changes occur which affect the critical path.
5. When contract modification necessitates schedule revision. When change order work is requested by NBC, PM/CM, or the DC, impacts to schedule shall be provided with the DC's cost proposal.

Any time between the planned completion date and the completion date stipulated in the design contract shall be delineated as an activity and identified as "Project Float". Project Float shall be for the use of the PM/CM and the DC. Revisions to the Contract completion date will only be permitted if: after removal of the Project Float activity and after inserting an activity (or activities) for a delay or additional work into the most recent approved updated or revised schedule, the Contract completion date is affected.

3.3.4 Progress Schedules

The DC shall prepare monthly Progress Schedules in the same format as the Baseline Schedule, for the duration of the design contract. Progress Schedules are to be submitted to the PM/CM with the DC's monthly invoice for payment. Each Progress Schedule shall represent a clear update of the overall project progress, and shall include:

1. Actual start dates of activities that have been started.
2. Actual finish dates of activities that have been completed.
3. Percentage of physical completion of activities that have been started but not finished.
4. Actual dates on which milestones were achieved.
5. Update of activities by inputting the forecast remaining durations.
6. Update of earned value.
7. Update of actual costs.

All progress schedules shall be accompanied by a narrative that provides an analysis of the updated schedule and the overall project progress. The narrative shall describe the following:

1. Added and deleted activities.
2. Current and anticipated delays and/or early completions.
3. Cause of the delay and/or early completion.
4. Corrective action and schedule adjustments to correct the delay.
5. Impact of the delay and/or early completion on other activities, milestones and completion dates (e.g. number of days behind or ahead of schedule)
6. Change in activity descriptions, activity ID's, project sequence, logic changes, relationship changes and/or duration changes and the rationale associated with each change that required the change to be made.
7. Analysis of critical path.
8. Pending issues and status of other items (i.e. permits, contract modifications, time extension requests, long-lead procurement items, other project or scheduling concerns).
9. A statement as to whether the project remains on schedule.

Should the monthly Progress Schedule show that project completion is anticipated earlier than the current contract completion date, the early completion time shall be tracked as schedule activity and identified as Project Float.

3.3.5 Review and Acceptance of Schedules

The PM/CM will review baseline schedules, progress updates to ascertain compliance with specified project and program constraints, compliance with milestone dates, reasonableness of durations and sequence, accurate inter-relationships, and completeness. Schedules may be subject to modification should unacceptable impacts to other projects or program progress be identified during such reviews.

3.4 Program Guidelines to Prepare Opinion of Probable Construction Costs

3.4.1 Purpose

The purpose of this section is to provide guidance to DCs preparing opinions of probable construction costs (OPCC) for individual design projects. The OPCC is the estimated cost to construct individual projects in accordance with design drawings and specifications within a specified period. An OPCC will be performed at each stage of design development to estimate construction costs within a range of accuracy appropriate for the level of project definition at that stage. Well-founded OPCCs are necessary for the successful forecasting and control of financial resources of each project and the entire program. This standard is intended to provide DCs with guidelines for the development and presentation of OPCCs that are uniform and consistent.

3.4.2 OPCC Classifications

OPCCs shall be perform in accordance with the applicable OPCC classification. The OPCC classifications for the Program are consistent with “Recommended Practice No. 18R-97: Cost Estimate Classification System – As Applied in Engineering, Procurement and Construction for the Process Industries” of the Association for the Advancement of Cost Engineering (AACE) International. A copy of the Program’s OPCC classification matrix, which was modified from that of AACE International, follows in Table 3-1.

Table 3-1 Estimate Classification Matrix (Modified AACE International)

Estimate Class	Level of Project Definition	End Usage	Methodology	Expected Level of Accuracy	Typical Contingency
5	≤ 5%	Preliminary Project Screening, Capital Budget OOM, Alternate Schemes Evaluation, Strategic Analysis	Capacity factored, parametric models, judgement, historical project comparison	*Low*: -20% to -50% *High*: +30% to +100%	15% to 40%
4	5% to 20%	Preliminary Project Estimate, Reality Check Estimate, Alternate Schemes Evaluation, Feasibility Study	Equipment factored parametric models, historical relationship factors, broad unit cost data	*Low*: -15% to -30% *High*: +20% to +50%	10% to 25%
3	20% to 60%	Project Funding Estimate, Fair Price Check, Alternate Schemes Evaluation	Semi-detailed unit costs with assembly level line items by trade, historical relationship factors	*Low*: -10% to -20% *High*: +10% to +30%	5% to 15%
2	60% to 99%	Project Funding Estimate, Control Estimate, Bid Estimate	Detailed estimating data by trade with detailed takeoff of quantities	*Low*: -5% to -15% *High*: +5% to +50%	5% to 15%
1	90% to 100%	Firm Bid Estimate	Detailed estimating data by trade with detailed takeoff of quantities	*Low*: -3% to -10% *High*: +3% to +15%	3% to 10%

The program's OPCC classification matrix utilizes a five-level Class System (1 through 5). Class 5 OPCCs are developed by the PM/CM at project conception. Class 1 OPCCs will not be performed by DCs, as this class of OPCC is typically performed by contractors when preparing bids. DCs shall develop an OPCC at each stage of design that corresponds to the OPCC class shown in Table 3-2.

Table 3-2 OPCC Class by Design Development Stage

Design Development Stage	OPCC Class	Typical Contractor Contingency
30%	4	10% to 25%
60%	3	5% to 15%
90%	2	5% to 15%
100%	2	5% to 15%

3.4.3 Basis of OPCC

A Basis of OPCC shall be established prior to developing each OPCC and included in the OPCC report. The Basis of OPCC shall consist of the following:

1. Project Scope - A brief description of the project to be constructed.
2. OPCC Classification - The class of OPCC per Table 3-1 and methodology used to prepare the OPCC.
3. Range of Accuracy - The expected range of accuracy of the OPCC.
4. Owner Contingency – Recommended owner contingency based on the class of OPCC
5. Project Documents – List of design drawings, specifications, referenced project and program documents, and other documents used to define the scope of work.
6. Sources of Unit Cost Information - Sources of unit costs such as cost databases, similar projects, quotes from contractors, etc.
7. Units – List of units of measure for quantities, and abbreviations.
8. Markups – Markups on direct costs of labor, equipment material, and subcontractors.
9. General Conditions – Percentage of total construction costs used to determine the cost of general conditions.
10. Estimating Team - Personnel who performed and contributed to the estimate. Also include consultants who contributed to the estimate.
11. Contracting Method – The type of project delivery method assumed to prepare the OPCC such as design-bid-build, design-build, construction manager at-risk, etc.
12. Contract Time – The time for completion of the project provided by the Program Manager, or any assumptions regarding contract time.
13. Surety and Insurance– Percentage of total construction cost assumed for the cost of surety and insurances.
14. Industry Capacity and Bidding Climate – Statement of how market conditions affect the OPCC and if adjustments to cost data have been made to reflect market conditions.

15. Construction and Material Cost Indices – Construction cost and material indices used in preparation of the OPCC and how they were used.
16. Year of Expenditure Dollars – State how inflation is considered in the estimate and state that the estimate is expressed in year-of-expenditure dollars. (i.e., the OPCC is expressed in the dollar value of the year of the start of construction and adjusted for inflation to the proposed midpoint of construction.)
17. General Assumptions - Assumptions made during the preparation of the estimate because of information not provided in the referenced project design documents and other project and program documents. Assumptions may include but are not limited to:
    a. Dimensions
    b. Materials
    c. Unit weights of soil and rock
    d. Soil and groundwater remediation requirements
    e. Permanent equipment
    f. Coordination or tie-in with other projects of the program
    g. Utility locations
    h. Unit costs
    i. Production rates
    j. General conditions requirements
18. Labor Assumptions - Assumptions made regarding labor during preparation of the estimate. Assumptions may include but are not limited to:
    a. Labor availability
    b. Productivity adjustments
    c. Lengths and number of work shifts
    d. Living per diems
    e. FICA/SUI/workers compensation insurance
    f. Note wage requirements such as Davis-Bacon.
19. Contractor's Equipment Assumptions - Assumptions made regarding contractor's equipment during preparation of the estimate. Assumptions may include but are not limited to:
    a. Types of construction equipment to be used
    b. Equipment rates not listed in published equipment databases
    c. Fuel rates
20. External Entities – Work on existing third-party structures within the contractor's scope of work. Work on third-party structures may include but is not limited to relocation of utilities, restoration of infrastructure, and shoring and protection of adjacent structures and foundations. Work on third part structures may be performed by the contractor, or by the affected third party but paid by the contractor.
21. Traffic Restrictions - Major projects often have traffic restrictions and controls. List requirements and assumptions for road closures, and restrictions on local trucking routes and times that will impact the costs of construction.
22. Contractor's Means and Methods – Assumptions made regarding the contractor's means and methods of construction.

23. Site Remediation and Disposal – Requirements and assumptions for soil and groundwater remediation, and transportation and disposal of soil and groundwater.
24. Exclusions and Exceptions – Exclusions and exceptions from the OPCC. Exclusions and exceptions shall be kept to a minimum if possible. It is preferred that assumptions regarding scope and unit costs be made and noted, rather than excluded from the estimate.
25. Escalation – Assumptions regarding the price volatility of construction materials and supplies such as asphalt, fuel, cement and steel.
26. Contractor's Risk and Uncertainty – Major project risks and uncertainties assigned to the contractor and used in the development of the contractor's contingency.
27. Allowances – Major project risks and uncertainties for which allowances should be assigned.

3.4.4 OPCC Methodology

Each OPCC shall be developed using the project drawings and specifications, basis of OPCC and the methodology associated with the class of OPCC as shown in Table 3-1. Class 3 and 4 OPCCs shall be based on unit costs and quantities, and be organized by structure (i.e., consolidation conduit, diversion structure, gate and screening structure, etc.) and CSI code. If it is necessary to base all or part of a Class 3 or Class 4 OPCC on equipment-factored parametric models and/or historical relationship factors, a detailed explanation of how the model and/or relationship factor is applied to the current project is required. Class 2 OPCCs are based on detailed unit costs and quantity takeoffs and shall also be organized by structure and CSI code. General conditions, surety and insurance may be estimated as a percentage of direct construction costs. Overhead and profit shall be calculated based on a percentage of the total construction costs including general conditions, surety and insurance.

After the cost estimate is prepared, it will be expressed in year-of-expenditure dollars by assigning an inflation rate per year to the proposed midpoint of construction.

3.4.5 Allowances and Contractor Contingency

Costs that are unknown at the time of the OPCC and potential costs associated with identified risks shall be included in the form of allowances and a contingency. Allowances are established for known items of work but uncertain quantities. Contractor contingencies are included in the OPCC to account for items in the scope of work that the contractor may have overlooked during pricing, and for other unexpected costs that cannot be charged to the owner. Unit costs for allowance items shall be based on direct costs. The overhead and profit for allowance items shall be included in the total cost of construction. Contractor contingency shall be based on total cost of construction including overhead and profit. The range of the typical contingency to be included in each class of OPCC is shown in Table 3-1. The selection of a contractor contingency within the range relies the judgment of the DCs based on the degree of uncertainty at that point in the design.

3.4.6 OPCC Report

The OPCC shall be presented in a report consisting of the basis of OPCC, quantity sheets and appendices. The basis of OPCC shall be organized and numbered as shown above. Additional items may be added. Quantity sheets will be organized by structure and CSI Code, and have columns for:

- Item
- Quantity
- Unit of Measure
- Unit Cost
- Item Total
- Reference for unit cost

Unit costs and total costs shall be based on direct costs. A total cost for each structure and for each CSI of each structure shall be presented. Mobilization and demobilization costs, and startup and commissioning costs shall also be presented. Markups for overhead, insurance, bonds, general conditions and profit shall be calculated based using appropriate percentages of the total direct cost of the project.

Calculations of how unit costs, production rates and other factors were determined, if not referenced to databases, shall be located in appendices. Documents used to prepare the estimate (e.g., vendor quotes) shall also be located in appendices.
OPCC reports shall be submitted as PDF files. Quantity sheets for each OPCC shall be submitted in Excel format along with the OPCC report.

3.4.7 Release of Estimates

While OPCCs may have been developed for a specific and unique purpose they may be subject to misuse by those who do not understand the applicable context. OPCC shall not be released to anyone except the PM/CM.

3.4.8 Quality Management

A Quality Management Plan (QMP) for all projects shall include the preparation of OPCCs. A competent independent review shall validate all OPCCs. Depending on the size and complexity of the OPCC, validation shall be performed by a peer reviewer, management reviewer, or multi-disciplinary review team. Items to be checked during validation include:

1. Basis of OPCC prepared
2. Level of estimate is appropriate for stage of design documents
3. Purpose of estimate understood
4. Review based on correct set of plans and specifications
5. Project can be constructed within the proposed period of construction
6. Review of design documents for completeness and errors
7. Review of “high priced” items
8. Labor rates are applicable to area
9. Source(s) of material pricing listed

10. Source(s) of equipment pricing listed
11. Labor rates are consistent with current Davis-Bacon rates for the area
12. Crew production rates and crew makeups are applicable to the CSI division
13. Estimator received all available documents needed to complete an accurate estimate
14. Site visits conducted to verify site topographic, utility, easement, surrounding public utility and other existing conditions
15. OPCC escalated to midpoint of construction
16. Identification of and assumptions regarding unknown and uncertain costs
17. Right-of-way, permit and administrative costs
18. General conditions costs
19. Contractor's engineering and design costs
20. Temporary support of adjacent structures and utilities.
21. Dewatering costs
22. Third party (e.g. utility, railroad) costs
23. Construction contingency

3.4.9 Updated OPCC Guidelines

A technical memorandum providing updated guidelines to DCs preparing OPCCs was issued on September 24, 2019. It is provided as Appendix G.

3.5 Program Guidelines for Geotechnical/Environmental Work Plans

The purpose of the work plan standards is to establish a guideline for DCs to follow in performing geotechnical and environmental investigations to promote consistency in all such activities performed for the Phase III CSO Program. It is the responsibility of the DCs to develop a site-specific work plan to detail required field investigation to support foundation design of permanent structures/features, design of temporary support of excavation, groundwater control, and soils management. The major topics covered in this plan include preparing for field activities, performing investigations, and reporting on findings and conclusions. DCs shall be required to prepare field investigation work plans for review and acceptance by the PM/CM, acting on behalf of the NBC that satisfactorily addresses these major topics.

DCs performing geotechnical and environmental field investigations shall be required to submit a work plan for review and approval by the PM/CM prior to initiating field activities. The work plan shall provide a site-specific analysis of required geotechnical and environmental data necessary to support the design of temporary and permanent facilities. Provided in Appendix B is Geotechnical/Environmental Investigation Work Plan Standards for the Program.

The work plan shall identify procedures for the following activities, as they apply to project specific scope of investigation:

- Project coordination
- Coordination and observation of exploration subcontractor operations and procedures
- Performance of soil sampling and bedrock coring
- Characterization of soil and bedrock

- Performance of visual, olfactory, and field screening for environmental characteristics
- Sample collection, handling, description, and geologic logging
- Photo documentation
- Installation of groundwater monitoring wells
- Geotechnical laboratory testing to classify soil and rock and to establish engineering properties
- Environmental laboratory testing to identify the chemical constituency of soils, rock, and groundwater
- Groundwater level monitoring
- Preparation of a Geotechnical and Environmental Data Report

Geotechnical investigation activities shall be performed in general accordance with the Field Manual for Subsurface Exploration, which is referenced in Appendix B. DCs shall prepare their work plan so to be consistent with the field manual and minimum requirements identified herein. DCs shall be responsible for developing project specific work plan to support design of the following, but not limited to support of excavation, construction dewatering, construction methodology, soils management, and foundation design.

3.6 Temporary Support of Excavation

3.6.1 Purpose

The purpose of this section is to provide guidance on how temporary support of excavation (SOE) and construction dewatering is to be accounted for on Phase III CSO Program projects. Temporary SOE and dewatering is necessary to support underground construction of structures requiring deep excavations. Construction contractors will be responsible for the final design of all temporary SOE. Design shall be performed by the Contractor's Engineer, who shall be a Professional Engineer registered in the State of Rhode Island. It shall be the responsibility of the DCs to provide clear direction on the minimum requirements and performance criteria through the technical specifications and contract documents. DCs shall provide minimum design load specifications and soil/rock properties for temporary SOEs, minimum standards for construction dewatering, geotechnical instrumentation, and construction sequence, as it relates to a temporary SOE. The technical specifications prepared by DCs shall require that temporary SOE and dewatering system design be submitted as shop drawings for review and acceptance in advance of its construction.

A subsurface exploration program, developed by the DC, must include any specific items in the scope, which are necessary to provide the Contractor sufficient information to design the required temporary SOE and dewatering program. This includes, but is not limited to, borings, in-situ testing, groundwater observation wells, and lab testing (refer to Appendix B for additional guidance on geotechnical explorations). The DCs shall develop, perform, analyze, interpret, and provide to the Contractor the results of a subsurface exploration and laboratory soil/rock testing program.   Geotechnical data shall be presented in a Geotechnical Baseline Data Report. Interpretive data to be used initially as a basis for existing site subsurface conditions and to support specific SOE and dewatering design elements shall be presented in a Geotechnical Baseline Interpretive Report.

The contract documents shall indicate that the Contractor shall be responsible for the design of SOE system(s) and dewatering system(s), including identification of the construction means, methods, materials, maintenance, and removal as specified and/or as directed by the DC. The construction, maintenance, and removal of SOE and dewatering system(s) cannot adversely affect new or existing construction. SOE system(s) construction shall be coordinated with the project's excavation, excavation dewatering, and instrumentation programs, as required.

The SOE and dewatering system design and the Contractor's construction operations must consider subsurface conditions and the proximity of adjacent structures during the installation and monitoring of SOE system(s) and dewatering system(s). Contractor's Engineer shall verify that the installed systems conform to the proposed design provided to the Contractor or shall identify any differences between the proposed design and installed conditions. The DC's technical specifications shall require that the Contractor's Engineer provide written confirmation, in the form of a signed letter or technical memorandum, that the installed conditions meet the design requirements Movement monitoring of SOE structure(s) and adjacent ground, utilities, and structures, and groundwater level monitoring, shall be performed by the Contractor in accordance with the project's geotechnical instrumentation program.

The contract documents shall require that the Contractor coordinate and schedule a pre-construction meeting(s) with the sole intent of reviewing SOE system(s) and dewatering system(s) prior to their construction. The intent of this meeting will be to discuss the design prepared by the Contractor's Engineer and to discuss the Contractor's proposed construction means, methods, materials, procedures, construction sequence and work schedule for SOE and dewatering system(s) construction, operation, maintenance and removal. The contract documents shall also require that the Contractor coordinate a minimum of two (2) formal progress meetings to review the extent, functionality, and performance of the systems. Contractor, Contractor's Engineer, Program Manager, NBC, and the DC shall all be attendees to each of these meetings described above.

All Contractor SOE system(s) rock and/or soil anchor design, inspection and testing shall conform to the Post Tensioning Institute's, "Recommendations for Prestressed Rock and Soil Anchors," latest edition.

3.6.2 Roles and Responsibilities

As noted above, DCs shall have responsibility for developing minimum design loads and soil properties required for the Contractor's Engineer to design temporary SOE, construction dewatering, construction sequence, and geotechnical instrumentation, as required, to facilitate construction of designed facilities. For clarity, the general roles and responsibilities of implementing the strategy are provided below. It is noted that the term Engineer is used to identify a licensed professional engineer with appropriate experience in SOE and construction dewatering related design. Both the DC and Contractor shall have an engineer that meets these requirements and will have the responsibilities noted below.

- ***Design Consultant's Engineer:*** Licensed professional engineer in the State of Rhode Island with appropriate design experience in geotechnical engineering and temporary SOE and construction dewatering systems. The DC's Engineer shall be responsible for developing the soil properties, minimum design loads for the SOE system, any specific project conditions or parameters, groundwater properties, subsurface properties, dewatering standards, and geotechnical instrumentation programs. The DC's Engineer shall have continued involvement during construction, to review Contractor submittals, to analyze the Contractor's SOE and dewatering system designs, to monitor system installations, perform construction Quality Assurance, and interpret geotechnical instrumentation data.
- ***Contractor:*** Contractor is defined as the firm responsible for installing the temporary SOE and associated dewatering and instrumentation systems. It shall be the responsibility of the Contractor to furnish and install the SOE in accordance with design documents and the design developed by the Contractor's Engineer and approved by the DC's Engineer, including construction sequencing.
- ***Contractor's Engineer:*** Licensed professional engineer in the State of Rhode Island with appropriate design experience in temporary SOE systems, dewatering designs and instrumentation programs, who is on the staff or hired by the Contractor. The Contractor's Engineer shall have a minimum of 10 years of relevant experience and shall have completed a minimum of 5 projects with similar design requirements. Three of these projects shall have been in the role as a subconsultant under contract with the Contractor responsible for installing and maintaining the SOE and dewatering systems. . Contractor's Engineer shall be responsible for developing design submittals for the DC's approval presenting their proposed design of the SOE, construction dewatering and, instrumentation programs and systems. The Contractor's Engineer shall also be responsible for observation and verification that system(s) have been correctly installed and working as intended through the course of construction.

3.6.3 Temporary Support of Excavation

The purpose of a temporary SOE system(s) is to:

- Comply with all applicable federal, state, local and OSHA health and safety requirements, codes, and regulations.
- Permit the safe and efficient construction of project below grade work.
- Prevent injury to persons or damage to adjacent facilities: pavements, utilities, structures, etc.
- Prevent injurious caving of excavation side walls, water intrusion, soil erosion, loss of ground, and/or heaving of excavation subgrade(s).
- Provide excavation and subgrade stability during all below grade construction phases against unbalanced soil, hydrostatic forces, and groundwater piping.
- Limit excavation influence on adjacent facilities due to removal of foundation support or changes in the groundwater elevation.

Support of Excavation Types: It is anticipated that designs for temporary SOE system(s) will consist of one or a combination of the following. It is noted the Contractor's Engineer may propose other SOE systems, as necessary:

- Trench box, slide-rail, other modular systems, and/or open-cut;
- Steel sheeting with/without bracing, with/without tie-back anchors, rackers and/or struts;
- Soldier pile and lagging with/without bracing, with/without tie-back anchors, rackers and/or struts; and/or
- Wood tongue and groove sheeting.

The DC's Engineer shall indicate on the contract drawing(s) or by reference to project stationing, the minimum design loads to be resisted by the SOE system and soil/rock properties that should be used for the SOE design required excavation. The Contractor's Engineer shall employ as a minimum the specified minimum design loadings and soil/rock properties. The Contractor's Engineer may utilize higher design loads (e.g. due to their preference or due to their planned equipment); however, it is the responsibility of the Contractor to provide a design that can be approved and to construct and maintain these systems in a professional manner and advise their Engineer, as well as the DC, of any issue that may require a design modification.

The use of trench box(es), similar modular systems, or open cuts (where appropriate) shall be a Contractor design submittal for Engineer review, evaluation, and approval (where appropriate) and shall allow for the safe excavation, construction, and backfill to the required final grades.

Inspection and Testing: The Contractor's Engineer shall perform SOE system(s) inspection and testing, as necessary, on a periodic basis. The results of all testing shall be provided to the DC's Engineer. The DC's Engineer shall witness testing when deemed appropriate. The Contractor shall provide the DC with access to SOE system(s) for additional inspections and testing if they are determined to be required including but not limited to the following components:

1. Welded Connections: visually inspect welds and weld materials according to AWS D1.1/D1.1M and use, at the DC Engineer's option, the following inspection procedures beyond visual inspection:
   a. Liquid Penetrant Inspection: ASTM E165.
   b. Magnetic Particle Inspection: ASTM E709; performed on root pass and on finished weld. Note: Cracks or zones of incomplete fusion or penetration are not acceptable.
   c. Radio graphic Inspection: ASTM E94, minimum level "2-2T"
   d. Ultrasonic Inspection: ASTM E 164
2. Soil and/or rock anchor inspections and testing, if used, shall be based upon and conform with the Post Tensioning Institute's, "Recommendations for Prestressed Rock and Soil Anchors," latest edition.
3. Bracing and system components preloading, where required.

The Contractor’s Engineer shall visually verify and inspect the following components, structural steel materials, member sizes, connection details, and anchor components - if used. The Contractor’s Engineer shall be notified of the results of this inspection. Unsatisfactory conditions shall be rectified and inspected by the Contractor’s Engineer. The Contractor shall proceed with SOE system(s) work only after unsatisfactory conditions have been corrected. The Contractor shall prepare and distribute inspection and testing reports on a timely basis to the Engineer for review and approval.

The ***Contractor and/or Contractor’s Engineer*** shall:

1. Coordinate with the DC and their Engineer, Program Manager, NBC, and local and State authorities having jurisdiction on all aspects of SOE system(s).
2. Carry all the costs associated with the design, construction, operation, maintenance, and removal of the SOE system including but not limited to design efforts, meetings, coordination, quality reviews, submittals, resubmittals, installation, maintenance, removal, and disposal.
3. Coordinate and schedule a pre-SOE system(s) construction meeting with their Engineer, the DC, and DC’s Engineer.
4. Be familiar with the project’s Geotechnical Baseline Data and Interpretive Reports and shall fully examine existing site conditions to ensure that project work can be performed as specified by the Engineer and in accordance with industry standards. The Contractor shall provide all required equipment, modified if needed, to accommodate site conditions and restrictions.
5. Provide all SOE system(s) submittals for proposed SOEs to the DC’s Engineer under the stamp of the Contractor’s Engineer, a registered professional engineer in the State of Rhode Island with experience in the submittal subject matter, who has personally developed or has supervised the development of the submittals.
6. Provide the DC with all proposed SOE system(s): materials sizes and member connection details; means and methods of installation and removal, construction sequence and schedule, including means and methods of preloading bracing, struts, rakers and/or anchorage components, as required.
7. Coordinate SOE system(s) construction with allied work scope tasks, e.g. the project’s geotechnical instrumentation, excavation and excavation dewatering programs, as necessary.
8. Provide the DC with the anticipated sequence of construction, indicating work section sequencing to complete project work, including SOE system installation(s) in coordination with other related operations, e.g. instrumentation, excavation, dewatering, structure/pipeline foundation construction like pile driving, as/if required.
9. Provide the DC with qualifications and experience of the SOE system(s):
    a. installer company, key installer company personnel in responsible charge of SOE system(s) construction, operation and maintenance, and removal, and
    b. proposed Contractor’s Engineer, the engineer(s) responsible for Contractor submittals and design preparation. Provide the name of the Contractor’s OSHA Qualified “competent person” that will inspect all SOEs prior to anyone entering an excavation.

10. Provide welder certifications and qualifications including welding qualification procedures in conformance with AWS D1.1/D1.1M, “Structural Welding Code - Steel.”
11. Provide mill test reports for all structural steel members including chemical and physical properties.
12. Resolve difficulties arising from misalignment of SOE system(s) components that are exposed during excavation, including providing the DC with plans/criteria for implementing remedial procedures.
13. Verify the SOE work installed corresponds to the approved submittal. Provide follow up observations of systems, as needed to certify complete and full system(s) installation.
14. After checking SOE area utility locations by field investigation, provide as-built drawings to the DC showing actual utility locations and highlighting any interference with SOE system(s), including measures proposed by the Contactor to overcome anticipated interferences and/or other problems.
15. Be responsible for maintaining SOE system(s) to:
    a. Permit the satisfactory and safe construction of project work,
    b. Provide adequate protection against damage to all existing nearby utilities, structures, and new construction
    c. Prevent injury to persons
16. Control surface water and surface grades adjacent to excavations to prevent surface water from draining into excavated areas, and to prevent damage to existing facilities and new construction.
17. Proceed with SOE work only after unsatisfactory conditions have been corrected to the Engineer’s satisfaction.
18. Submit modifications to the SOE system(s) design, for DC review and approval, due to any additional loadings imposed by Contractor’s planned operations. SOE modifications shall be designed by the Contractor’s Engineer. The Contractor shall implement modifications to SOE system(s) only after approval by the DC’s Engineer.
19. Be aware of any DC, or other authority having jurisdiction, imposed restriction(s) on construction procedures or operations.
20. Maintain timely delivery and use of materials to avoid extended on-site storage, and keep all materials protected during fabrication, delivery, storage, handling and use/erection.
21. Be responsible for maintaining SOE system(s), take all precautions necessary to prevent movement/settlement of soil material along and adjacent to the sides of excavations, and prevent the intrusion of water into excavations.
22. Require Contractor’s Engineer to perform periodic observations on the SOE systems and provide status reports following each inspection.
23. Agree that when SOE structures are used, the Contractor has the sole responsibility for: any damages, delays, or injury due to SOE construction; and for the settling of backfill, pipeline, manhole, structure or other new construction and/or existing adjacent grounds, utilities and structures.
24. Monitor the performance of SOE system(s), including horizontal and vertical SOE structure and adjacent ground movement; and excavation interior/adjacent exterior groundwater levels in conformance with the project’s Geotechnical Instrumentation program. The

Contractor is responsible for notifying the DC when instrument monitoring indicates excessive movement in relation to DC defined Threshold Values. The Contractor shall provide the DC access to monitoring instrument locations and shall protect instrumentation from damage. Contractor shall immediately replace any damaged instrumentation. Daily SOE inspections are required per OSHA by a competent person.

25. Submit for approval to the DC any proposed changes to SOE system(s) design or construction procedures to accommodate field conditions prior to implementation.
26. Construct SOE system(s) in conformance with the Contractor's Engineer's designs in the approved Contractor submittals, and DC directives.
27. The Contractor's Engineer shall have continued responsibility during construction, to review the Contractor's work for conformance with approved designs and standards, to monitor construction methodology and inspection of the work, to implement Construction Quality Control inspections and testing, interpret instrumentation data, be on site to observe and comment on all construction work designed by the Contractor's Engineer and approved by the DC. The Contractor's Engineer shall have primary construction responsibility to be on site to monitor, observe and inspect the work on a regular basis that he/she has designed and is approved by the DC and to coordinate and communicate with the DC on all relevant construction matters for the preparation and submission of construction documents, e.g. Requests For Information, Construction Change Orders and/or Differing Site Conditions documents, to prepare for and attend construction meetings with the DC and/or other Design Team members, as a minimum during the time the work they designed (SOE and dewatering) is being constructed and maintained.

The ***DC's Engineer*** shall:

1. Provide minimum design loads, restrictions, and soil properties for the design of SOE systems by the Contractor's Engineer.
2. Monitor and oversee SOE and associated system(s) construction. Provided minimum design loads, restrictions, and soil properties should be reviewed prior to publishing of Contract Documents by an independent reviewer to verify that requirements and conditions do not make construction, operation, and/or maintenance of proposed SOE system(s) infeasible.
3. Provide estimated costs associated with SOE systems(s) for incorporation into project OPCC estimates, including cost of design, reviews, construction, operations, maintenance, inspections, meetings, and ancillary components.
4. Develop, perform, analyze, interpret and provide to the Contractor the results of a subsurface exploration and laboratory soil/rock testing program, in the form of Geotechnical Baseline Data and Interpretive Reports. Geotechnical Baseline Reports should contain adequate information to design and construct proposed SOE system(s), per current engineering design standards-of-practice and construction industry standards.
5. The DC shall indicate on the contract drawing(s) or project specification(s) the responsibilities of the Contractor and their Engineer for the design, installation, operation, and maintenance of the SOE systems.

6. Prepare for and attend a pre-SOE systems(s) construction meeting with the Contractor and Contractor's Engineer.
7. Review, comment on, and return Contractor-submittal items in a timely manner.
8. Identify the qualifications and experience requirements of the Contractor's Engineer and the SOE system(s) installer company and that of the company's key personnel in responsible charge of SOE system(s) construction, maintenance, and removal.
9. Review Contractor's SOE system design(s);
10. Prepare and distribute SOE inspection and testing reports, as required, on a timely basis and perform additional SOE system(s) testing, as necessary.
11. Provide the Contractor with SOE system(s) design criteria, e.g. minimum design loadings and soil/rock properties, required inside excavation dewatering level(s) and outside excavation groundwater level(s) utilized in the design, etc. that will result in a feasible and functioning SOE system.
12. Notify the Contractor of any construction restrictions or requirements, such as:
    a. Equipment exclusions, e.g. "swinging" versus fixed pile driving leads; and/or equipment/material stockpiling load restrictions when near excavations,
    b. The need for auxiliary power back up, as required,
    c. SOE system(s) construction procedures,
    d. SOE system(s) construction sequence relative to other allied project components,
    e. The disposition of SOE components at end of construction, to be left in place or full/partial removal requirements,
    f. The limiting of construction vibration levels (frequency, amplitude) generated near new construction, fresh concrete requirements/restrictions, existing structures, etc.
13. Verify that restrictions or requirements described above do not make construction, installation, and operation of SOE systems infeasible.
14. Direct the Contractor to modify SOE construction design, means, methods and/or sequence, if the Contractor's instrumentation reports indicate groundwater or structure/ground/utility movement levels approach or exceed Threshold Values that are defined by the DC as part of the project's Geotechnical Instrumentation program.
15. The DC Engineer's oversight and Quality Assurance role during construction means:
    a. the review and comment on construction generated documents,
    b. performance of inspections and witnessing the Contractor's Engineer's inspections,
    c. assessment of construction conformance with approved designs and/or construction standards,
    d. performing materials and structure testing as necessary,
    e. calling for meeting with DC, Contractor, and Contractor's Engineer relative to construction issues,
    f. communicating and coordinating with the Contractor's Engineer and Instrumentation Program Supervisor.

3.6.4 Construction Dewatering

The DC shall set design criteria for the construction dewatering program, including the development of dewatering system details and required notes. The DC shall develop, perform, analyze, interpret and provide to the Contractor the results of a project subsurface exploration and laboratory soil/rock testing program in the form of Geotechnical Baseline Data and Interpretive Reports. The results of this exploration and testing program will be the basis for conceptual dewatering system(s) design, and a general understanding of site subsurface conditions. The subsurface exploration program must provide adequate information necessary to design the excavation dewatering system(s) and associated work scope items, e.g. SOE system(s), Geotechnical Instrumentation Program, and project foundation element(s) design.

The DC shall prepare contract documents that require the Contractor's Engineer to design, and the Contractor to implement, all surface water mitigation and below grade dewatering work necessary to complete all below grade construction in-the-dry and on stable subgrades. These documents will state that the Contractor and Contractor's Engineer are responsible for designing, furnishing, installing, testing, operating, maintaining and removing dewatering systems when no longer needed. The Contractor's Engineer shall also size all pumps and dewatering discharge sedimentation tanks and discharge lines and Contractor shall coordinate with the DC (which includes the NBC) on all groundwater discharge and permit issues. It shall be noted that the DC is not responsible for the design of individual or collective dewatering systems.

The contract documents shall state that the proximity of adjacent facilities, e.g. pavements, utilities, structures, etc. shall be considered in the design of dewatering system(s). However, care must be taken by the Contractor during the construction and operation of dewatering system(s) so that nearby facilities are not negatively impacted. In accordance with the project's Geotechnical Instrumentation program near dewatering system(s): ground, utility, structure groundwater level movement and groundwater level monitoring shall be performed by the Contractor. Groundwater monitoring will typically be by standard groundwater observation wells and may also be by more specific piezometer instrumentation. Contractor shall perform pre-condition surveys to document the pre-construction condition of adjacent facilities.

The contract documents shall require that the Contractor coordinate and schedule a pre-dewatering system(s) construction meeting with the DC and the Contractor's Engineer to discuss the design, construction means, methods, procedures, sequence, schedule and anticipated performance for dewatering system(s) installation, operation, monitoring and removal. The issue of contaminated groundwater shall be addressed and coordinated with the DC. Contaminated groundwater items such as potential contaminants; groundwater handling and disposal procedures; and frequency of groundwater sampling, testing, and treatment shall be discussed.

The excavation dewatering system(s) construction and operation shall also be coordinated with related work scope items, e.g. Geotechnical Instrumentation, SOE system(s) construction / operation along with project pipeline and structure foundation element(s) construction. This excavation dewatering guide shall primarily consider the typical NBC case of a below grade and groundwater level pipeline construction of significant length.

The purpose of the dewatering system(s) and the requirements of the Contractor's Engineer is to:

1. Lower groundwater levels and/or hydrostatic pressure heads within the excavation to a minimum of two (2) feet below the deepest excavation subgrade when dewatering sandy soils and four (4) feet or more below the deepest excavation subgrade when within silts or clayey soils, to stabilize the bottom of excavations and to reduce pressure heads in below excavation strata so as to keep the effects of upward seepage gradients within safe limits.
2. Maintain a dry and stable excavation subgrade at all times.
3. Minimize the amount of the groundwater level lowering, below pre-construction ambient levels, outside of the excavation support system by incorporating a groundwater recharge system, if necessary. The areal extent and magnitude of dewatering system groundwater lowering shall be estimated by the Contractor's Engineer and provided to the DC, along with a remediation plan, if and as necessary.
4. The use of dewatering elements, well points or deep wells, located outside of SOE limits should be allowed only where their groundwater lowering impacts are estimated to not be detrimental to nearby facilities – ground, pavements, utilities, and/or structures.
5. Control and remove seepage, surface and precipitation water from excavations.
6. Provide suspended solids removal, sedimentation control, in dewatering system discharge.

Dewatering Equipment Types: It is anticipated that three (3) types of construction dewatering equipment might be employed: vacuum well points, drilled wells with contained submersible pumps, and sump pit, pump and subgrade ditching (channeling). Well point and drilled well systems are typically augmented by in-excavation sump pit and pump unit(s), and by groundwater level monitoring wells that are located both inside and outside of the excavation.

- Well point components consist of a series of individual well points, installed by jetting, drilling or both within a temporary casing and surrounded by a filter sand medium. The well points are connected to a header pipe manifold and ultimately to a common vacuum pump.
- Drilled wells consist of a single or network of submersible pumps, each installed at the bottom of a drilled-in perforated casing and surrounded by a filter sand medium.
- Sump pits and ditching consists of a single or network of perforated casing and crushed stone enveloped by a suitable geotextile (filter medium), or simply a subgrade excavated pit lined with an appropriate geotextile that envelops a crushed stone mass that surrounds a submersible pump. Sump pits can only operate at relatively shallow depth below subgrade, typically incorporating subgrade ditching to more efficiently channel and evacuate surface and near surface ground and other seepage water source. This system working exclusively may only be appropriate for a nominal amount of surface

dewatering, or more typically used in coordination with and as an enhancement for well point or drilled well dewatering systems.

***Types of Dewatering*:** The Contractor's Engineer shall clearly identify project dewatering system(s) by type and location anticipated to be required and shall provide complete and detailed dewatering system(s) design in their Construction Submittal for DC Engineer review. Dewatering system(s) design can be categorized into four (4) main types by the following designations:

A. <u>Type A</u> dewatering is for structural excavations that are above the observed groundwater table and normally will be dry. Type A dewatering is typically required in the event of excavation subgrade saturation from rainwater or runoff that enters the excavation. It is anticipated that Type A dewatering will be performed with sump pit (s) with/without excavation ditching located inside excavated areas to be dewatered. Intermittent operation of the system is anticipated.

B. <u>Type B</u> dewatering is for structural excavations that are at or below the observed groundwater table in soils that consist of miscellaneous granular fills or sandy soils. These excavations will require continuous dewatering to maintain a dry and stable excavation subgrade. Type B dewatering shall be activated prior to excavation, to pre-drain subgrade soils to a minimum of two (2) feet below the deepest part of the excavation. It is anticipated that Type B dewatering will require a well and submersible pump system (drilled well system) at locations around the excavation or a well point and header system (well point systems). It is anticipated that some of these types of systems will have to be designed and installed by a Specialty Dewatering Subcontractor.

C. <u>Type C</u> dewatering is for excavations that are at or below the observed groundwater table in silt, varved silt, laminated silt, sandy silt soils or clayey oils. Type C dewatering systems shall be activated prior to excavating and shall pre-drain the subgrade soil strata to four (4) or more feet below the deepest part of the excavation. It is anticipated that Type C dewatering will require a well point and header system that will have to be designed and installed by a Specialty Dewatering Subcontractor. Type C dewatering is necessary in soils that rapidly become unstable if not properly dewatered.

D. <u>Type D</u> dewatering is for depressurization of saturated pervious stratum located beneath a less pervious soil at the bottom of the excavation. Typically, these pervious soils are coarse grained granular (sands and gravels) which underly a finer soil (silt, sandy silt, or clay). The purpose of this dewatering is to reduce the hydrostatic pressure in the underlying coarse-grained soil to reduce the hydraulic gradient from the underlying stratum to the bottom of excavation to acceptable levels. This type of dewatering is usually required in conjunction with one of the other types of dewatering.

E. Groundwater level monitoring by observation well(s) will be required for dewatering system Types B, C and D. For dewatering system Types B and C, typical groundwater observation well(s) will extend a minimum of ten (10) feet below the anticipated bottom of excavation's dewatered groundwater level, and will typically be located in well pairs, one within and another external to the excavation. For dewatering system Type D, typical relatively shallow groundwater observation wells will be required similar to Types B and C dewatering, and additionally relatively deep groundwater observation wells will be required to monitor the deep pervious stratum to be depressurized. These groundwater monitoring wells will be required to be installed and monitored continuously starting prior to excavation, to determine that the required groundwater lowering and/or depressurization is achieved. Dewatering system operations will need to be continuous until backfilling and/or structure weight without the aid of dewatering can provide a stable excavation condition, or as directed by the DC.

Considering a typical NBC pipeline construction case, the Contractor may need to excavate and operate dewatering systems in discrete (incremental) lengths, based upon estimated dewatering discharge volume and treatment and/or receiving facility flow-volume acceptance requirements. The Contractor's Engineer shall identify the dewatering system type by pipeline section and/or individual structure. It is anticipated that the appropriate dewatering system type will be shown on pipeline plan/profile drawings and/or tabulated by pipeline station or both, as appropriate, and submitted for review by the DC's Engineer. The Contractor's Engineer shall identify the estimated dewatering flow-volume generated per pipeline length for each dewatering system type indicated.

The DC's Engineer shall identify the type of discharge water treatment required; the requirement for temporary on-site storage capacity; and receiving facility flow-volume acceptance requirements based on the anticipated discharge permit conditions. This shall be provided in contract documents prepared by the DC, but the Contractor is responsible to obtain the required discharge permit. Discharge is anticipated to be to the collection sewer unless otherwise specified by the DC, which will be subject to a pre-treatment permit issued by NBC. The Contractor shall perform all environmental discharge water sampling and testing and provide results to the DC in a regular, timely manner as specified. Details associated with proposed excavation SOE, dewatering incremental lengths, dewatering system component testing, production dewatering system construction operation and removal will be designed and produced by the Contractor's Engineer and shall be Contractor submittal items.

Dewatering System Component Testing and Monitoring: For each dewatering system identified, the DC's Engineer shall indicate the necessary testing and monitoring. The Contractor's Quality Control testing is an integral part of the dewatering system design and operation process, to ensure that system components have been designed and installed adequately for optimum system efficiency, meeting the excavation dewatering requirements.

Wellpoint Systems: Details of the proposed construction means, methods and schedule for the well point system design, testing and construction, including well screen slot opening size, slot entrance velocity and filter pack gradation requirements shall be Contractor submittal items. The well point system design shall identify individual well point locations, depth (or elevation including the well screen section) and spacing. The Contractor's Engineer shall provide a detailed plan for wellpoint systems testing, where specified. It is anticipated that extended (plan view) length wellpoint systems will be constructed in discrete sections to limit dewatering discharge flow-volume relative to treatment and/or discharge receiving facility flow-volume capacity. Each incremental excavation/dewatering section length shall be tested as a unit, as will each individual well point. Wellpoint system testing will precede each system construction phase. After the vacuum pump and header manifold pipe are installed, the installation and testing of section test wellpoints shall be completed. It is anticipated that these test wellpoints will be located at the ends of each incremental section length and/or at other locations identified as significant variations in subsurface conditions. After successful completion of section wellpoint testing, the installation and testing of each individual production wellpoint will follow. This testing regime is part of the design process to ensure that a proper well spacing, depth and filter is developed so that the system can function efficiently, meeting excavation dewatering requirements.

The Contractor's Engineer shall identify the sequence of well point system testing. This process may proceed as follows:

- Initial section well point testing shall begin with the Contractor installing a minimum of two (2) sets of well points, one set at each section ends with each set consisting of two (2) individual well points located approximately 10 feet apart in accordance with the Contractor's Engineer's design, and extending to the designed well point depth.
- The Contractor shall pump test each test wellpoint separately, and measure draw-down in the adjacent test wellpoint for a minimum period of 30 minutes and up to 4 hours to assess discharge water clarity, well point capacity, drawdown extent, and filter effectiveness.
- Modifications to the production well point system, e.g. wellpoint spacing and/or sand filter gradation, can be implemented at this time, as/if needed or as directed by the Contractor's Engineer.
- Each production wellpoint shall be pump tested for a minimum of 15 minutes to verify discharge clarity and volume, i.e. well point filter sand gradation appropriateness. Any wellpoint not pumping clear within 30 minutes shall be re-drilled and reset using an alternate sand filter medium, as proposed by the Contractor's Engineer and as approved by the DC.

Wellpoint installations and initial pump testing shall be observed by the Contractor's Engineer as well as the DC's Engineer. Test wellpoints may be located at production wellpoint locations. Contractor's Engineer shall make periodic inspections and provide reports documenting the performance and operation of installed system(s) for the duration of its use during construction.

Drilled Well System: The Contractor's Engineer shall provide a detailed plan for the testing of drilled well system components. The plan shall include initial pump testing of each drilled well individually. A minimum of two (2) near-by groundwater monitoring wells shall be installed or used by the Contractor. While pump testing the drilled well, measure draw-down in the monitor wells for between 15 to 30 minutes, to assess the areal extent of drawdown, while simultaneously observe and measure drilled well discharge water clarity and quantity, i.e. well filter effectiveness. Modifications to the drilled well system, e.g. drilled well spacing, depth pump capacity and/or filter sand gradation, can be implemented at this time, as/if needed or as directed by the Contractor's Engineer or DC. All drilled well installations and pump testing shall be observed by the Contractor's Engineer as well as the DC's Engineer. Details of proposed design, construction means, methods and schedule for drilled well systems testing and construction including selection of casing slot opening size, slot entrance velocity and filter pack gradation shall be Contractor submittal items. The drilled well system design shall identify individual drilled well locations, depth, spacing and pump characteristics.

Groundwater Monitoring Wells and/or Borehole Piezometers: The DC shall require at a minimum that the Contractor install 2-inch nominal diameter PVC pipe groundwater monitoring wells at locations identified on the project drawings, in technical specifications, and as approved Contractor submittals. Piezometers, which accurately measure groundwater pressure and thus groundwater depth/elevation at a specific stratum location, may also be employed for more precise and targeted groundwater measurements. The monitor wells and/or piezometers are designed to monitor and determine the adequacy of dewatering system drawdown inside of the excavation, and the areal extent and depth of groundwater draw-down outside of the excavation. The Contractor shall install and monitor observation wells generally in pairs (one inside and another outside of the SOE) at approximate 100-foot intervals or less along the pipeline alignment at locations approved by the DC prior to commencement of excavation. Each pair of observation wells shall be installed to a minimum depth of 10 feet below the deepest adjacent excavation elevation to be dewatered. The Contractor's Engineer and DC shall witness all monitor well/piezometer installations. The Contractor shall monitor groundwater elevations and maintain at least the minimum number of groundwater monitor wells indicated by the Contractor's Engineer's approved dewatering system(s) design and instrumentation program. Additional observation wells may be required by the DC. Refer to Section 3.6.5 for the Geotechnical Instrumentation guidance for further groundwater monitoring well information. Where strata below the bottom of excavations are required to be depressurized (Type D Dewatering), additional observation wells and/or piezometers shall be required to confirm the adequacy of the depressurization. These observation wells shall be installed to the depth of the deep depressurization wells.

Dewatering Systems Operation and Performance: Once started the dewatering system shall be continuously operated 24 hours per day, 7 days per week, until construction work below and potentially above existing groundwater levels is complete or as directed by the DC. The Contractor shall measure and record the performance of dewatering system(s) using the groundwater monitoring wells and piezometers, if utilized. The Contractor shall adapt and modify the dewatering systems, including associated discharge treatment, e.g. sedimentation or chemical treatment, as required over the dewatering operational period to meet project requirements. The Contractor shall control the excavation inflow of seepage/surface water at all times during construction, prevent excessive groundwater lowering outside of the excavation, and permit all below groundwater level excavation work to be performed in-the-dry and on a stable subgrade. Where required the DC's Engineer shall specify the maximum groundwater lowering outside the excavation limits.

The Contractor shall be directed to provide, install, maintain, and operate all dewatering system equipment, including standby equipment of sufficient capacity, to adequately dewater excavations until no longer needed and the Contractor's Engineer shall design system(s) that achieve these requirements. When constructing below grade structures, e.g. vaults, manholes, pipelines, pump stations, etc. that may be subject to buoyant forces, the Contractor will be required to maintain dewatering operations until sufficient structure and backfill dead-weight is in-placed to resist hydrostatic uplift forces. The Contractor's Engineer shall provide calculations in their submittal which establish the level of backfill or construction completion required to adequately resist uplift forces. The Contractor shall also not permit standing water to accumulate in excavations.

The dewatering system, well points or drilled wells, may require additional sump pits and pumps within the excavation, to handle seepage from a variety of sources, e.g. support of excavation walls, excavation ends, from adjacent or SOE penetrating utilities, etc. Ditching at bottom of excavation may be required to channel seepage water toward sump pit and pump locations. Refer to the engineered developed project dewatering drawings and specifications for dewatering system sump pit and pump requirements.

In coordination with excavation dewatering systems, the Contractor shall be required to install, operate, maintain and remove when no longer needed, a temporary surface water control program. This program shall be designed to divert surface water away from excavations, trenches, utilities, and all other project work areas.

The ***Contractor and/or Contractor's Engineer*** shall:

1. Coordinate with the DC, Program Manager, and the NBC as well as local and State authorities having jurisdiction, and obtain all permits required to discharge groundwater during construction dewatering operations.
2. Carry all the costs associated with the dewatering system(s) including but not limited to design efforts, meetings, coordination, quality reviews, submittals, resubmittals, installation, operation, observation requirements, maintenance, removal, and disposal.
3. Coordinate and schedule a pre-dewatering system(s) construction meeting with the DC.
4. Be familiar with the project's Geotechnical Baseline Data and Interpretive Reports, and fully examine site conditions to ensure that project work can be performed as specified by the DC and in accordance with industry standards. The Contractor shall provide all required equipment, modified if needed, to accommodate site conditions, any site restrictions imposed by DC or NBC, and the Contractor's approved dewatering design.
5. Provide all construction dewatering submittals to the DC under the stamp of the Contractor's Engineer, a registered professional engineer in the State of Rhode Island with experience in the submittal subject matter, who has personally developed or has supervised the development of the submittal.
6. Provide the dewatering design with details of dewatering system(s) construction means, methods and equipment, sequence of construction and operation, the estimated time required for each operation, details of backup equipment, e.g. generators, pumps and that required for groundwater discharge treatment systems, and any other pertinent information required or requested by the DC.

7. Provide the qualifications and experience of the Contractor's Engineer and the dewatering system installer's key individuals in responsible charge of the dewatering work to the DC for review, evaluation and approval.
8. Have available and in an organized fashion the dewatering system(s) submittal, design calculations and all supporting information.
9. Submit modifications required to the dewatering system design(s) for DC review and approval, due to any additional dewatering system(s) requirements to be implemented for the exclusive benefit of Contractor planned operations or due to the inadequacy of dewatering system(s) currently in place. The Contractor shall implement DC-approved modifications to the dewatering system(s).
10. Coordinate and schedule a pre-dewatering system(s) construction meeting with the DC to discuss the Contractor's design and construction means, methods, procedures, sequence and schedule for dewatering systems construction, operation, monitoring and removal. In addition, installation, operation, and maintenance of pre-treatment systems(s) as well as sampling and reporting for permit compliance shall also be reviewed at this meeting.
11. Coordinate dewatering operations with other allied Contractor work scope items, i.e. SOE system(s) construction, excavation, geotechnical instrumentation, and foundation elements construction, e.g. pile driving, if utilized.
12. Manage the discharge of construction dewatering to prevent off-site surface water runoff and damage to new or existing construction. The Contractor shall control dewatering discharge to prevent the spread and/or increase of contamination in any portion of the site and in off-site areas.
13. Design the size and number of dewatering system(s) discharge sedimentation basins and/or tanks of appropriate capacity to be provided and use appropriate filter materials, equipment, and techniques to capture, remove, and dispose of sediments deemed unsuitable for discharge under the applicable groundwater discharge permit(s). Dewatering system(s) discharge chemical requirements and/or chemical treatment shall also conform to the applicable discharge permit(s) and/or as directed by the DC.
14. Immediately modify dewatering activities and notify the DC, if evidence of groundwater contamination is suspected or detected due to dewatering activities. If contamination is suspected or detected, discharge from dewatering operations shall be pumped directly from the excavation into dedicated on site fractional tanks/basins. Sufficient tank/basin storage capacity shall be provided to allow for dewatering system(s) discharge storage during groundwater environmental testing and temporary treatment without affecting the construction progress or schedule.
15. Provide a calibrated flow meter(s) of DC approved accuracy to measure the dewatering discharge flow rate and the total volume of groundwater discharged.
16. Measure and record the performance of dewatering system(s) using groundwater monitoring well(s) and piezometers (if used) installed to monitor dewatering system(s) performance.
17. Install the dewatering system(s) in accordance with DC approved Contractor submittals and/or system design requirements.

18. Provide suitable filter sand materials to prevent the migration or pumping of existing soil fines and subsequent subgrade disturbance and/or weakening, due to construction dewatering operations.
19. Provide the DC access to the dewatering systems at all times to obtain samples of the dewatering effluent prior to and after treatment.
20. Modify dewatering procedures that cause or may cause, in the opinion of the DC, damage to new construction or existing facilities.
21. Be responsible to completely clean and remove all sediment from impacted utilities and other facilities to the satisfaction of their Owner(s), if sediment or other materials discharged from the dewatering system(s) accumulate in storm water drains or other designated discharge receiving facilities.
22. Remove, backfill, or otherwise decommission dewatering system(s) elements when no longer required, using methods acceptable to the DC.
23. Inform the DC in writing of any changes made to the dewatering system(s) to accommodate field conditions or for the benefit of Contractor operations. No dewatering system(s) modifications will be made without approval by the DC.
24. During dewatering system(s) testing, construction, and operation, the Contractor's Engineer shall maintain a regular on-site presence to observe and/or modify dewatering system(s) as necessary to meet requirements, and to coordinate/communicate with the Contractor and DC on a regular basis.

The ***DC and/or DC's Engineer*** shall:

1. Develop, perform, analyze, interpret and provide to the Contractor the results of a subsurface exploration and laboratory soil/rock testing program, in the form of Geotechnical Baseline Data and Interpretive Reports. However, it shall be noted that the DC is not responsible for the design of site and/or project specific dewatering components or systems.
2. Specify, monitor and oversee the construction dewatering program, including identifying the subsurface data required to be used along each section of pipeline and/or at each structure for dewatering design.
3. Indicate on the contract drawing(s) or project specification(s) the responsibilities of the Contractor for the design, installation, operation, and maintenance of the dewatering system(s).
4. Prepare for and attend a pre-Dewatering system(s) construction meeting with the Contractor/Contractor's Engineer.Review, comment on and return Contractor submittals in a timely manner.
5. Monitor the sequence of dewatering system(s) operations with other allied contractor work, e.g. geotechnical instrumentation, SOE system(s) construction, excavation and structure/pipeline foundation elements construction.
6. Identify the required qualifications and experience of the Contractor's Engineer to complete the design of the dewatering system, and installer Company and key project assigned installer individuals in responsible charge of dewatering system(s) installation and operation.

7. Identify the maximum dewatering discharge flow-rate that the receiving facility will accept, and thus the maximum length of wellpoint system or number of drilled well system(s) to be in operation at any one time, to limit the impact of construction dewatering discharge on the designated discharge facilities.
8. Review modifications to the dewatering systems receiving design(s) prepared by the Contractor's Engineer, where necessary, due to unforeseen below grade conditions.
9. Sample, test and evaluate dewatering discharge on a regular basis for groundwater contamination evaluation and notify the Contractor promptly of findings and/or potential dewatering operation impacts.
10. Communicate and coordinate with the Contractor's Engineer during dewatering system's design submittal period and during dewatering system's field testing, construction and operation.

3.6.5 Geotechnical Instrumentation

Instrumentation work includes the Contractor furnishing, installing, monitoring, reporting of data, maintaining instrumentation; protecting instrumentation from damage; promptly replacing damaged, malfunctioning, and/or worn-out instruments; and removing instrumentation when no longer required. Instrumentation work also includes the installation of additional instruments and data collection that the Contractor deems necessary to ensure the safety of personnel and of the project in general. The Contractor shall implement required precautionary and remedial measures, based upon the instrumentation data and/or as directed by the DC.

The DC shall design a geotechnical instrumentation program to be incorporated into the contract documents. The purpose of the instrumentation program shall be to monitor and protect existing buildings, walls, and structures of significance. The instrumentation program shall:

- Define the necessary threshold values for each site to be monitored,
- Require the Contractor to be responsible for the installation, operation, maintenance, monitoring, and reporting of results to PM/CM,
- Require that a preconstruction condition survey of all significant structures within 200 feet of project work, prior to commencement of construction activities,
- Require that Contractor's Engineer be responsible for the review of all data and take action if threshold values are exceeded,
- Require that the Contractor's Engineer share the results with the PM/CM as requested and during an exceedance, and
- Require that the Contractor shall coordinate a pre-construction meeting with the DC to discuss Contractor means, methods, procedures and schedule for instrumentation systems construction, operation, readings, reporting, threshold data criteria and contractor developed action plans, and instrumentation removal.

DC shall specify the required types of instrumentation that the Contractor's Engineer should consider for use on their project. The number, locations, frequency of readings, reporting, threshold data criteria and Contractor developed action plan requirements shall be selected by the DC.

The purpose of the Instrumentation Program includes, but is not limited to, providing:

1. Pre-construction baseline data for comparison with construction and post-construction data.
2. Detecting movement of the SOE system, and selected: ground locations, existing significant structures, and below grade utilities prior to, during and after construction to determine whether they have been adversely affected by construction activities. In addition, groundwater monitoring wells shall be read to assess the effectiveness of dewatering and the impact of dewatering on adjacent facilities and groundwater conditions.
3. Provide a forewarning of unforeseen conditions that may require precautionary or remedial measures.

It is anticipated that the types of instrumentation to monitor the impact of construction activities may include the following:

1. Movement Monitoring Points (MMPs): shall be installed at defined key locations on the support-of-excavation system as determined by Contractor's Engineer, and at other locations directed and/or approved by the DC.
2. Ground Monitoring Points (GMPs): shall be installed at defined existing ground surface locations near support of excavation structures as determined by Contractor's Engineer, and at other locations directed and/or approved by the DC.
3. Structure Monitoring Points (SMPs): shall be installed at defined existing significant structures located within 200 feet of project work as determined by Contractor's Engineer, and at other locations directed and/or approved by the DC.
4. Utility Monitoring Points (UMPs): shall be installed on Engineer defined ground and below ground utility pipelines and/or structures located within 200 feet of project work as determined by Contractor's Engineer, and at other locations directed and/or approved by the DC. Utility monitoring points may be installed on ground or above ground features of primarily below ground utility structures and/or pipelines, e.g. ground surface manhole cover rims or pipeline valve monitoring within a gate box structure, or shall be installed directly onto a below ground utility structure or pipeline, e.g. by steel rod(s) attached to or installed within a concrete mass poured over an exposed below ground pipeline/structure section that is then extended to ground surface through a protective steel casing and ground surface gate box with cover, for top-of-steel rod (and thus below grade utility) movement monitoring.
5. Groundwater Monitoring Wells (MWs): shall be installed at defined locations near excavation dewatering system(s) as determined by Contractor's Engineer, screened and isolated at depths defined by Contractor's Engineer, typically located in adjacent pairs both inside and outside of the excavation(s) to be dewatered, and at other locations directed and/or approved by the DC.

All instrumentation will require baseline readings prior to construction start to establish existing conditions. Installation of instruments and performance of initial baseline readings shall be in general conformance with the following schedule, as modified by the DC, or modified by the Contractor's Engineer with approval from DC:

1. Movement Monitoring Points (MMPs) on SOE structures shall be installed and initial baseline readings obtained immediately following installation and submitted to the DC not less than one week before any excavation starts.
2. Ground Monitoring Points on ground surfaces (GMPs) shall be installed and initial baseline readings obtained and submitted to the DC not less than one week prior to any area construction work.
3. Structure Monitoring Points (SMPs) on existing structures shall be installed and initial baseline readings obtained and submitted to the DC not less than one week prior to any area construction work.
4. Utility monitoring points (UMPs) shall be installed and initial baseline readings obtained and submitted to the DC not less than one week prior to any area construction work.
5. Groundwater Monitoring Well readings (MWs) shall be initially made at the time of well installation, and stabilized groundwater readings made at a minimum of 24 hours after well installation. MWs shall be installed and initial baseline readings obtained and submitted to the DC not less than one week prior to any area construction work.

The Contractor's Engineer shall propose a schedule for instrumentation readings by the Contractor, subject to approval by the DC. The following Instrumentation Guide Specification provides typical instrumentation program information which shall be modified accordingly for the specific needs of the project.

The Contractor shall submit to the DC, on a regular basis approved by DC, all results of movement and groundwater monitoring well instrumentation data. Data shall be analyzed, reduced, and summarized in tabular format by the Contractor on typically standard letter size paper stock. Site elevation information shall be incorporated into the data reporting, where appropriate and as directed by the DC. Data shall also be presented in graphical format, indicating absolute vertical and/or horizonal movement versus time, as appropriate. The DC will also require other information to be provided in these reports. The Contractor shall provide appropriate plots of the data and provide an Excel file containing this data and plots. The Contractor shall not disclose any instrumentation data to third parties and shall not publish instrumentation data without prior written consent by the Owner.

Action Plans and Movement Threshold Values: Prior to the start of construction, the Contractor shall submit to the DC plans of action to be implemented in the event that any Threshold Values of structure movement or groundwater level are approached or reached. The generalized plans of action shall be positive measures by the Contractor, as follows and as applicable, made to:

1. Limit further induced movements by construction activities, e.g. sheet pile and/or pile foundation driving, excavation, demolition, and excavation backfill and/or vibratory soil or asphalt compaction.
2. Limit further decrease or increase in groundwater levels.
3. Maintain the integrity of adjacent ground, structures and utilities.

Threshold Values: The DC shall present a listing of Threshold Vibration Levels for each instrumentation type, which will require action to be taken by the Contractor should Threshold Levels be approached or reached. Threshold Levels for each instrument will trigger specific Contractor actions to be undertaken.

The Contractor shall take all necessary steps so that damage to existing adjacent and/or newly constructed facilities does not occur. The Contractor may be directed by the DC to suspend activities in the affected area(s), except for those actions necessary to avoid damage.

The ***Contractor and/or Contractor's Engineer*** shall, as appropriate:

1. Coordinate a pre-construction meeting with the DC and the Contractor's Engineer to discuss Contractor means, methods, procedures and schedule for instrumentation systems construction, monitoring, data analyses and reporting and instrumentation replacement and removal.
2. Design, specify and oversee the instrumentation program, including the development of instrumentation location drawings, drawing details and drawing notes. Furnish and maintain all instrumentation.
3. Provide the DC with all geotechnical instrumentation submittals under the stamp of a registered professional engineer or land surveyor in the State of Rhode Island with experience in the submittal subject matter (Contractor's Instrumentation Supervisor), who has personally developed or has supervised the development of the submittals.
4. Install, monitor, analyze and report data from all instruments on a regular engineer defined basis.
5. Protect from damage and maintain instruments installed by the Contractor, and any instruments installed by others throughout the duration of construction. Promptly replace any damaged instrumentation.
6. Install, monitor and interpret data from instrumentation, in addition to that specified by the DC, and that the Contractor deems necessary to ensure the safety of personnel and existing/new construction.
7. Acquire permission from property owners, where required, to install and monitor instrumentation.
8. Propose for DC evaluation, approval and implementation remedial response actions resulting from instrumentation data review.
9. Provide the DC with surveyed as-built location drawings of all instrumentation, monitoring points and groundwater monitoring wells, upon installation that shall be up-dated on a regular basis during construction work when new locations have been added or when existing locations have been modified. The Contractor shall identify each instrument location by a unique label that shall be used in the instrumentation data analyses and reporting.
10. Provide dedicated instrumentation personnel including an Instrumentation Supervisor (Supervisor) who will be in responsible charge of the geotechnical instrumentation program. The Supervisor can be the, or one of the, individual(s) responsible for installing and collecting data from all instrumentation. The Supervisor shall have prior field experience in the installation and monitoring of instrumentation of the types

specified and shall have performed or supervised instrumentation programs of similar type, magnitude and under similar construction circumstances. The Supervisor shall:

   a. Be on site and supervise and/or perform all instrument installations.
   b. Supervise and/or perform all data collection, reduction, plotting, and reporting.
   c. Be a Registered Professional Engineer or Land Surveyor in the State of Rhode Island with experience in measurements of the types and accuracies specified.
   d. Perform or supervise data interpretations, and work closely with the DC on these matters.
   e. Employ personnel, e.g. a field survey party chief, who shall also have experience in survey measurements of the types and accuracies specified, and with monitoring data analyses, tabulation, graphical presentation and interpretation.

11. Collect data at the monitoring points and groundwater wells in accordance with the frequencies specified, but in no case less than once per week.
12. Provide labelled and tabulated field data and data plots to the DC on a minimum weekly basis, or as directed by the DC, which shall include a detailed description of construction work performed during the week.
13. Have the primary responsibility (the Supervisor's responsibility) for instrumentation data interpretation. Interpretation shall include making correlations between instrumentation data and specific construction activities. Instrumentation data shall be evaluated to determine whether the response to construction activities is reasonable and comparable to the project's defined Threshold Values for response action(s).
14. Be responsible for the safety of the work.
15. The Contractor's Instrumentation Supervisor shall be the DC's sole contact for instrumentation program responsibility and he/she shall be in continuous communication and coordination with the DC before, during and after the instrumentation monitoring period.

The ***DC*** shall:

1. Prepare for and attend a Geotechnical Instrumentation system(s) pre-construction meeting with the Contractor and Contractor's Engineer. This meeting shall be coordinated and attended by the Contractor's pre-instrumentation supervisor as well, if different from Contractor's Engineer.
1. Review, comment on and return Contractor submittals items in a timely manner.
2. Review the Contractor's instrumentation personnel qualifications, including the Supervisor, field survey party chief, and other field and office personnel.
3. Review for approval purposes:
   a. The proposed movement and groundwater level monitoring locations and reporting frequencies for all instrumentation.
   b. The precision and accuracy of Contractor data.
   c. The format of the Contractor's Instrumentation Reports.
   d. The Supervisor's weekly (or other frequency) instrumentation reports documenting monitoring results, which shall include:

i. The location of all monitor points and groundwater observation wells, the time lapse between initial reading and start of construction, and the time lapse between subsequent instrumentation monitoring.
ii. As a minimum, instrumentation data reporting shall be presented in spreadsheet tabular format, from top-to-bottom identifying each type of monitoring point followed by all individual point IDs for each instrumentation type with a brief physical description of each point. From left-to-right following each monitoring point's ID and description, the monitoring data values (by elevation), shall be presented chronologically by monitoring date with the most recent data presented first followed in descending chronological order by successive monitoring data. All monitoring points shall be listed on each report spreadsheet, with current reporting period monitored points (data) highlighted. The instrumentation programs elevation datum shall be indicated and described.
iii. Data plots showing indicated Threshold Values for each type of instrument, if requested and the time lapse between subsequent instrumentation monitoring.
iv. The reports shall contain a summary of relevant instrumentation data impacting construction activity during the reporting period. Relevant construction activity shall be described in location specific terms, e.g. stationing and pipeline baseline reference. The report shall also contain space for the instrumentation Supervisor's comments.
v. Each report shall also contain graphical excerpt(s) from the instrumentation locations that have monitoring data during the current reporting period. Instrumentation drawing excerpts shall show the location(s) of relevant reporting period construction activity. Instrumentation drawing excerpts shall show instrumentation data points by unique symbol, ID and color. Each instrumentation drawing excerpt shall contain a symbol legend (highlighted with unique symbol color) bar scale, and the date of the current report period monitoring. The report spreadsheet and graphical drawing excerpt(s) shall contain the Instrumentation Supervisor's initials, signifying that he/she has either developed and/or reviewed the data/graphic.
vi. A report of any unusual Construction or otherwise events that may have affected the instrumentation readings. The report shall include a description of any remedial or precautionary measures that were implemented during the week/month in response to geotechnical instrumentation or other data, including when these actions were implemented and for what reason. The report shall also include a description of any future remedial or precautionary measures that are anticipated or planned in response to existing instrument or other data.

e. The determination, from a review of instrumentation data, that a data change has occurred, which is likely to require remedial or precautionary measures. The DC shall then notify the Contractor to verify the change and take appropriate action.

4. Have the right to perform their own interpretation of data collected and provided by the Contractor. However, the Contractor's Supervisor will have the primary responsibility for interpretation. Interpretation shall include making correlations between instrumentation data and specific construction activities. Instrumentation data shall be evaluated to determine whether the response to construction activities is reasonable and comparable to the project's defined Threshold Values for response action(s).
5. Identify in the bid documents, the quantity of each instrument type, including any contingency amounts, that the Contractor shall plan for in their bid.
6. Not be responsible for the safety of the work based upon the instrumentation data.

3.6.6 Construction Sequence

Construction sequence is an important element of effective SOE design. It is the Contractor's responsibility of incorporating construction sequence into the design. The Contractor and Contractor's engineer shall develop an understanding of the construction sequence and proposed means and methods to guide the design accordingly. The design shall consider how the sequence of construction may negatively impact the stability of an SOE and adjacent structures. Drawing notes and/or specifications shall provide language regarding construction sequence as it relates to SOE stability and potential for ground movement.

Section 4.0

Project Delivery System

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4.0 Project Delivery System

4.1 Purpose

The purpose of this section is to outline the recommended approach for project-level governance activities. The objective of project-level governance is to provide strategies and processes for delivering design projects in alignment with the overall goals and objectives of the Phase III CSO Program, while also meeting key objectives of scope, schedule, cost, and risk.

This objective will be achieved by confirming the following minimum elements:

- Project has been adequately defined and executed to date;
- Project need(s) and scope remain unchanged or, if changes have occurred, that they remain in alignment with the NBC's overall goals, objectives, and guiding principles;
- Impacts of project decisions are understood;
- Latest forecasted project schedule corresponds to the latest approved project baseline schedule, or appropriate justification is provided to justify a change to the project baseline schedule;
- Project stakeholders have been identified, and a plan is in place to engage them at the right time and at the right level;
- Project risks have been identified, tracked, and responded to as specified in the Risk and Value Management Plan;
- Project changes have been addressed as specified in the Change Management Plan;
- Project is in compliance with the overall governance structure established for the delivery of the Program (i.e., in compliance with NBC-specific policies, plans, procedures, business processes, and systems); and
- Project warrants progression to the next stage of the Project Delivery System (PDS).

4.2 Background

Program and project management activities focus on controlling outcomes with a primary goal to deliver projects, as planned. It is challenging to meet that goal when implementing large, complex infrastructure programs without a robust governance structure to frame how projects are consistently delivered. A program's governance structure consists of plans, guidelines, policies, procedures, business processes, systems, and/or tools applicable to project delivery within the Program.

The cornerstone of the Phase III Program governance structure is the project delivery system (PDS). It provides project managers with specific instructions as to how to deliver projects in an efficient and standardized way. Complementing the PDS are many documents and tools associated with specific program management functions (including project controls, risk management, change management, quality management, and value management).

The PM/CM Team developed the governance process to support the Program, which included the following:

- Confirming the project delivery life cycle for design-bid-build projects;
- Defining the approval stage gate points within the project delivery life cycle;
- Defining stages of a project when technical review meetings are required;
- Developing a set of procedures that define how a project is executed, managed, monitored, and approved throughout its life cycle; and
- Documenting the criteria by which a project within the program will be assessed for either approval to proceed to the next Stage Gate or denied advancement until necessary remedial actions are completed.

4.3 Overview of Project Delivery System (PDS)

The PDS establishes a standardized project delivery framework and defines the overall project lifecycle and the discrete project management activities for all projects within the Program. It provides Project Managers a roadmap with step-by-step instructions on how to deliver projects from cradle to grave. Furthermore, it provides a standardized decision-making process for project delivery that:

- Defines a set of criteria to base decisions against;
- Forces deliberate reviews of projects at critical points in delivery; and
- Documents the decisions and commitment to move the project forward.

The objective of the PDS is to drive consistency, efficiency and quality in the delivery of projects from planning and predesign through design, construction, commissioning and closeout. Project governance is achieved through prescribed approval stage gates as well as defined technical review stages.

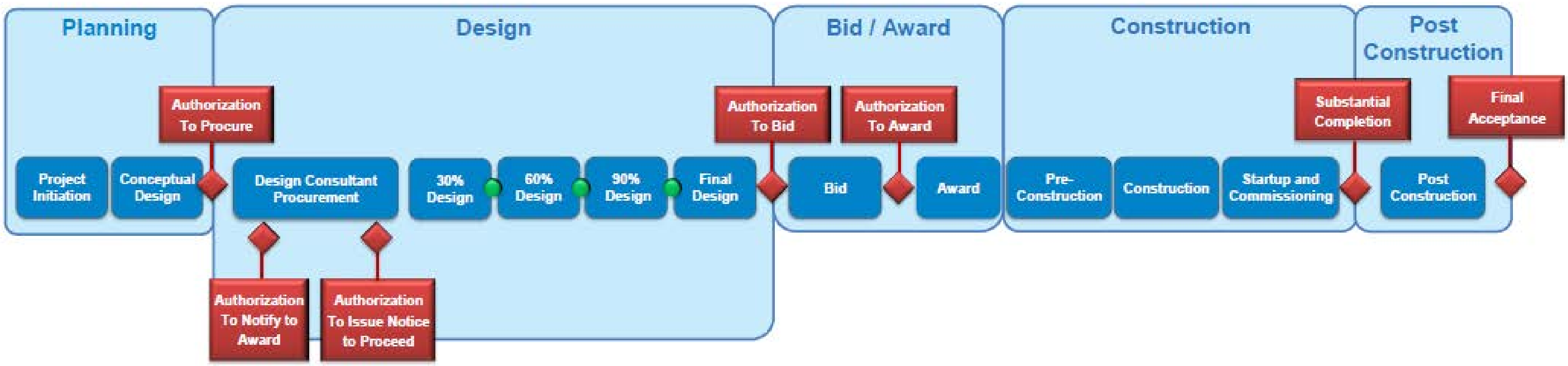
The PM/CM Team developed the governance process to support the Program, which included:

- Confirming the project delivery life cycle for design-bid-build projects;
- Defining the approval stage gate points within the project delivery life cycle;
- Defining stages of a project when technical review meetings are required; and
- Developing a set of procedures that define how a project is executed, managed, monitored, and approved throughout its cycle.

4.4 Project Delivery Life Cycle Overview

The PDS outlined herein was developed in close coordination with the work breakdown structure (WBS) and schedule templates developed for the Program as part of the project controls activities documented in the Program Management Plan (see Figure 4-1). The statement of work for each design package shall be developed to match the defined PDS and WBS.

Figure 4-1 Phase III CSO Program Project Delivery System



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The PDS is currently structured for projects using a design-bid-build (DBB) delivery method. If other delivery methods are employed for the Program, the PDS will be adapted for the selected method(s) and this plan will be updated accordingly. There are three main components to the PDS: the delivery life cycle, stage gates, and design technical reviews. These PDS components are described below. The statement of work, which is developed by the DC, and project execution plan (PXP) are based upon the structure developed in the PDS framework. The PDS is posted on the SharePoint with interactive links containing input, output, templates, and responsibility assignment matrix (or responsible, accountable, consulted, and informed (RACI)).

4.4.1 Delivery Life Cycle

The delivery life cycle divides the project into distinct phases and stages. Each phase and stage has a defined start and end point, a specific purpose and defined deliverables. The delivery life cycle for the Design-Bid-Build (DBB) delivery model is shown in Figure 4-1. This life cycle consists of five (5) phases (planning, design, bid/award, construction, and post-construction), thirteen (13) stages, and seven (7) stage gates. Each stage is further defined into a set of specific activities.

4.4.2 Stage Gates

Stage gates are mandatory decision points with defined criteria. The stage gate review process is designed to reflect the overall requirements of the PDS, as well as Program requirements. The benefit of the stage gate review is that it provides structured decision points and standardizes and formalizes how decisions are made to allow projects to advance to subsequent stages. There are seven stage gates included in the DBB PDS, as indicated in Table 4-1.

Appendix C contains the Stage Gate Criteria and Inputs, which shows the detailed requirements for each stage gate. It includes the purpose, key evaluation criteria that the project must meet, and all deliverables that must be complete prior to the stage gate. It outlines the information the project manager, with support from the project team, is responsible for presenting to the stage gate review panel (e.g., schedule and budget updates, cash flow, scope changes, risks). The Criteria and Inputs documents the evaluation criteria for each stage gate. The criteria vary depending on the preceding stage, the purpose of the stage gate, and unique characteristics of the project.

The PDS contains the detailed project deliverables requirements for each of the stage gates. The project team may suggest deviations from the required document set prior to the stage gate review.

The cost and complexity of a project identified during project initiation will determine the nature of the stage gate review. Projects with a high cost and/or complexity will be required to prepare a slide presentation in addition to providing the base stage gate requirements.

Table 4-1 Stage Gates in the Design-Bid-Build Project Delivery System

Stage Gates	Purpose
#1 Authorization to Procure	To verify 1) adequate due diligence and compliance with all conceptual requirements and 2) readiness to procure a design consultant.
#2 Authorization to Notify to Award	To verify 1) the preferred Design Consultant is the appropriate firm to complete the design of the project.
#3 Authorization to Issue Notice to Proceed	To verify 1) the amendment to the PM/CM contract is authorized / executed, and 2) the PM/CM can issue the NTP to the Design Consultant
#4 Authorization to Bid	To verify 1) detailed design documents are appropriately complete and have been adequately reviewed, 2) project risks are properly addressed, and 3) readiness to procure a construction contractor.
#5 Authorization to Award	To verify the integrity of the procurement process and confirm final, contracted project construction cost.
#6 Substantial Completion	To verify 1) construction and associated permits/environmental compliance activities have been completed and 2) contract terms have all been satisfied. To confirm 1) the asset performs as designed, and 2) the work has been completed per the specifications. To initiate warranty period.
#7 Final Acceptance	To verify 1) punch list items have been satisfactorily completed and 2) authorization for lien releases by subcontractors and suppliers; and 3) regulatory compliance closeout documents are drafted and submitted to NBC. To initiate program-level closeout process.

4.4.3 Design Technical Reviews

Formal technical reviews occur at the completion of 30, 60 and 90 percent complete design. The purpose of each design technical review is to verify the following:

1. Design meets the requirements specified in the applicable design guide and design contract and
2. Design submittals accurately represent the desired level of design. Furthermore, design technical reviews allow the Program's project manager to confirm that activities are complete, and outputs are in accordance with Program requirements.

Design Technical Review Checklists, which describe the inputs (supporting documents) required to support the 30, 60 and 90 percent technical reviews, are included in Appendix D. These checklists have been revised in April 2020 to incorporate a section documenting acceptance of the design deliverable and authorizing advancement of the project to the next stage of design.

4.4.4 Stage Gates and Technical Reviews

Stage gates and technical reviews are vital parts of the PDS. These reviews occur throughout the project delivery life cycle, as previously illustrated in Figure 4-1. The review process is designed to reflect the overall requirements of the PDS as well as the Program's review/decision-making processes.

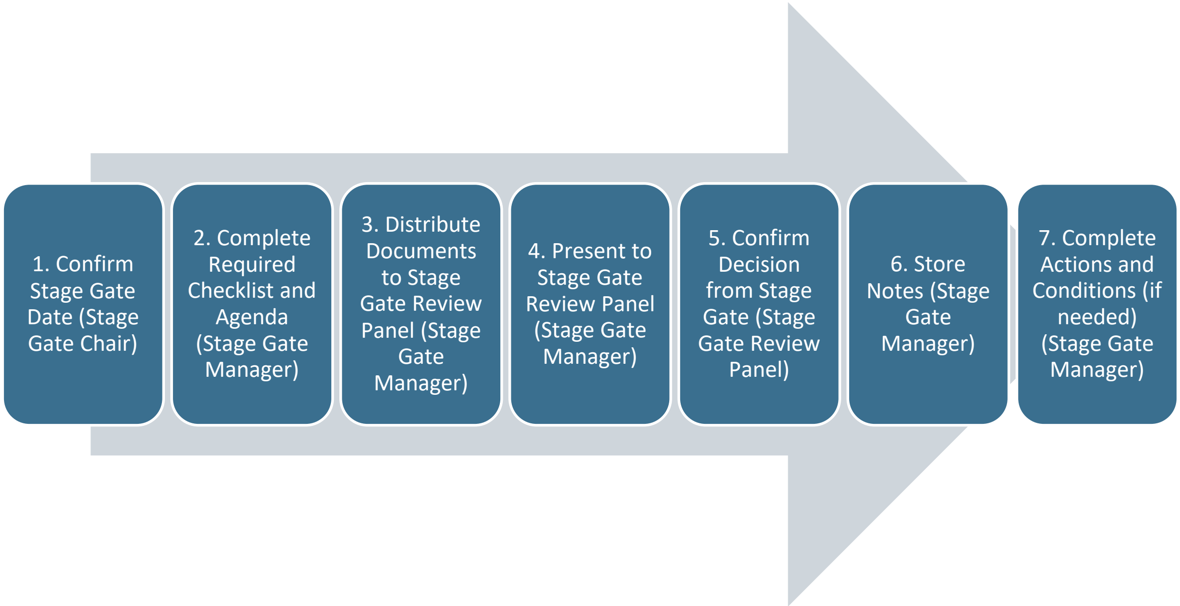
Stage gates mainly occur at the end of each phase or decision points at major project milestones to confirm that the proposed project scope, schedule, and budget continue to be in alignment with the project's predetermined objectives and approved baselines. The Program Manager, or his designee, will serve as Stage Gate Chair while the project manager assigned from the PM/CM Team will be the Stage Gate Manager.

Compliance with the overall governance structure (including policies, procedures, and business processes) will also be verified at each stage gate. Intermediate technical reviews occur between the stage gates to verify the design, supporting plans, and documentation meet the requirements specified in the applicable design guide, design contract, and the Stage Gate Criteria and Inputs.

4.5 Stage Gate Process

As part of the normal course of project progression, the project manager will be responsible for preparing presentations and required documents in a timely manner to facilitate a successful stage gate review. There are generally seven steps that, when completed sequentially, will facilitate a successful stage gate review (see Figure 4-2).

Figure 4-2 Stage Gate Review Process



1. **Confirm stage gate date:** The Stage Gate Chair will confirm the stage gate date with the State Gate Manager and Stage Gate Review Panel approximately ten business days before the review takes place.
2. **Complete required checklist and agenda**: The Stage Gate Manager will meet with select members of the project team and the Stage Gate Chair at least ten business days before a stage gate review to finalize the agenda and required deliverables and collect other pertinent information. The purpose of this activity is to provide quality and consistency of information contained in stage gate presentations and deliverables.
3. **Distribute documents to stage gate review panel:** The Stage Gate Manager will distribute the stage gate agenda and supporting documentation to the Stage Gate Review Panel at least three business days ahead of the meeting.
4. **Present to stage gate review panel:** The Stage Gate Manager and any appropriate project team representatives will present the information to the Stage Gate Review Panel using the checklist and/or presentation. The purpose of this meeting is to present the key aspects of the project, its future direction, project technical risks and opportunities, and a proposed recommendation for approval. The Stage Gate Review Panel reviews the status of the project and identifies conditions, if applicable, for proceeding with the next phase of work.
5. **Decision by the stage gate review panel:** The Stage Gate Review Panel decision (approve, approve conditionally, or decline with conditions) will be documented and recorded by the Stage Gate Manager.
6. **Store notes:** After the stage gate review, the Stage Gate Manager will publish meeting minutes for presentations and record any conditions for approval. The Stage Gate Manager will make requested edits to the presentation or checklist and post a final version to the SharePoint Site.
7. **Complete actions and conditions (if needed)**: The Stage Gate Manager will complete action items and/or meet any conditions recorded during the stage gate review before finalizing the stage gate documents.

4.6 Stage Gate Review Roles and Responsibilities

Table 4-2 shows each member of the Stage Gate Review Panel and the stage gates they attend.

Table 4-2 Stage Gate Review Panel Members and Participation

Stage Gate Review Panel Members	Stage Gate Participation*
NBC Staff	Attends all stage gates and to be staffed commensurate with the decision point defined by the stage gate criteria and inputs. It is anticipated that the NBC will determine the required attendees from their organization for each stage gate, but at a minimum will include NBC Engineering staff engaged in the Program.
Program Manager (Stage Gate Chair)	Attend all stage gates - stage gate review panels will not be convened without the Chair in attendance unless otherwise arranged in advance. Provides an opinion on the project progressing.
Planning and Design Manager	Attends all stage gates during planning, design, and bidding phases; provides an opinion of the project progressing.
Construction Manager	Attends all stage gates during bidding and construction phases; provides an opinion of the project progressing.
Program Technical Leader/Chief Engineer	Attends all stage gates; provides an opinion of the project progressing.
Project Manager (Stage Gate Manager)	Schedules and facilitates all stage gate meetings.
Deputy Program Manager	Attends all stage gates but is not a voting member. Facilitates stage gate review in absence of Program Manager.

Note * If a stage gate review panel member is not available for the stage gate, written comments, including recommendation for stage gate approval, should be provided to the Program Manager prior to meeting.

Each panel member is responsible for examining the project under consideration and providing feedback regarding whether the project should proceed to the next stage.

Additional attendees may participate to provide technical input during the meeting as well as status updates on specific technical activities. These additional attendees are not considered stage gate review panel members and do not vote. The attendees at the stage gate reviews may include technical leads, subject matter experts, and other stage gate support staff as needed.

4.7 Stage Gate Review Format

The stage gate review will follow an agenda to be developed by the Stage Gate Manager and the project team. Templates for agendas, and presentations when required, for each stage gate reside on SharePoint in the PDS Document Library under the PDS Site.

The typical format for the meeting is as follows:

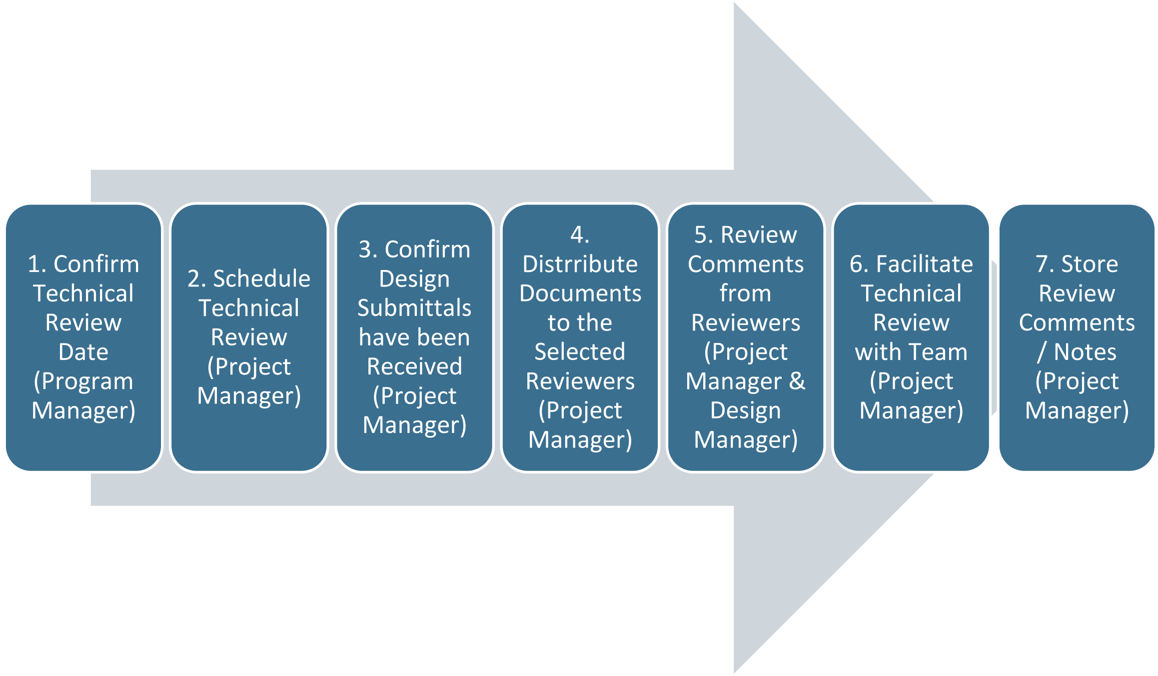
- Stage Gate Manager presents key project information, including evidence to support evaluation criteria, and proposes a recommended approach for future delivery activities. The Program Manager, in consultation with the Stage Gate Manager, will determine whether a project warrants a slide presentation for stage gate reviews
- Stage Gate Manager and other technical resources (where applicable) answer questions from the Stage Gate Review Panel
- Stage Gate Review Panel categorizes concerns or issues based on stage gate decision criteria; Stage Gate Manager documents issues raised during the stage gate review and records them as either:
    - *Conditions* – issues that the project team needs to address within a specified period for the stage gate to be formally passed; these conditions cannot involve a material change to need, scope, schedule, or cost
    - *Action Items* – issues that the Stage Gate Review Panel asks the project team to address going forward, which may or may not involve a date for completion; unlike conditions, formally passing the stage gate is not made conditional on the project team completing action items
- Chair reviews the action items and conditions before soliciting opinions from each Stage Gate Review Panel member on whether the project should receive stage gate approval; the options open to the Stage Gate Review Panel are as follows:
    - *Approve*: allow a project to process to the next stage
    - *Approve with Conditions:* allow a project to proceed to the next stage if certain conditions are met
    - *Decline with Conditions:* the project does not meet the required decision criteria and must repeat all or part of the current stage gate; alternatively, the project may be put on hold or cancelled
- Chair summarizes the findings of the Stage Gate Review Panel into a final recommendation, including any conditions with a timeline for resolution; the final decision on whether the project has passed the stage gate will be determined by the Chair.

The Stage Gate Manager will formally record the decision of the Stage Gate Review Panel in the checklist along with any actions or conditions. If the project is approved with conditions, the Stage Gate Manager is responsible for notifying the Stage Gate Review Panel of actions taken to resolve the conditions. If conditions are not met within the required timeframe, the Stage Gate Manager will advise the Stage Gate Review Panel of the causal circumstances and the project will be deemed not to have met the stage gate criteria and could be put on hold, at the discretion of the Chair.

4.8 Technical Review Process

Design technical reviews occur during the Design phase to confirm quality of the design solution. These technical reviews allow the Project Manager and project delivery teams to confirm that activities are complete, and outputs are in accordance with Program requirements. The reviews are technical approval points that are used to update NBC staff on key interim design and construction products (see Figure 4-3).

Figure 4-3 Technical Review Process



1. **Confirm technical review date**: The Program Manager will confirm the technical review meeting date with the Project Manager.
2. **Schedule technical review**: The Project Manager schedules the technical review and specifies the applicable reviewers, respective areas of review, hours budgeted, and review dates. The Project Manager notifies required participants of the upcoming technical review approximately one month prior to the review and provides reminders sent at two weeks and one week prior to the review.
3. **Confirm design submittals have been received**: The Project Manager confirms design submittals have been received and validates the documents are generally complete.
4. **Distribute documents to the selected reviewers**: The Project Manager forwards a SharePoint link to the applicable documents to the technical review participants, and comments are received through SharePoint within the specified review period (typically ten business days).

5. **Review comments from reviewers**: The Project Manager reviews and accepts, declines, or appropriately modifies comments. The Project Manager also engages with the Design Manager to validate review comments prior to submitting them to the DC to further address.
6. **Facilitate technical review with design consultant**: The DC reviews the consolidated comments. The Project Manager distributes the agenda and associated materials for the technical review meeting at least two days before the technical review meeting. At the technical review meeting, technical reviewers discuss their comments with the Project Manager, Design Manager and Design Consultant.
7. **Store notes**: After the technical review meeting, the Project Manager will publish meeting minutes for presentations and record any conditions for approval and action items.

4.9 Technical Review Roles and Responsibilities

The role of the Technical Review Committee is to test the validity of the project's design and proposed management of risk and offer design advice and/or alternative solutions. Alternative solutions may be identified by the Project Manager during the preceding stage activities and accepted by the Technical Review Committee during technical reviews.

The Technical Review Committee includes NBC Engineering staff as well as three decision-making individuals from the PM/CM Team: Program Manager, Program Technical Leader/Chief Engineer, and Design Manager. The purpose of the Committee is to approve the project to move forward through the design stages.

Table 4-3 Technical Review Participants

Required Participants	Optional Participants
• Program Manager • Program Technical Leader/Chief Engineer • Design Manager • Project Manager • DC Project Manager • NBC Engineering Staff	• NBC Executives • Deputy Program Manager • Construction Manager • Subject Matter Experts

4.10 Consent Agreement Design Submissions

Design deliverables will be submitted to the RIDEM Office of Water Resources at preliminary design (i.e., 30%) and 90% levels of design development, in accordance with the Consent Agreement between NBC and RIDEM.

The 30% design submission shall include the following:

- A Cover Letter, prepared on NBC standard letterhead and signed by the NBC Program Manager or designee;
- Project Summary Form, using the template provided in Appendix D;
- 30% Design Drawings; and

- Index of Specifications.

The 90% design submission shall include the following:

- A Cover Letter, prepared on NBC standard letterhead and signed by the NBC Program Manager or designee;
- Project Summary Form, using the template provided in Appendix D;
- 90% Design Drawings; and
- 90% Design Technical Specifications.

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Section 5.0

Standard Program Details

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5.0 Standard Program Details

5.1 Introduction

Standard program details shall be utilized by DCs and incorporated into design drawings, as applicable (see Appendix E). Standard details from State and local agencies shall also be utilized as part of the standard program details. The purpose of standard details is ~~facilities~~ to facilitate efficient construction, material procurement, and bidding. It also promotes consistency in design deliverables, which promotes efficient review. Standard details will be made available on the SharePoint portal for reference in PDF for planning. Standard details will also be incorporated into standard CAD templates (see Appendix A). It is acknowledged that standard program details are not applicable for all design projects.

The DC will be responsible for carefully reviewing standard details and verifying their applicability on their design project. The DC takes responsibility for using the standard details. Edits or revisions proposed by the DC shall be brought to the attention of the Program Manager/Construction Manager (PM/CM) for review.

Standard details from Rhode Island Department of Transportation (RIDOT), Pawtucket Water Supply Board (PWSB), and National Grid encroachment standards are incorporated by reference. The details have been organized on the SharePoint portal, which will be made available to all DCs. It is noted that standard details from these agencies are current as of the date this Design Guidance Manual is published and last updated. The DC shall be responsible for confirming that standard details from other agencies are the most current prior to incorporating them into design drawings.

5.2 Program Standard Details

Provided below is a list of program details developed for the program.

1. Sanitary Sewer Details
    a. Drain/Sewer Trench
    b. Exterior Drop Manhole
    c. Gravity Sewer Service Relay 1
    d. Gravity Sewer Service Relay 2
    e. Sewer Chimney
    f. Sewer Lateral Connection
    g. Sewer Manhole Frame and Cover
    h. Shallow Sewer Manhole
    i. Gravity Sewer Manhole
    j. Minimum Restrained Pipe Lengths
    k. Trench/Box Shield
    l. Water/Sewer Crossing
    m. Supports for Utilities

2. Site Details
    a. Curb Setting Detail
    b. Bollard
    c. Hot Mix Asphalt Sidewalk
    d. Cement Concrete Sidewalk
    e. Expansion and Control Joints for Sidewalk Paving
    f. Detectable Warning Pavers
    g. Vehicular Concrete Pavement
3. Stormwater Details
    a. RIPRAP Spillway Detail
    b. RIPRAP Level Spreader
    c. Field Stone Headwall Detail
    d. Headwall Protection Rack Detail
    e. Outlet Hood Detail
    f. Area Drain Detail
    g. Drain Cleanout
4. Erosion and Sedimentation (E&S) Details
    a. Erodible Material Stockpile
    b. Compost Filter Sock Detail
    c. Tree Group Protection Detail (TGP)
    d. Temporary Inlet Protection (TIP)

Section 6.0

Standard Program Specifications

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6.0 Standard Program Specifications

6.1 Introduction

The PM/CM Team has developed standard program specifications to improve the efficiency and consistency in project delivery. The focus of the program specifications is procurement, general agreement, administrative requirements, schedule, and construction quality control. It shall be the responsibility of the DCs to develop required technical specifications to support the design of a given project. It is acknowledged that technical speculations on common elements and/or materials may be provided to DCs as the program design elements evolve.

6.2 Program Specifications Format

The standard program specification utilizes the Division 0 through 16 specification formats in accordance with Construction Specification Institute (CSI). The PM/CM may evaluate transitioning to the updated CSI format. A sample Table of Contents for a sample project follows.

Template for the standard program specifications shall be provided to each DC team at project initiation. The template provides a complete document overview of the organization and format of the specifications. It shall be the responsibility of the DCs to use the template and remain consistent with formatting requirements. The templates will also be located on the NBC collaboration portal on the documents template tab on the page. The documents template tab has been organized to facilitate easy access to specification templates.

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NARRAGANSETT BAY COMMISSION
PHASE III COMBINED SEWER OVERFLOW PROGRAM

{PROJEC TITLE}
NBC CONTRACT NO. 308.XXC

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DIVISION 1 – GENERAL REQUIREMENTS (continued…)

Section 7.0

Design Guidance Memoranda

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7.0 Design Guidance Memoranda

The PM/CM Team has developed a series of technical memoranda to advise Project Managers and DCs on technical requirements or the general processes and procedures for Phase III CSO Program design projects.

7.1 Instrumentation Guidelines

A technical memorandum entitled *Design Consultant Instrument Guidelines* was issued to DCs on May 29, 2019. A copy of this memorandum is provided as Appendix F.

The *Design Consultant Instrument Guidelines* memorandum describes and identifies the instrumentation required to implement control and monitoring at proposed gate and screen structures, the receiving shaft, and at regulator modifications where specified. The key points addressed in this memorandum include:

- Providing instrumentation where it is necessary for regulatory reporting, controlling flow, protecting equipment, and where otherwise requested by NBC;
- Providing redundancy to provide an appropriate level of reliability;
- Selecting instrumentation and identifying installation methods to support cost effective maintenance;
- Identifying preferred instruments based on input from NBC; and
- Complying with general codes and requirements as they relate to instrument selection and installation.

7.2 OPCC Guidelines

A technical memorandum entitled *Opinion of Probable Construction Costs (OPCC) Guidelines* was issued to DCs on September 24, 2019. A copy of this memorandum is provided as Appendix G. This memorandum provides revised guidelines and a template to ensure consistency on the OPCCs prepared by DCs so that the project costs for all Phase III CSO Program projects can be compared and evaluated collectively.

7.3 Gate and Screening Structure Guidelines

A technical memorandum entitled *Program Standardization – Slide Gates and Actuators* was issued to DCs on February 24, 2020. A copy of this memorandum is provided as Appendix H.

The *Program Standardization – Slide Gates and Actuators* memorandum was prepared to standardize the control gates proposed at the gate and screening structures. The memorandum addresses the following:

- Gate Type/Material;
- Gate Sizing and Design Head;
- Gate Installation;

- Actuator;
- Closure Time/Travel Speed; and
- Gate Operation and Control.

7.4 American Iron and Steel Requirements

A technical memorandum entitled *American Iron and Steel Requirements* was issued to DCs on April 14, 2020. A copy of this memorandum is provided as Appendix I. This memorandum provides guidance on the selection of products and materials that conform to domestic iron and steel requirements. It lists the products that need to comply, identifies manufacturers that produce conforming products, lists known waivers and describes the process for requesting a waiver.

Appendix A - Program CAD Standards



Phase III CSO Program

CAD Standards

Title:	CAD Standards
To:	Narragansett Bay Commission
Author(s):	Greg Frazier
Date:	March 17, 2020
Reviewed by:	Christopher Feeney, P.E. Stantec

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Revisions

Revision History

Date	Version	Description	Author(s)	Reviewer(s)	Date of Review(s)
04.30.18	0.1	1st Internal Draft	G. Frazier	C. Feeney	05.01.18
05.03.18	0.2	Draft for NBC Review	G. Frasier C. Feeney	M. Carter	05.08.18
05.20.18	1.0	Issued Final	G. Frasier C. Feeney	K. Kelly	
01.21.19	2.0	Updated Final	D. Wais	C. Feeney	01.21.19
03.17.20	3.0	Updated Final	M. Luh	C. Feeney	03.17.20

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ASME	American Society of Mechanical Engineers
CAD	Computer Aided Design
CSO	Combined Sewer Overflow
DC	Design Consultant
NBC	Narragansett Bay Commission

Section 1.0

Introduction

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1.0 Introduction and Purpose

1.1 Introduction

The Narragansett Bay Commission (NBC) embarked on a three-phase Combined Sewer Overflow (CSO) control program in 1998, aimed at lowering annual CSO volumes and reducing annual shellfish bed closures in accordance with a 1992 Consent Agreement with the Rhode Island Department of Environmental Management (RIDEM). Phases I and II of this program, which focused on the Fields Point Service Area (FPSA) in Providence, were completed in 2008 and 2015, respectively. The program to date has succeeded in lowering annual CSO volumes and reducing annual shellfish bed closures to levels that are in keeping with a 1992 Consent Agreement between NBC and the RIDEM.

Phase III of the program (Phase III CSO Program), which began in 2016, is focused primarily on the Bucklin Point Service Area (BPSA) in the communities of Pawtucket and Central Falls. The final sub-phase of the program does address the final remaining outfalls in the FPSA. Its projected completion date is 2041. The Phase III CSO Program has been subdivided into four sub-phases, as follows:

- Phase IIIA: Pawtucket Tunnel
- Phase IIIB: Upper Blackstone Valley Interceptor (BVI) Relief Structure and OF-206 Sewer Separation
- Phase IIIC: Stub Tunnel to Control OF-220
- Phase IIID: West River Interceptor and OF-035 Sewer Separation

The Stantec/Pare Team is under contract with NBC to serve in the role as the Program Manager/Construction Manager (PM/CM) for Phase III CSO Program. The program is currently in the planning phase preparing a Design Criteria Report (DCR) for Phase IIIA and IIIB Facilities and transitioning into design. The PM/CM is implementing a procurement plan for soliciting qualifications and proposals from Design Consultants (DCs). The DCs will be responsible for design of identified project packages for Phases IIIA and IIIB, under contract to Stantec. DCs shall serve in the role as Engineer of Record on a given (i.e. assigned) project. The PM/CM will provide program oversight and management of the design of individual projects.

1.2 Purpose

The CAD Standards is a referenced component of the Design Management Plan (DMP). The purpose of the CAD Standard is to develop consistency in design drawings being developed by the DCs for the design project in Phase III. The PM/CM is responsible for maintaining the CAD standards and updating them as the program evolves. Standard CAD templates have been developed, which will be provided to DCs upon project initiation. The CAD Standards have been developed to be consistent with National CAD Standards.

The CAD Standards have been organized into the following sections:

- Section 1.0 Introduction defines roles and responsibilities and general purpose of the standards.

- Section 2.0 Drawing Elements focuses on the border file of the sheet set. One border will be used by all DCs to create a uniform look for all drawings. Each subsection of the Drawing Elements section explains all aspects of the border file and for what each aspect is used.

- Section 3.0 General Drawing Conventions and Symbols explains the general drawing conventions and symbols. It is important to use these conventions to develop a uniform look for all texts, symbols, and leaders. All conventions and symbols are found in the C3D Templates and NBC_COMMON.dwg block library files supplied on ProjectWise. No changes will be made to these files to assure that all drafters are using the same Standard.

ProjectWise will be used as a central database to house the CAD Standards such as C3D Templates and NBC_Common.dwg block library files. A Project Standard folder will be found on ProjectWise that will also store custom linestyles and plotting config files. The MWH_Acad_2016i.ctb file will be used to plot all sheet sets with a consistent line weight and color. All drawing sets will be saved on ProjectWise under the corresponding discipline folder.

Section 2.0

Drawing Elements

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2.0 Drawing Elements

2.1 Blocks and Electronic Files

All general blocks, drawings and files for AutoCAD platforms presented in this guide are available on ProjectWise. DCs should not attempt to add or modify the files contained in this folder; it is replicated each evening. The files will be overwritten. DCs shall coordinate with the PM/CM to place something in this location, if needed.

2.2 Drawing Sequence

Sheets must be arranged in a logical manner. Table 2-1 presents a drawing sequence as a general guideline to DCs for sheet order. Drawings within a discipline are to start with the discipline general sheets, followed by the demolition and project specific drawings arranged in order by area (if applicable).

Table 2-1 Drawing Sequence

Discipline	Discipline Designator
General	G
Survey and Mapping (as applicable)	V
Geotechnical	B
Civil	C
Instrumentation and Control	I
Landscape	L
Architectural	A
Structural	S
Process Mechanical	M
HVAC	H
Plumbing	P
Fire Protection	FP
Electrical	E

General discipline sheets are to have G +Discipline Designator and then proceed with their corresponding discipline – here are some examples and their proper Discipline Titles:* ***GC* *– General Civil,* ***GV*** *– General Survey,* ***GL*** *– General Landscaping, etc.*

** Demolition discipline sheets are to have D +Discipline Designator and then proceed with their corresponding discipline – here are some examples and their proper Discipline Titles:* ***DC*** *– Demolition Civil,* ***DV*** *– Demolition Survey,* ***DL*** *– Demolition Landscaping, etc.*

2.3 Area Designations (For WWTF Improvements Only)

Area Designations for the treatment plant will be provided to the DC based on the recent Bucklin Point WWTF upgrades.

2.4 Standard Drawing Sizes

Drawing sheet size is to be in accordance with ASME Standard Y14.1-2002 as shown below. The Imperial Unit standard 'full size' construction drawing is a 'D' size sheet, with dimensions as shown in Table 2-2. 'Half size' prints are to be printed at 50% scale. **The size of sheets for construction drawings is to be consistent throughout the drawing set.**

Table 2-2 Drawing Sheet Size

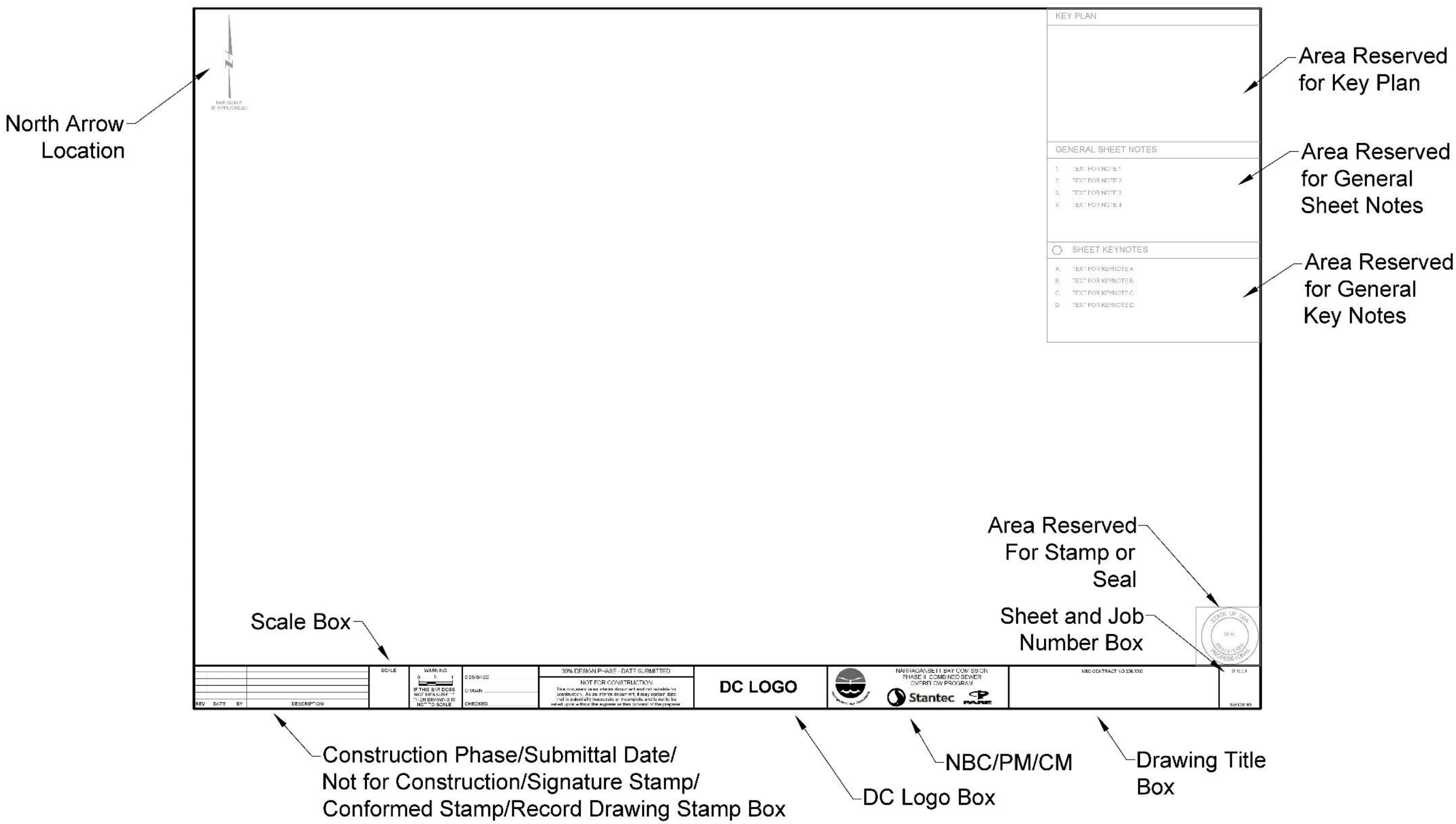
ASME Designation	Height (inches)	Length (inches)
D	22.0	34.0

2.5 Border and Title Blocks

2.5.1 'D' Size Border and Title Block

The 'D' size border and title block is to be used for construction drawings. This border and title block can also be used for change orders and requests for information. The contents of this title block may change due to NBC's request or by the State of Rhode Island's registration and licensing requirements. Figure 2-1 depicts the 'D' size border and title block to be used for construction drawings. A standard cover sheet will be provided by the PM/CM for use on all design packages. The cover page will be formatted consistent with Program guidelines and requirements to be eligible for funding of the RI Infrastructure Bank. The standard cover page includes appropriate names and logos for the RI Infrastructure Bank.

Figure 2-1 D Size Border and Title Block



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2.6 Description of Title Block Contents

BORDER-ANSI-D-TAGS

The title block has an attribute/tag that is inserted into the project border and into a project template. This is then populated with the project specific information in the border and when a project template or seed file is created; the sheet specific information will be added as sheets are created. Borders can be found under the project standards folder for each project. C3D templates have border files referenced in them.

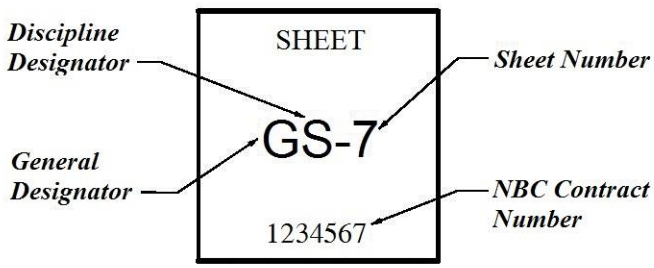
2.6.1 Sheet and Contract Number Box

2.6.1.1 Sheet Number

Drawings should be numbered to identify the discipline involved and the sheet number. Area numbers are to be used for WWTF only or as set by the Program Team's Project Manager and the DCs' Project Manager at the beginning of the project. Area numbers may be used to designate different sites instead of different areas within one site.

Please note: In order to not overcrowd the Sheet Number Box, do not use leading zeros in the Sheet Number. For file naming, this is desired to allow sorting, but not desired here due to space limitations within the box.

Figure 2-2 Sheet and Contract Number Box



2.6.1.2 Discipline designators

Standard discipline designators are shown on the first page of this chapter.

2.6.1.3 Contract Number

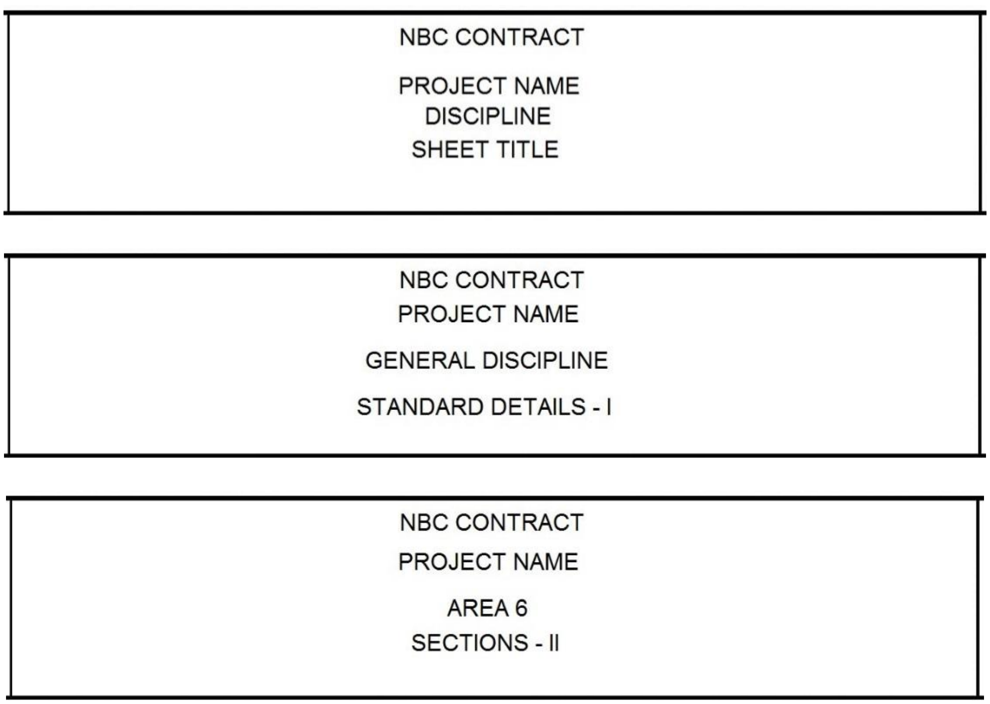
The contract number should be the overall NBC project contract number, i.e. 308.03C.

2.6.2 Drawing Title Box

Figure 2-3 depicts examples of the Drawing Title Box. The first line of this box is for the NBC's contract number i.e.308.xxc. This will be filled in on the border so it is not necessary to add for each sheet.

<u>The second line</u> is for the project name. For General Discipline sheets the discipline is GENERAL CIVIL, GENERAL INSTRUMENTATION AND CONTROL, GENERAL ARCHITECTURAL, etc. **<u>The third line</u>** is for the Building or Area name. General, General Discipline and most Civil sheets would leave this blank. **<u>The fourth line</u>** is for the Sheet Title. **Do not repeat the discipline in the Sheet Title**. The attribute/tag includes an extra line in the event the Sheet Title needs two lines. Sheets in sequence should utilize Roman Numerals – this prevents confusion with the Sheet Number or Area Number. Some examples of this are STANDARD DETAILS – I, STANDARD DETAILS - II, etc.

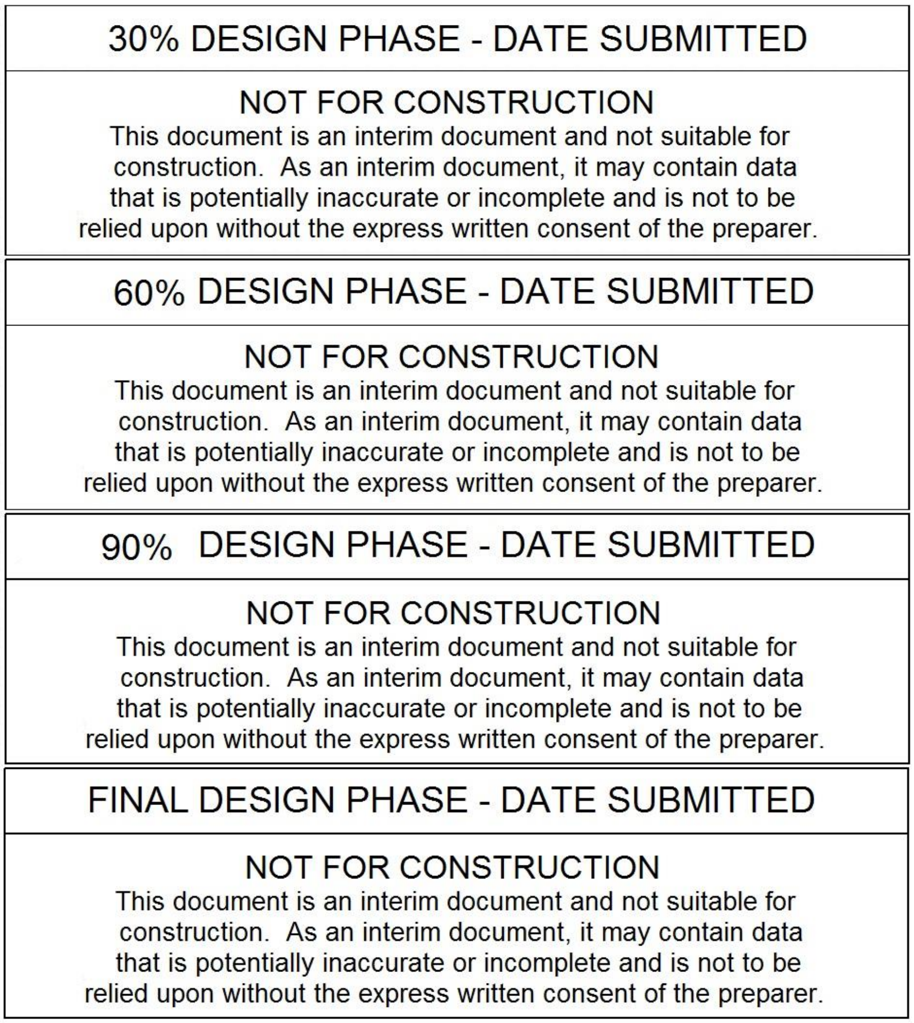
Figure 2-3 Drawing Title Box



2.6.3 Design Phase/Submittal Date/Not for Construction/Issued for Bid Stamp/Conformed Stamp/Record Drawing Stamp Box

At each phase of the project, insert the appropriate Design Phase/Submittal Date/Not for Construction Stamp on the border in this designated area. The stamps can be found in the **NBC_Common.dwg** block library. Figure 2-4 provides examples.

Figure 2-4 Design Phase/Submittal Date/Note for Construction Stamp



When the drawings are being issued for bid, the following stamp is to be inserted on the border. The stamp can be found in the **NBC_Common.dwg** block library. There is a a STAMP-IFB also that is to be used where submittals are Issued for Construction.

Figure 2-5 Stamp – Issued for Bid

ISSUED FOR BID - DATE SUBMITTED
ANY PRINTS NOT BEARING THIS STAMP MAY HAVE BEEN PRINTED PRIOR TO ADVERTISING AND CANNOT BE CONSIDERED AS BID DOCUMENTS

2.6.4 Designed/Drawn/Checked Box

The names to be entered in the **DESIGNED** or **DRAWN** space should be done **upon initiation of work** so that any questions regarding drawing content can be directed to the appropriate DC lead person(s). This includes general drawings as well as discipline specific drawings. The name to be entered in the **CHECKED** space **should not be entered until after the final discipline checking by the DC is accomplished and comments of the checker have been incorporated and back-checked.**

The DC reviewer name(s) are to be entered as first initial and full last name in upper case letters. An example is J DOE. **(Note: Periods after the initial are not used for consistency and to conserve space).**

DESIGNED

The person(s) responsible for the technical content of the drawings and associated specifications, and who prepared the supporting engineering calculations are entered in this space – typically the DCs' Engineer/Architect of Record. This space is filled in when the sheet is created – typically by the individual who is named in the **DRAWN** space. The **DESIGNED** and the **DRAWN** names could be the same if the Engineer/Architect created the sheet.

DRAWN

The person(s) responsible for the graphic presentation of the drawings is(are) entered in this space. The person(s) who is(are) entered in this space may be the same as entered in the **DESIGNED** space. This space is filled in when the sheet is created. If another individual works on or continues the work on the graphic presentation, their first initial and last name should be added to this space after the previous name. For example, **J DOE/J SMITH** – no more than two names should be listed. If another individual continues the work on the graphic presentation, and there are already two names indicated, the first name should be removed and the last name should go in the first slot. For example, **J DOE/J SMITH** becomes **J SMITH/J HOBBS**.

CHECKED

The DCs' person(s) responsible for the final discipline check of the drawings is entered in this space. Detailed checking consists of a "red line/yellow line" review procedure that is primarily focused on the identification of potential errors and omissions. The detailed check is internal within each design discipline. Refer to the Phase III Program Quality Management Plan for more information on checking procedures and requirements.

The person who is named in the checked space should not be the same person entered in the **DRAWN** or **DESIGNED** spaces. This individual should be a qualified independent alternate reviewer.

2.6.5 Scale Box

This block is for scale information that applies to the entire sheet. Recommended scales are shown in the drawing layout section of this chapter. Follow the guidelines below to show the scale on a drawing:

- The general rule regarding scale selection is to use the smallest possible scale to show the view without obscuring vital detail.
- Clarity must be maintained when notes and dimensions are added.
- Drawing must be legible when reduced to half size.
- When multiple views on a drawing are not to the same scale, show the appropriate scale below the title of each view, and enter **"AS SHOWN"** in the title block scale box.
- When the entire drawing is to the same scale, place the scale in the title block.
- When an entire drawing (e.g., a diagram, a schematic, an isometric, or standard detail sheets) is unscaled, enter the words, "NO SCALE" in the title block scale box. If only one view on the drawing is not to scale, place the words **"NO SCALE"** below the view in question. **Do not use NONE or NTS in the Scale box.**
- The notation "NTS" (not to scale) should only be used for specific dimensions within the drawing that are not to scale.

2.6.6 Revisions Box

Revisions that occur prior to bid or Issued for Construction Document:

Design submittals will typically progress through four stage gates for the Phase III Program – 30% Design, 60% Design, 90% Design, and Final Design (i.e. 100%). These submittals are documented in the Revisions Box to allow the Project Manager/Design Manager to monitor the production document. The Revisions Box is populated with letters A, B, C, for the submittal dates. All projects are required to indicate this to better document revision control. In the case that a major change has occurred in between the major submittals, a number is to be added to the current submittal package revision letter. For example, if the site layout is drastically changed after the 60% Design phase submittal, B1 would be used to denote the change when distributed out to staff and/or the client. These revisions do not get clouded nor does a revision triangle get placed on the sheet. The tracking of the document is handled only in the Revisions Box.

Issued for Bid:
When the project drawings are submitted for bidding, the Revisions Box is to be cleared of all information from interim submittals. Prior to printing the submittal, a “0” (zero) is to be placed in the revision number area, the initials of the person submitting the drawing and the date of the submittal; “Issued for Bid” or “Issued for Construction” is to be put in the description area.

Refer to **Figure 2-5** of this guide for the Issued for Bid Stamp. If needing to mark a drawing set as Issued for Construction, insert the stamp STAMP-IFB from the **NBC_Common.dwg** block library.

Revisions that occur after Bid or Issued for Construction Document:
Revisions to the drawings between the date the project is advertised for bids and the date the work is accepted as complete by the owner are documented in the Revisions Box also. Since 0 (zero) is used for the Issued for Construction submittal, consecutive numbers represent the changes that happen after that submittal beginning with 1, 2, 3, etc.

Revisions are listed in the title block of the drawing and show the following:

- Consecutively number the revisions on each drawing beginning with the number 1. **Note: A particular set of revisions, which may affect several drawings, will not necessarily be identified with the same revision number, depending on the number of prior revisions made to each particular drawing**.
- The date the revision was made on the drawings. **Note: A particular set of revisions which may affect several drawings should all be assigned the SAME DATE even though the actual work involved may take several days to complete.**
- The initials of the person making the revision.
- A brief description of the revision, including addendum number, change order number, etc.

Cloud the particular area of the drawing where the revision has been made and add the appropriate revision number in a revision triangle in that location. Place the revision triangle and clouds in accordance with the standard drawing conventions presented in **Section 3** of this guide.

If the revision is issued **prior** to bid opening, it must be transmitted, in the form of an **addendum**, to all parties who have taken out plans and specifications. If the revision is issued **after** bid opening, it must be transmitted, in the form of a **change directive** to the successful bidder and to other appropriate parties.

2.6.7 Conformed Drawings

After bidding, a set of conformed drawings that incorporate any addenda may be required. Conformed Drawings are not considered contract documents. Figure 2-6 depicts the Conformed Drawing stamp.

NBC preference is the following: **Retain Issued for Bid Rev 0 stay in the Rev Block along with the addendums to the sheet. All revisions shall be retained on the drawings.**

Conformed drawings should include the following:

- A **CF** in the revision number area **(please note this has changed from “C” in the previous standards documentation)**

  Note: Retain previous changes to the drawings by addenda using the revision box.

- The date the conformed drawings are being issued.

  Note: Assign the SAME DATE to all drawings even though the revisions may take several days to complete.

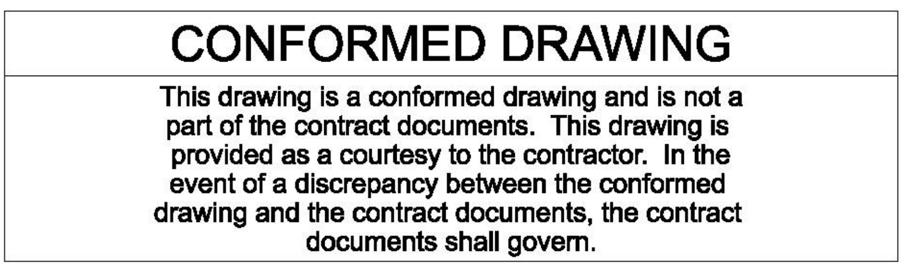
- The word “Conformed” in the description box

  Note: Every drawing in the set should show “Conformed” even though in some cases there may have been no revisions.

Please note – Rrevisions are to be left on the drawings as determined by NBC. The revision clouds and the Rev triangles will be left in their current locations. The Rev Block would have the previous revisions listed (including Issued for Bid Rev 0) and have CF added after the last listed.

Insert the Conformed stamp in the Design Phase / Submittal Date / Not For Construction / Issued for Bid Stamp / Conformed Stamp / Record Drawing Stamp Box. (See example below). The stamp STAMP-CONDWG can be found in the **NBC_Common.dwg** block library.

Figure 2-6 Stamp – Conformed Drawing



2.6.8 Record Drawing Revisions

If required by the contract, a record drawing set is to be produced. Record drawings are usually started after construction has been completed and the contractor has submitted to the Engineer a set of prints with markups showing the additions, deletions, and changes reflecting the constructed project. Such markups should be incorporated on the contract drawings. Record Drawings are a clean set of drawings without clouds to represent what was built, not what was changed. **<u>Never use the words “As-Built” on the drawings.</u>**

List record drawing revisions in the title block of the drawing and show:

- An “R” in the revision number area.

  Note: Remove notations from the revision box for previous changes to the drawings by addenda, change orders, conformed sets, etc.

- The date the record drawings will be issued.

  Note: Assign the SAME DATE to all record drawings even though the revisions may take several days to complete.

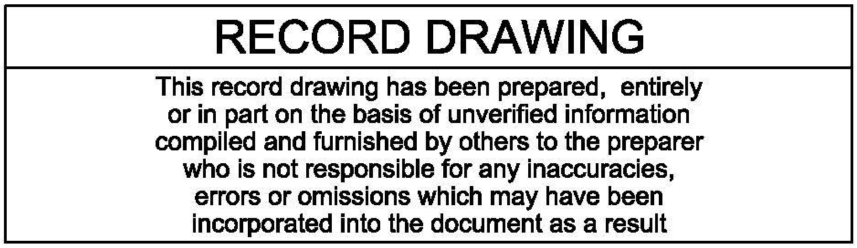
- The initials of the person making the revision.
- A brief description of the revision.

  Note: Every drawing in the set should show “Record Drawing” entry in the Revision Box, even though in some cases there may have been no revisions.

Remove any clouds, signatures, and stamps from the drawings, and place a Record Drawing Note in the submitted by box.

Figure 2-7 depicts the Record Drawing stamp.

Figure 2-7 Stamp – Record Drawing



The stamp STAMP-RECDWG can be found in the **NBC_Common.dwg** block library.

2.6.9 Stamps/Seals

When drawings are required to be sealed, see the state registration laws from which the seal is issued for information on electronic seals, signing, dating, location, etc. The preferred location of the seal is in the right lower corner, above the Sheet Number Box.

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Section 3.0

General Drawing Conventions and Symbols

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3.0 General Drawing Conventions and Symbols

3.1 General

This chapter covers the standard conventions and symbols used for the Phase III CSO Program. These conventions and symbols are to be used on all drawings. The use of standard symbols will reduce drawing time, clarify the drawings, and increase consistency. The sizes referred to in this chapter are the size of the symbols and text when **printed** at full size. **Drawings produced by DCs should comply with the designated project standards including all drawing conventions and symbols.**

3.2 Block and Electronic Files

All general drawings and files presented in this guide are available on ProjectWise. The symbol/file names for general symbols and drawings are presented in this guide in the following type style:

EXAMPLE. NBC AutoCAD equivalent blocks are in the **NBC_Common.dwg** block library.

3.3 Linework

The goal is to keep the presentation of design deliverables consistent and compliant to the documented project CAD Standards. Levels/layers define the line weight and line type for each element drawn. All linework must be clear, sharp, and uniform.

Symbology is required to be by level/by layer. This means that there are distinct levels/layers for each unique symbology. For example, a line that is weight 1, NBC-2 line type will be on a different level/layer than a line that is weight 0, NBC-1 line type.

Refer to the chart presented as Figure 3-1 for comparisons between Line Weights and AutoCAD Thicknesses.

Figure 3-1 Line Thicknesses

Appearance	*Thickness (inches) Full Size Plot*
	0.005
	0.010
	0.014
	0.020
	0.024
	0.028
	0.031
	0.039
	0.047
	0.055
	0.060
	0.065
	0.070
	0.075
	0.080
	0.085
	0.090
	0.095
	0.100
	0.110
	0.120
	0.130
	0.140
	0.150
	0.160
	0.170
	0.180
	0.190
	0.200
	0.300
	0.400
	0.500

3.4 Text

Text in CAD files should be placed using NBC Standard text styles created using True Type Arial font, as shown in Table 3-1. The primary reasons for using a TrueType font such as Arial are that it is virtually guaranteed to exist on all Windows software programs, and it is a single font resource that is supported by AutoCAD platforms.

All lettering should be upper case except unit designators (e.g., mm, pH). Line spacing for text should be one-half the text size. Text should have equal height and width. Text (except for titles and sub-titles) should be left justified. Text within bubbles should be center justified.

Table 3-1 NBC Standard Text Styles

Text Style	Height (Inches)	Justification	Font	Application
NBC10pt	3/32" (0.10)	Top Left	TT Arial	Standard Details, Abbreviation Sheet, Pipe Schedules Discipline General Sheets, Project Specific Standard Details
NBC10pt-CenterCenter	3/32" (0.10)	Center Center	TT Arial	
NBC10pt-CenterCenterUnderlined	3/32" (0.10)	Top Right	TT Arial	
NBC12pt	1/8" (0.12)	Top Left	TT Arial	Notes, Dimensions, General Text, Room Names, Sheet Names, Matchline Text
NBC12pt-CenterCenter	1/8" (0.12)	Center Center	TT Arial	
NBC12pt-CenterCenterUnderlined	1/8" (0.12)	Top Right	TT Arial	
NBC18pt	3/16" (0.18)	Top Left	TT Arial	Section and Detail Titles
NBC18pt-CenterCenter	3/16" (0.18)	Center Center	TT Arial	
NBC18pt-CenterCenterUnderlined	3/16" (0.18)	Top Right	TT Arial	
NBC24pt	1/4" (0.24)	Top Left	TT Arial	Main Sheet Titles
NBC24pt-CenterCenter	1/4" (0.24)	Center Center	TT Arial	
NBC24pt-CenterCenterUnderlined	1/4" (0.24)	Top Right	TT Arial	

Example of Size and Font

EXAMPLE OF MAIN TITLES

EXAMPLE OF SUB-TITLES

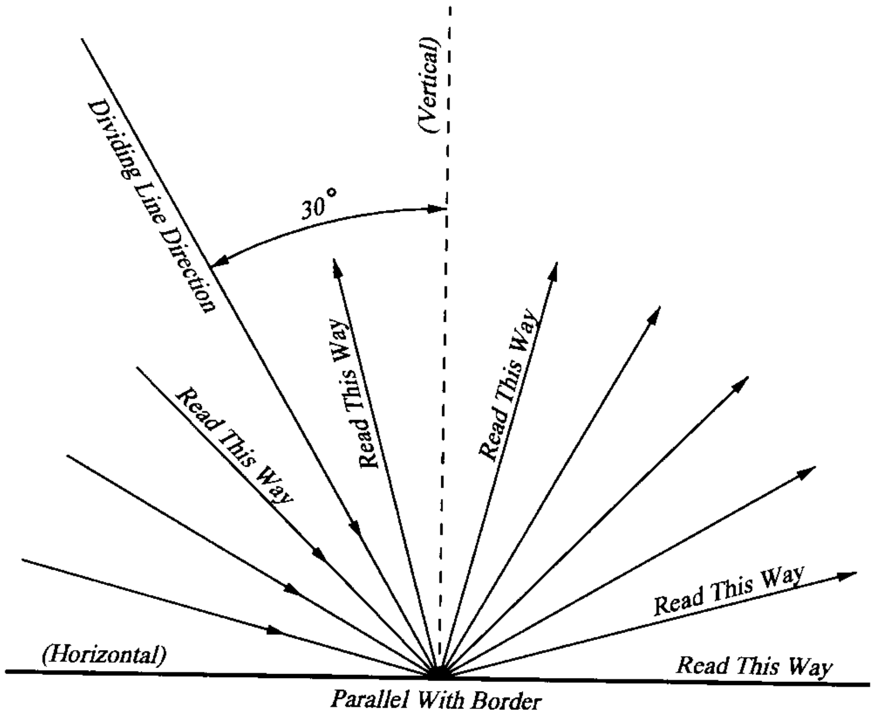
EXAMPLE OF GENERAL NOTES

EXAMPLE OF STANDARD DETAIL TEXT

3.5 Reading Direction

All letters and figures should be readable from either the bottom or right edge of the sheet.

Figure 3-2 Reading Direction



3.6 Text Notes

3.6.1 General

There are multiple types of notes used on drawings. Depending on their type, they apply to different elements in the drawings. Below are some general guidelines for all notes.

- Notes and callouts on drawings should match the terminology used in the specifications
- Minimize the use of abbreviations; if using abbreviations, do not put a period after them
- Notes should be left justified
- Referring to notes on other drawings should be avoided
- Use generic terminology on, not trade names, e.g. use “Gypsum Board” not “Sheetrock”, “Access Hatch” not “Bilco Hatch”.
- Do not call out manufacturers or model numbers on drawings; call them out in the specifications.
- Do not use NEW or PROPOSED to define design elements – this should be evident in the presentation where existing is called out and screened and active elements are bold

3.6.2 General Discipline Notes

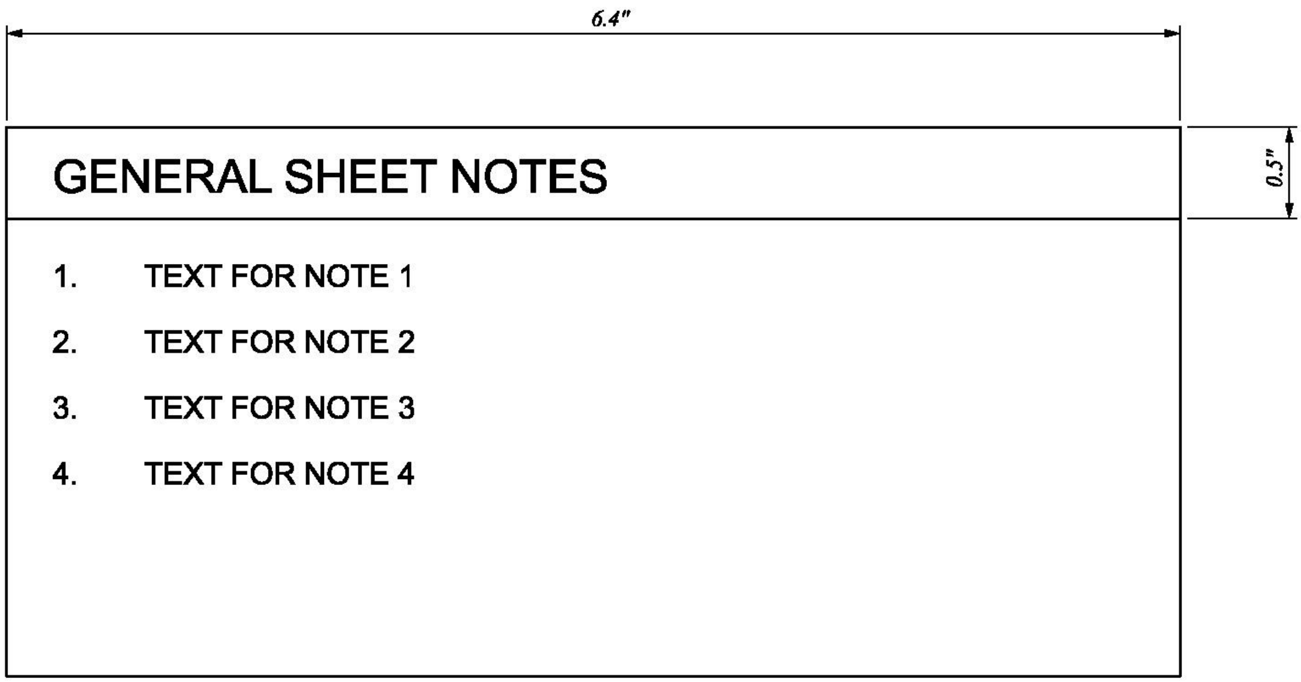
General Discipline Notes appear on the first sheet(s) within a particular discipline and apply to all subsequent sheets within that discipline. For example, General Civil Notes appear on sheet GC-1 and apply to all civil sheets within the drawing set.

Since General Discipline Notes apply to all drawings of a discipline, they should not be repeated on other sheets within that discipline. Coordination is necessary to ensure General Discipline Notes are consistent with the project information, project requirements, and drafting conventions. NBC has General Discipline Notes for many of the disciplines. These notes are standardized, but **MUST** be modified and tailored to each project. The general notes are located in the **NBC_Common.dwg** block library.

3.6.3 General Sheet Notes

General Sheet Notes are used to communicate sheet-specific information or instructions. General Sheet Notes apply to the entire sheet. General Sheet Notes should be numbered sequentially within the General Sheet Note Block and located in the upper right corner of the drawing, below the Keyplan (if applicable). In the event the sheet content doesn't allow for the General Sheet Notes to be docked in the upper right corner, try to locate the box along the right edge and move down as necessary. **Avoid locating randomly or altering the width of the block other than the height – this will allow for consistent presentation across the set.**

Figure 3-3 General Sheet Note Block



3.6.4 Keynotes

Keynotes are tabulated sequentially within the Keynote legend. The Keynote legend should be located in the upper right-hand corner of the drawing, below the Keyplan (if applicable) and General Sheet Notes (if applicable).

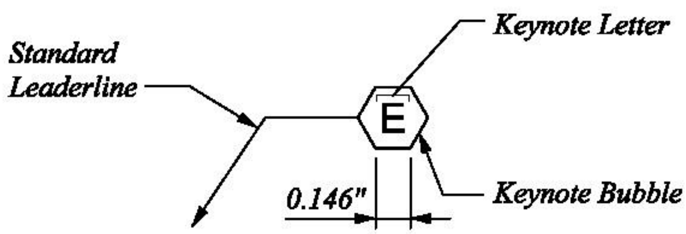
Keynotes should begin with the letter A on each sheet. If a Keynote is deleted late in a project, the note in the legend may be replaced by **NOT USED** instead of renumbering all the notes.

Keynotes are called out using a Keynote symbol, containing a letter within a hexagon. Keynotes should only be used when space is limited on the drawing field.

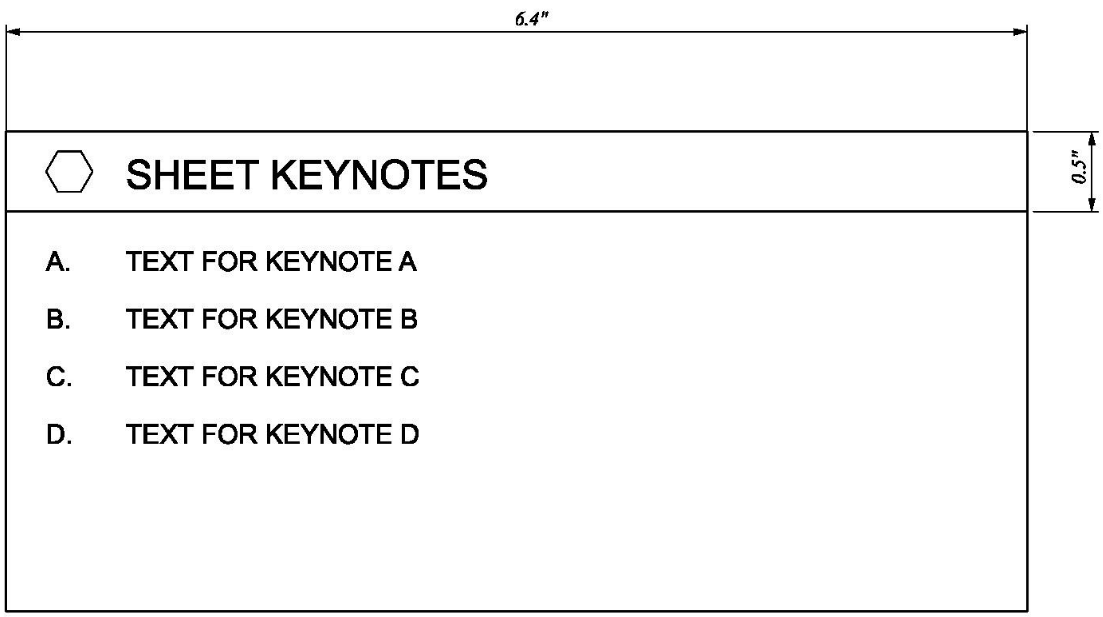
When a Keynote is called out, the legend for that keynote should appear on the same sheet where the reference is made. **Avoid locating randomly or altering the width of the block other than the height – this will allow for consistent presentation across the set.**

Figure 3-4 Keynote Block and Keynote Callout

BUBBLE-KEY



BLOCK-SHEETKEY

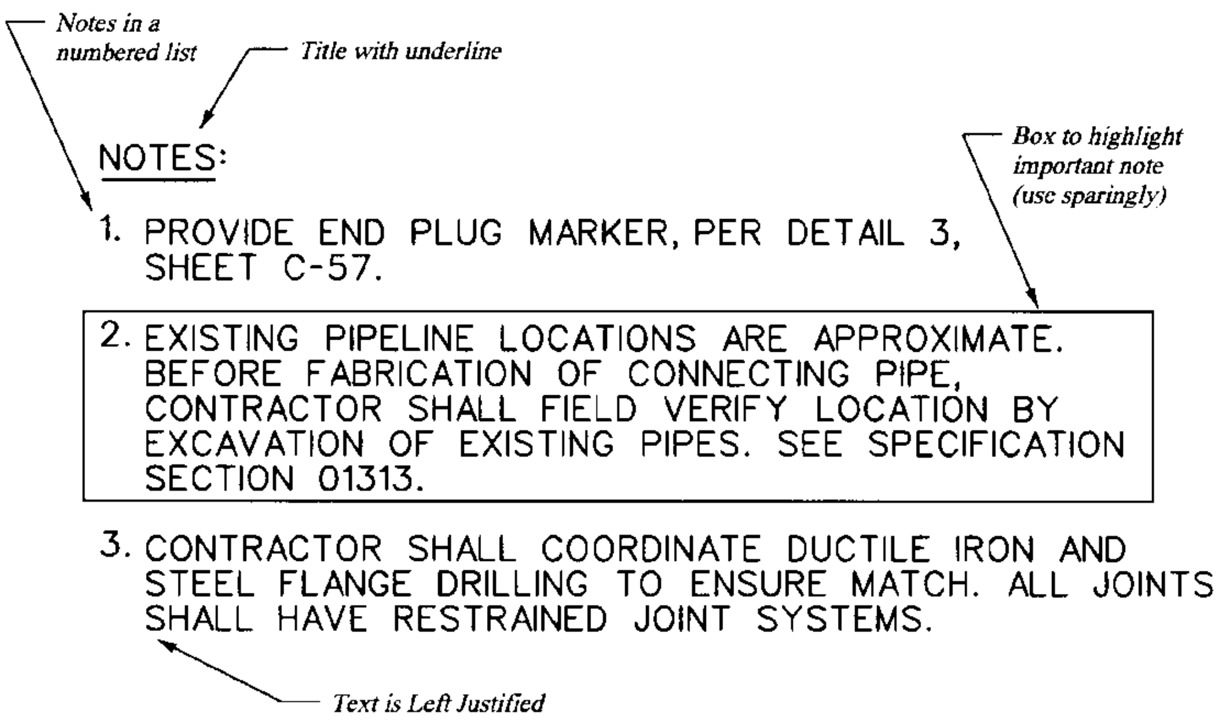


3.6.5 Section/Detail Notes

Notes which apply to one section or detail on a drawing should be located such that it is clear to which section or detail they apply. If there is any doubt, use a title such as: **NOTES FOR DETAIL 3:**

Section/Detail notes are not located within a note block. Refer to Figure 3-5 for an example.

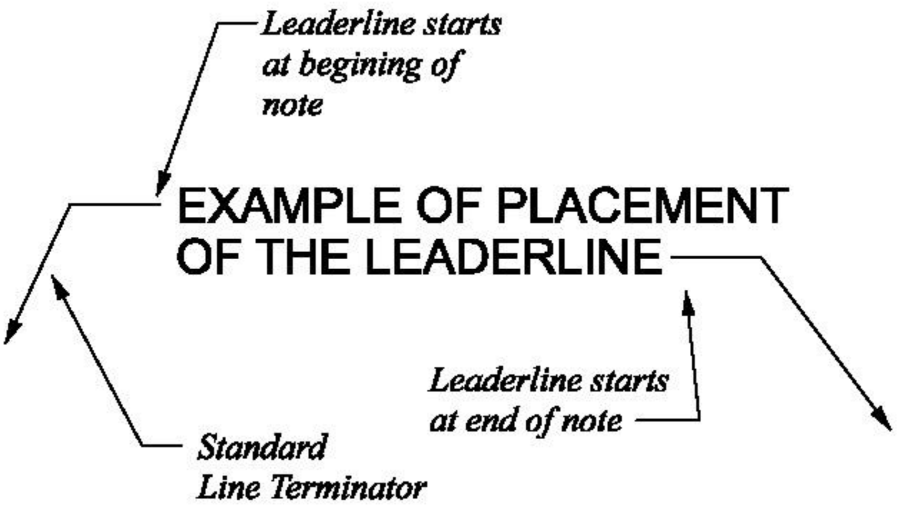
Figure 3-5 Section and Detail Notes



3.7 Leaders

Leaders should start at the note with a short horizontal line then angle before terminating at the appropriate feature with a standard line terminator. When the note is to the right of the drawing, the leader should start at the first word of the note. When the note is to the left of the drawing, the leader should start at the last word of the note. Leaders that end at encircled areas will NOT have a line terminator. Refer to Figure 3-6 for an example.

Figure 3-6 Leaders

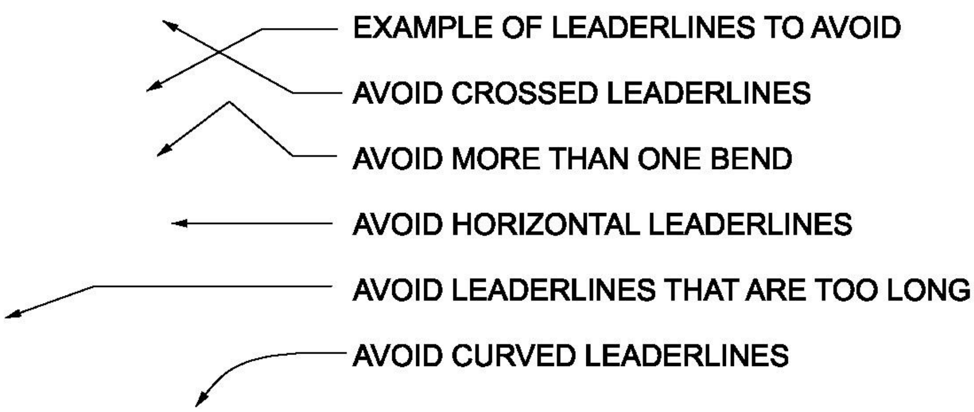


Avoid leaders that are:

- Horizontal or vertical only
- At the same angle as crosshatching
- At very small angle to the terminating surface
- Parallel to extension or dimension lines
- With multiple bends
- Curved
- Crossed
- Too long

Figure 3-7 shows examples of leaders to avoid.

Figure 3-7 Leaders to Avoid



3.8 Dimensions

NBCDetaildim – These are for General Discipline Sheets including Standard Details only

NBCdim-DecFt – These are for Civil Discipline Sheets only (Civil Units)

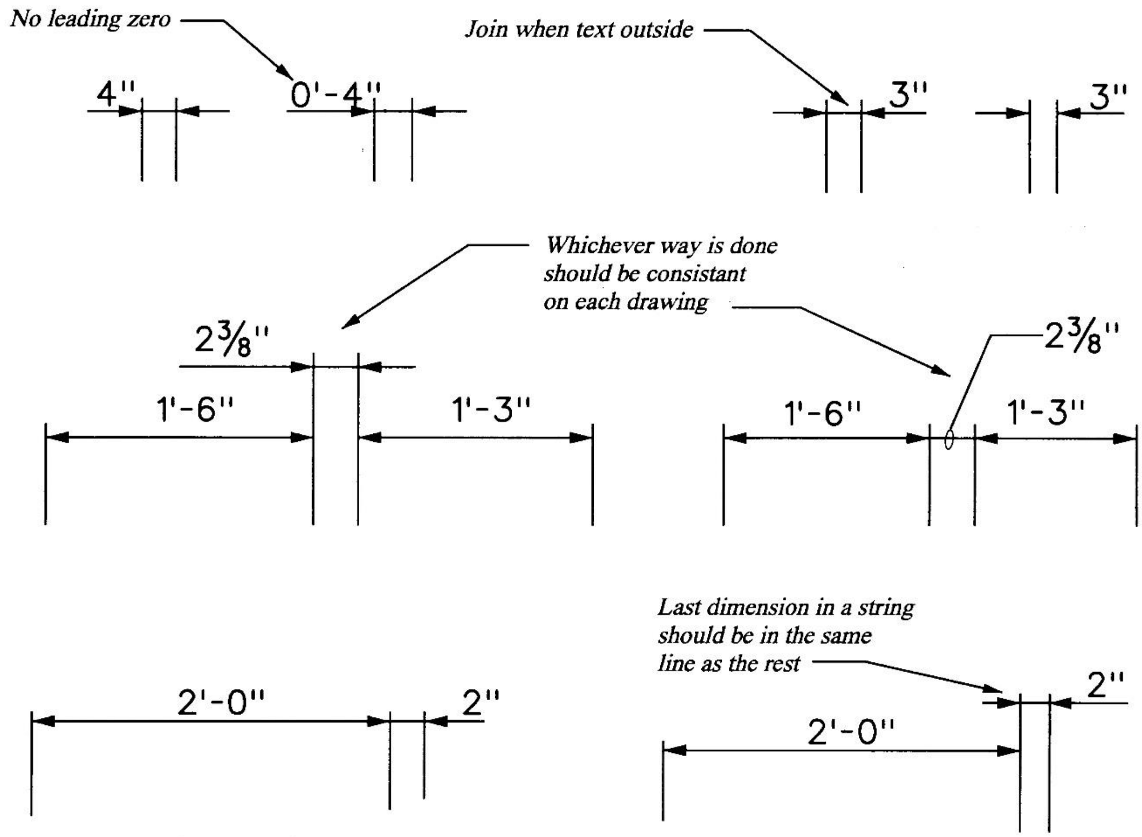
NBCDetailnote-ARROW – These are for General Discipline Sheets including Standard Details for the notes with leaders only

NBCnote-ARROW – These are for all Discipline Sheets where there are notes with leaders

- Overall dimensions should be given on the plans. If the structure is too long to be shown, then the overall dimensions should be shown across a breakline. NEVER dimension to breaklines.
- Horizontal dimensions should be shown on plans, not sections unless too small or congested to be clear. Do not repeat dimensions except as necessary to relate one drawing or view clearly to another.
- Dimensions 12" and larger should be in feet and inches, except pipe diameters, weld dimensions, reinforcing spacing, column sizes, and structural steel should be in inches.
- If the dimension text can fit between the extension lines the arrows should also sit inside, but if the dimension text needs to sit outside the extension lines, the arrows should also.

Figure 3-8 shows examples of dimensions to use on drawing sheets.

Figure 3-8 Dimensions

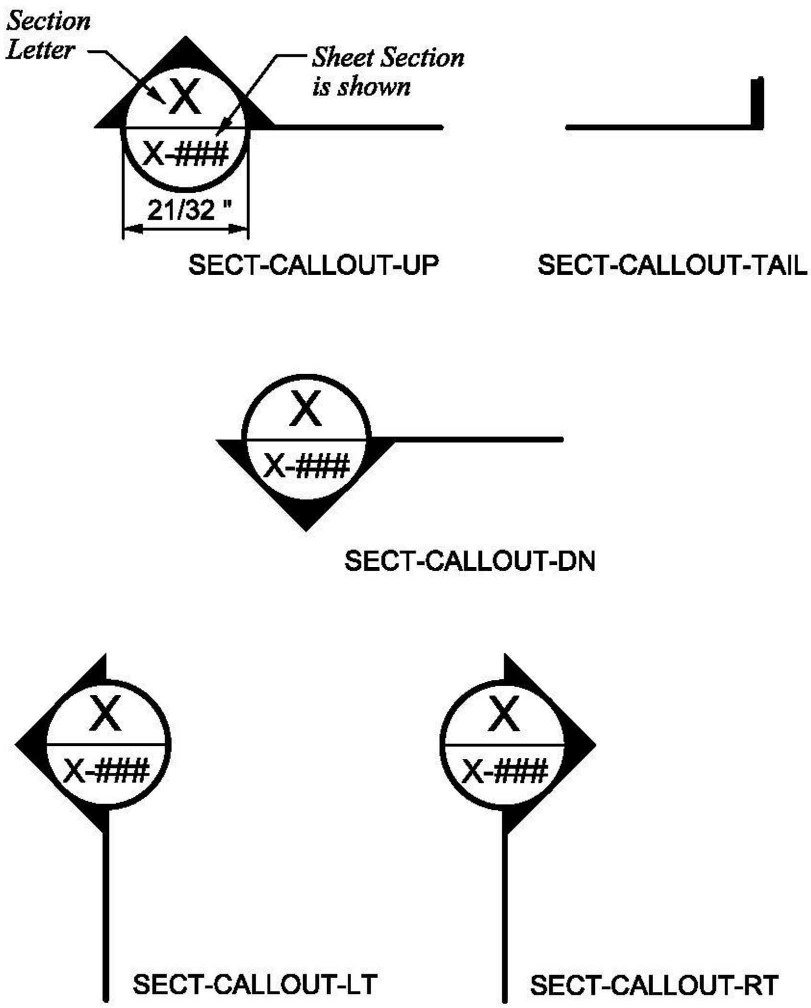


3.9 Section Cuts

Sections should point up, to the left, or to the right if possible. Sections should be letters, and preferred presentation sequence in set is in alphabetical order, filling the sheet from left to right and top to bottom. Ideally, sections should align with other sections on the sheet by common elevation. Section letters should NOT be repeated in the same building/area to avoid confusion.

Figure 3-9 shows examples of section cuts.

Figure 3-9 Section Cuts



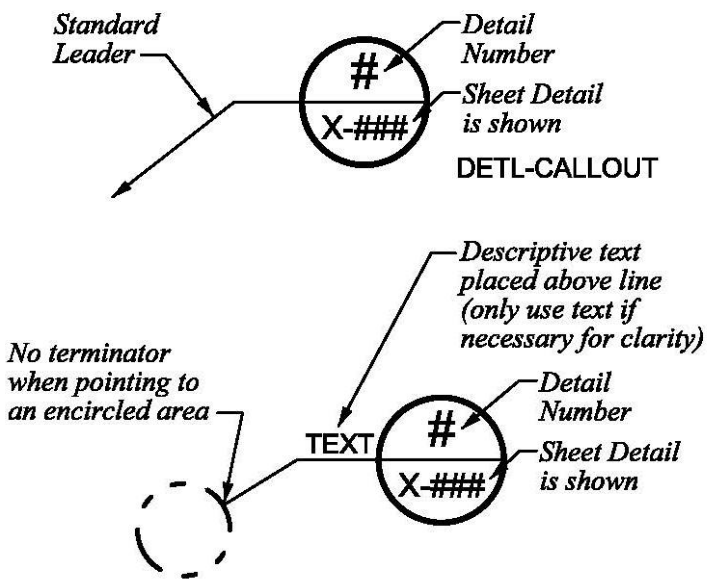
3.10 Detail Callouts

Details should be numbered and should be in numerical order in the order they appear. When populating the sheet, details sit after the sections, in numerical order, filling the sheet left to right and top to bottom as much as possible.

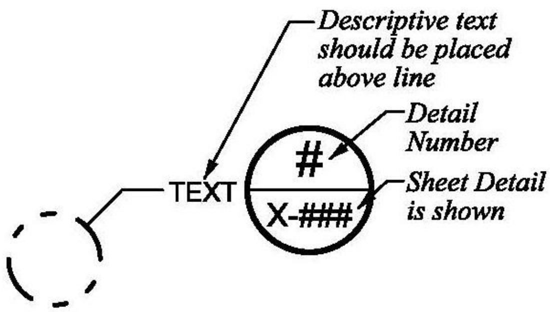
Detail numbers should NOT be repeated in a building/area to avoid confusion.

Encircle area to be detailed with a circle, box, or oval as required for clarity. Leaders pointing to encircled areas will not have a line terminator. Figure 3-10 shows examples of detail callouts.

Figure 3-10 Detail Callouts



Acceptable



Poor Practice

3.11 Elevation Callouts

Elevations should be numbered and should be in numerical order in the order they appear. Elevation numbers should **NOT** be repeated in an area to avoid confusion. Refer to Figures 3-11 and 3-12 for examples.

Figure 3-11 Exterior Elevations

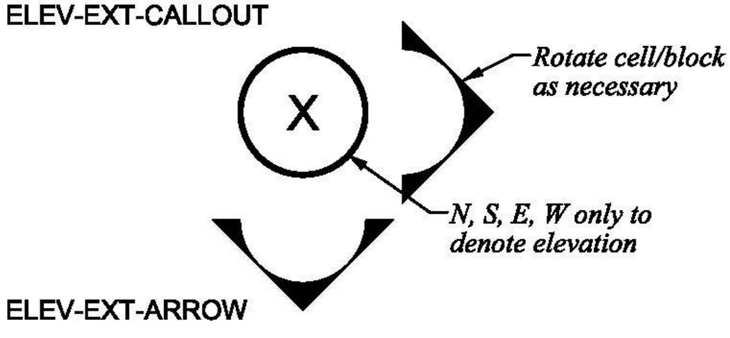
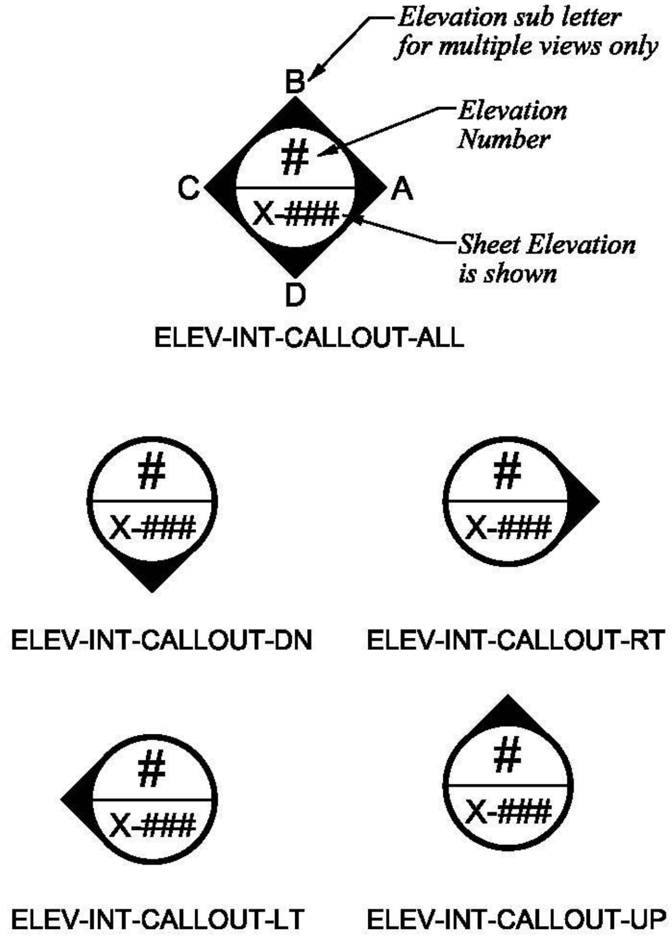


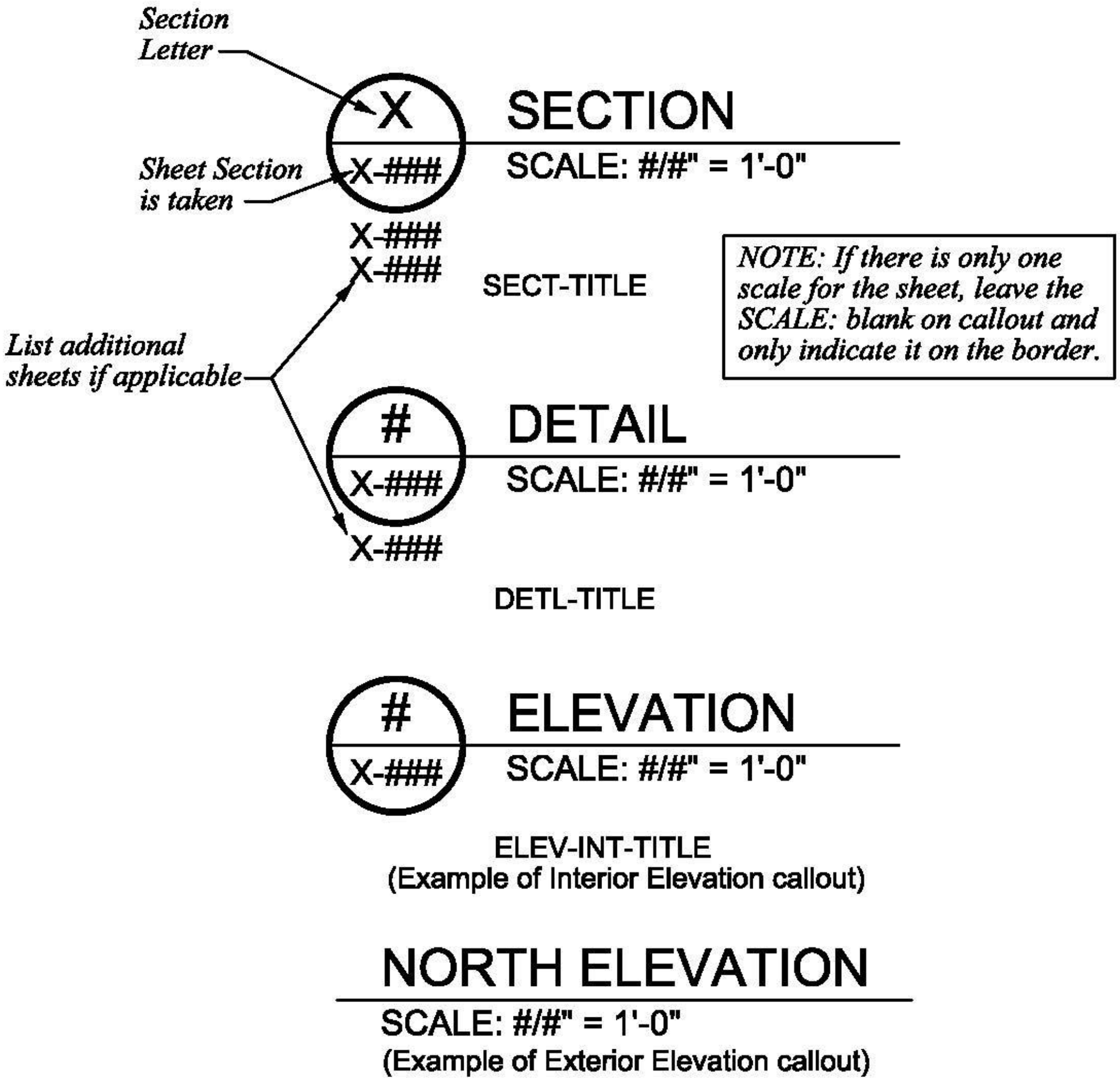
Figure 3-12 Interior Elevations



3.12 Section/Detail/Elevation Titles

Titles should say **'SECTION'**, **'DETAIL'**, or **'ELEVATION'** rather than a long description of the items depicted. Multiple sheet callouts are to be placed below the callout block (see Section Title in Figure 3-13 for example).

Figure 3-13 Section/Detail/Elevation Titles

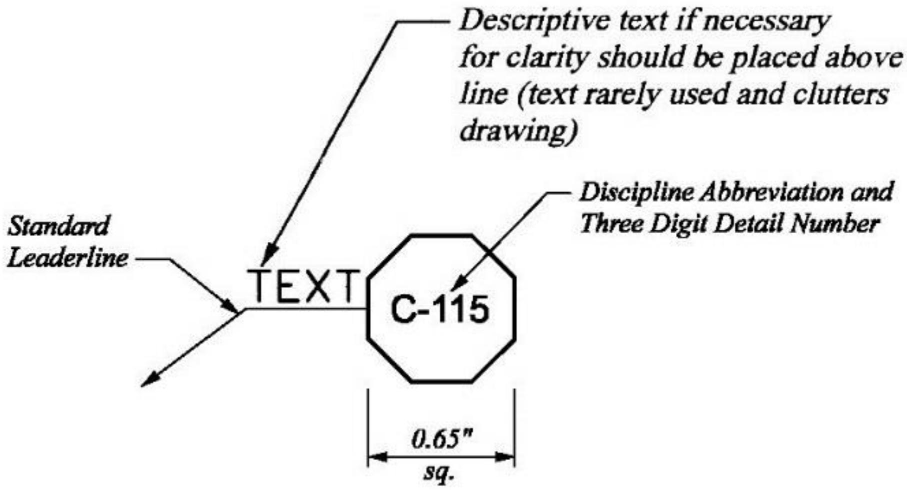


3.13 Standard Detail Callouts

Detail numbers should include discipline abbreviation and three-digit detail number, as depicted in Figure 3-14.

For standard detail block see next page.

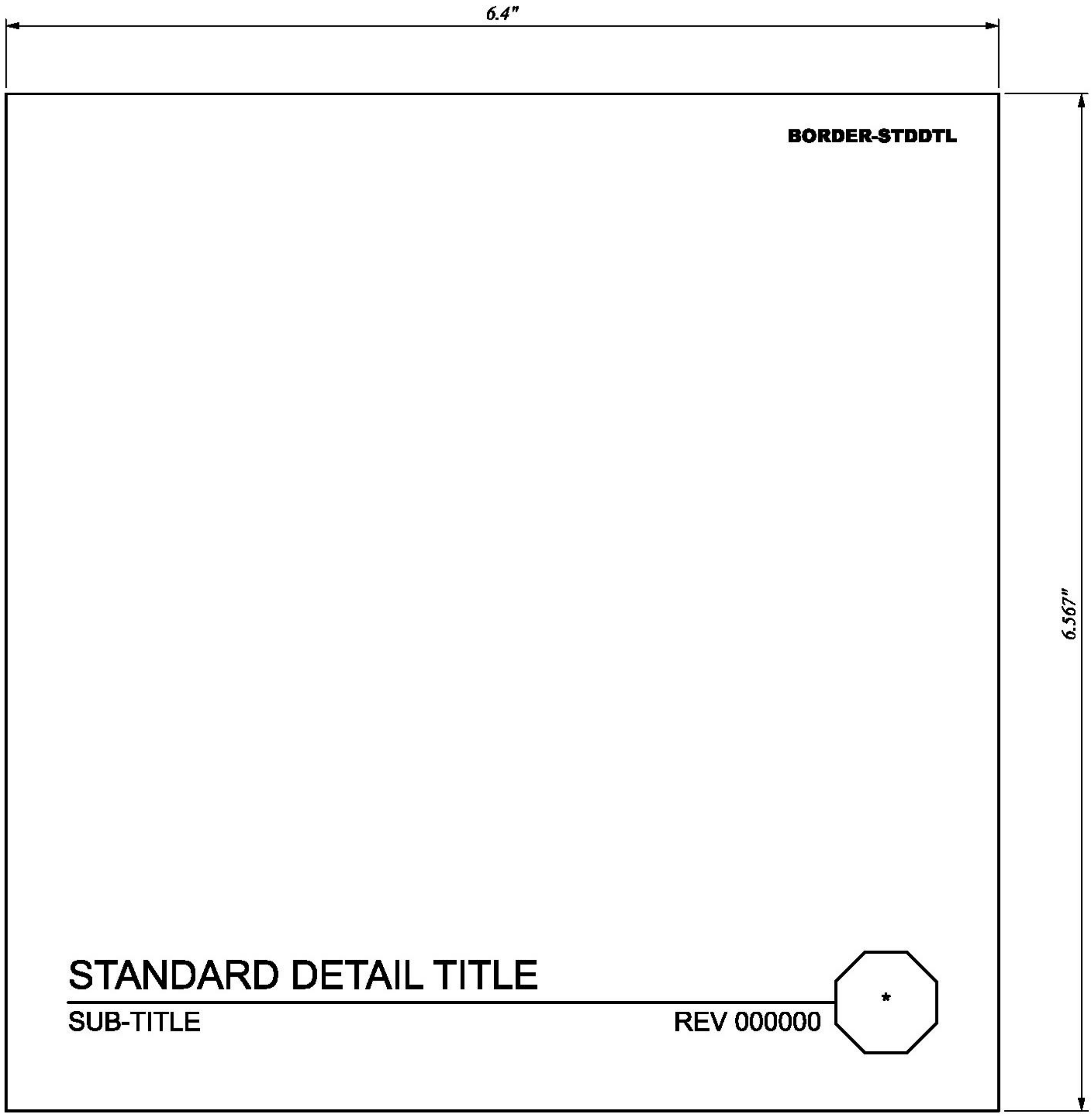
Figure 3-14 Standard Detail Callouts



3.14 Standard Details

Standard Details should be put in numerical order from left to right and from top to bottom, on the discipline general sheets. Standard details should be drawn in multiples of this block, preferably in horizontal format not vertical. If modification of a standard detail is necessary for a job, the revision date is to be removed. Standard detail numbers should be NBC approved numbers. If the detail cannot be pulled from a NBC Styles block library, then they are not approved as NBC Styles and must become a series 900 detail if used project wide. Project specific details that are common to more than one area should be given a 9XX number and placed in numerical order after the NBC Standard Details; they will have NO revision date. Scales are assumed not scaled unless a scale is provided – do not add NO SCALE if the border has a scale box; put NO SCALE only if multiple scales exist on the sheet. (This detail is not shown to scale.)

Figure 3-15 Standard Detail Title



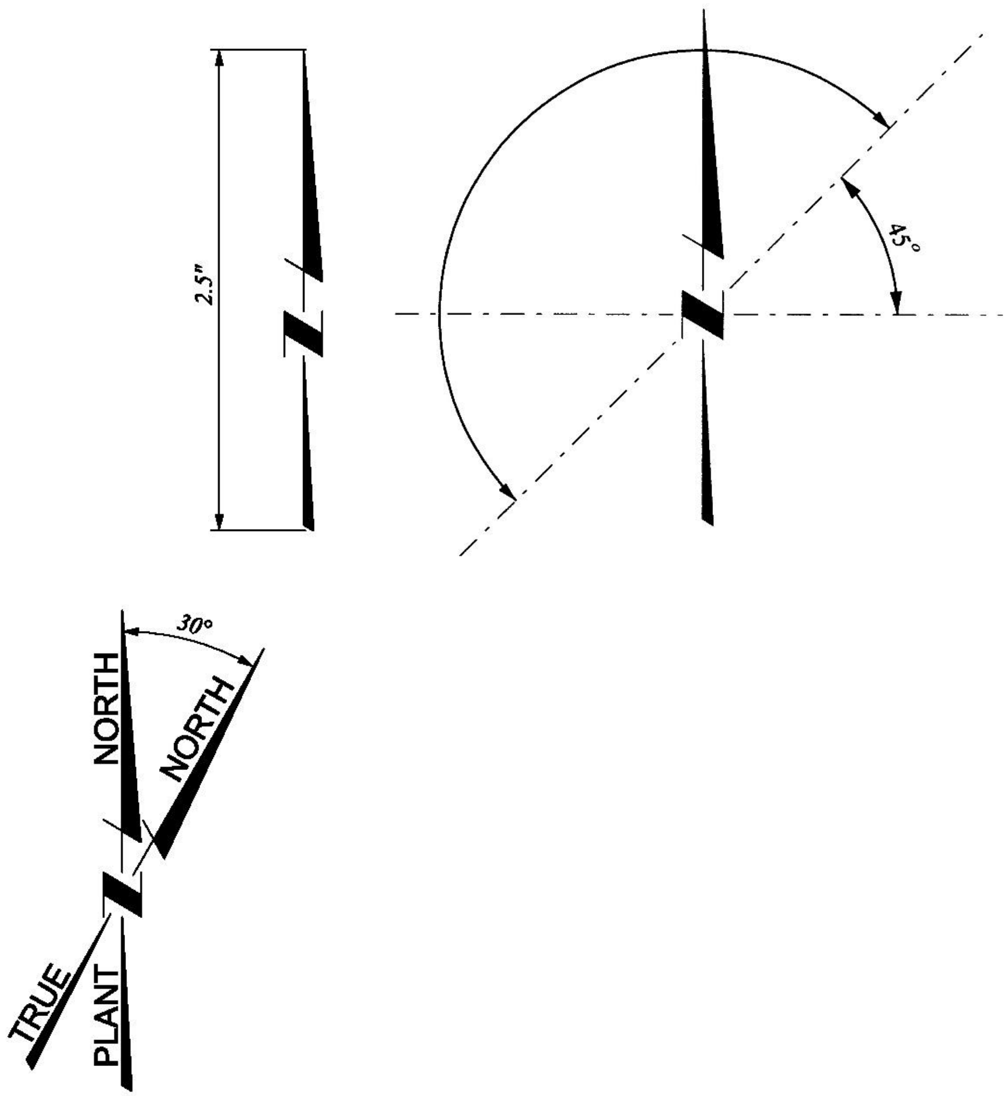
3.15 North Arrow

North arrow orientation should be in the indicated quadrant and consistent for all disciplines, as depicted in Figure 3-16.

On piping plan and profile drawings, stationing and flow direction should take priority over north arrow placement.

North arrows should be shown on all plans, including key plans, vicinity, and location maps.
All north arrows should be project north arrows unless you note on the drawings otherwise.
North arrows should be located in the upper left corner of plans and maps.

Figure 3-16 North Arrow



3.16 Gridlines

Gridlines in **Civil** discipline projects identify the coordinate grid system that is the basis for locating the project geospatially in the world and providing horizontal control. The coordinate system to be used is... The symbology for the line is defined in the Civil Level/Layer table. Northing/Easting numbers should be placed in the plan as callouts at regular intervals to allow horizontal control information to be readily available.

3.17 Matchlines

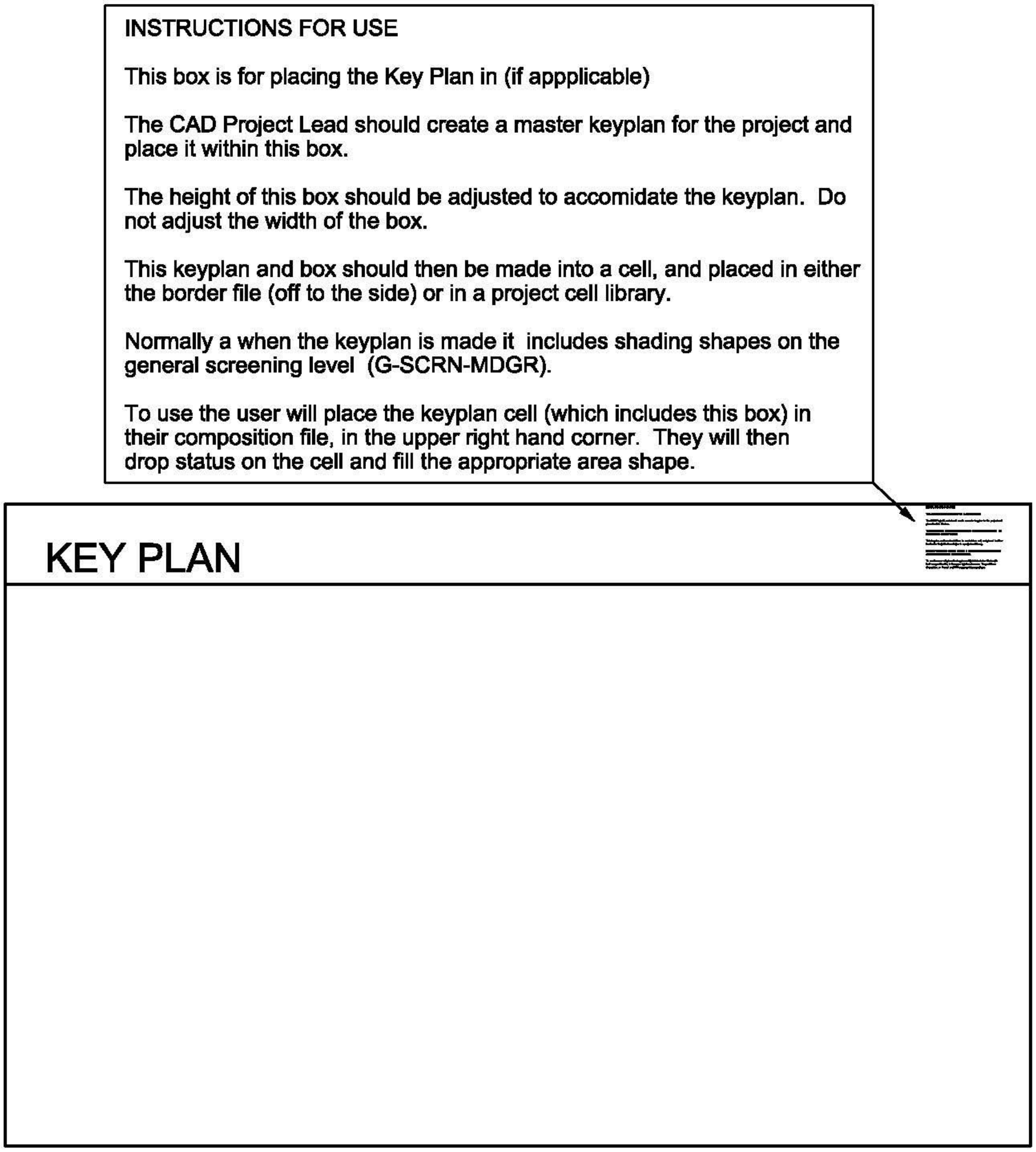
Matchlines are used to delineate the division between two or more areas of a continuous structure or area that must be shown on separate sheets because of sheet size limitations. Below are some guidelines for using Matchlines:

- Do not locate Matchlines on column lines, gridlines, or expansion joints. Locate them instead at the centerline of a wall or corridor not on the grid.
- Matchlines should be shown at the same location within the structure on both sheets containing adjacent segments.
- Clip the plan clean to the matchline unless a small amount of overlap is necessary to establish the relationship between adjacent plan segments. (Only in the case that the Key Plan doesn't assist in clarifying!)
- Always label matchline with the word '**MATCHLINE**' or as done in examples below. **Matchline text style is NBC12pt Center Center.**
- If section/plan continues on another sheet, label matchline with the sheet number that it continues on.
- NEVER dimension to a matchline, you may dimension through a matchline to an element on the next section or plan.

3.18 Key Plans

A Key Plan is a small-scale layout of the overall site shown by crosshatching or shading the location of the partial plan. Key Plans should be placed in the Key Plan box that is docked in the upper right corner of the drawing. Key Plans should be no larger than what can fit comfortably in the box, although the box height can be modified as necessary. **Do not alter the width of the Key Plan box.** They should be consistent (the same figure or outline) for all drawings. Partial plans and Key Plans should have the same north orientation. The North Arrow symbol should be located in the upper left of the plan and be half the scale of any North Arrow in the main sheet content area.

Figure 3-17 Key Plan

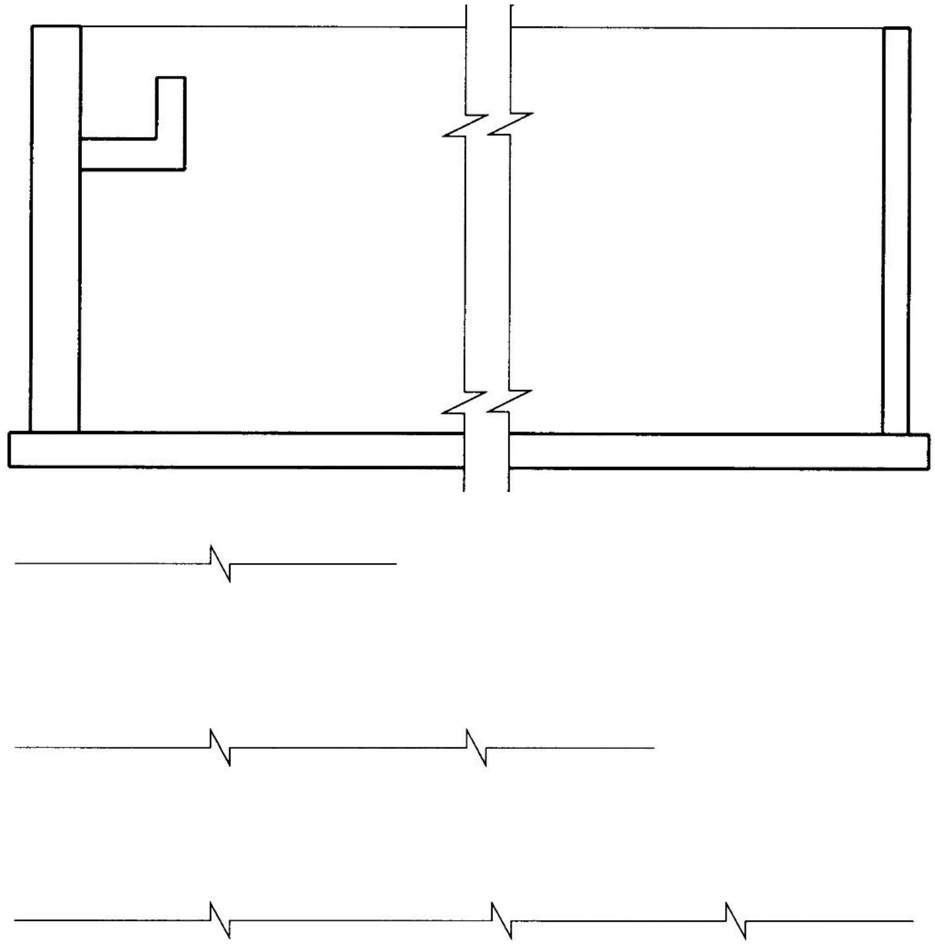


3.19 Shortened Sections

A shortened view is a view in which a piece has been removed, so the entire view may be shown at a larger scale. A view that is broken must be consistent throughout the break. A breakline is used to delineate the break.

NEVER dimension to a breakline, but you may dimension through a breakline to an element on the next section or plan.

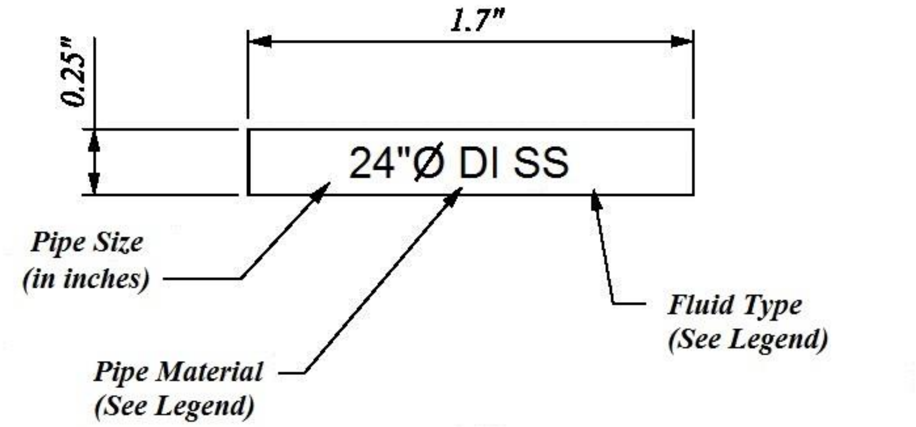
Figure 3-18 Shortened Sections and Breaklines



3.20 Piping Callouts

Call out pipe diameter in inches, not in feet and inches, as shown in Figure 3-19.

Figure 3-19 Piping Callouts



3.21 Revisions

Figure 3-20 shows an example of a revision triangle, while Figure 3-21 shows an example revision cloud. Revision Clouds are to be set to G-REVC-CLDS, size 0.2" using the REVCLOUD command. Refer to previous sections for a full explanation of revisions.

Figure 3-20 Revision Triangle

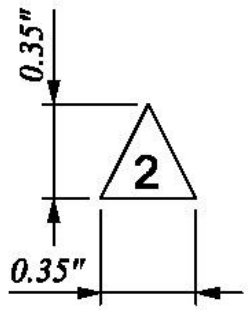
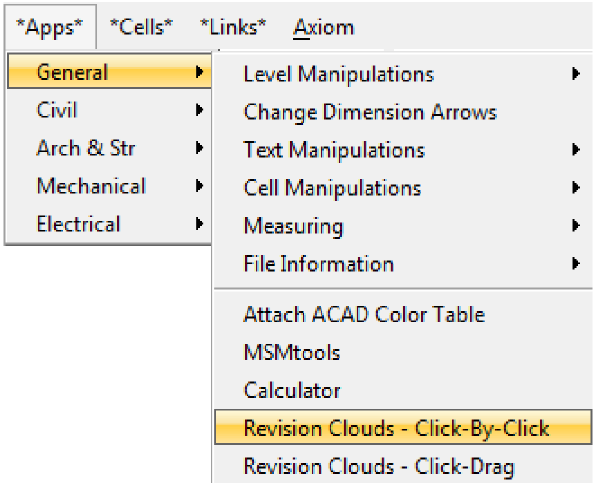
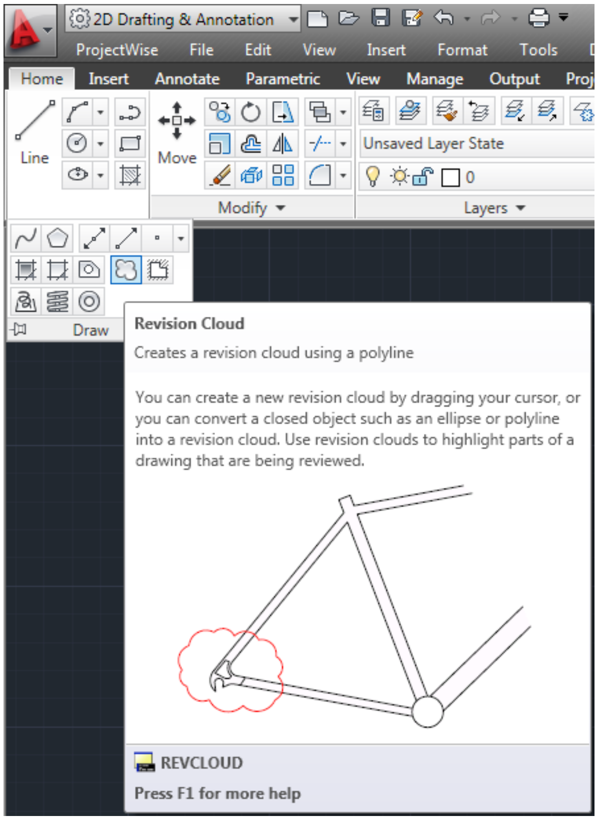
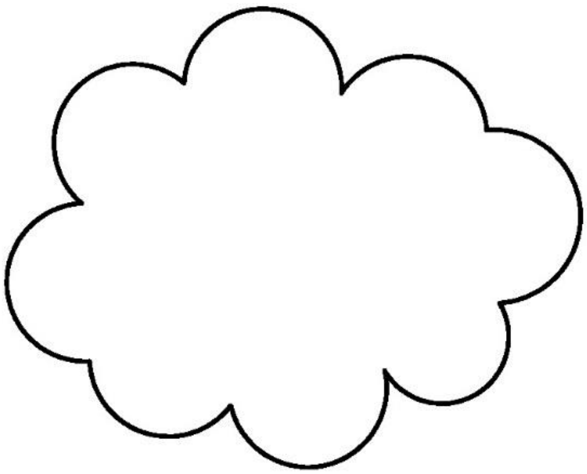


Figure 3-21 Revision Cloud







3.22 Avoiding Redundant Information

Do not needlessly repeat information. If called out on the plan, do not callout again on sections and details.

Avoid double dimensions, e.g., placing both dimensions and elevations on a section.

Do not render elevations and show shadows. A small area of texture or hatching at corners, or a simple detail showing pattern and direction is sufficient. However, avoid using regular or geometric patches of patterning that may appear to be a specific feature.

Do not use the term **BY OTHERS,** use **BY OWNER** or **NIC (NOT IN CONTRACT)**.

When using the word **(TYPICAL)**, **(TYP)**, **(SIMILAR)**, or **(SIM)** it should be placed in parentheses.

When using typical, do not callout all cases and use the typical callout.

When calling out new construction, do not use the words **NEW**, or **PROPOSED**. Do use the word **EXISTING** when calling out existing construction.

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Appendix A
Quick Reference Guide
And Symbol Sheets

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Discipline Sequence & Designator — Chapter 5

Discipline	Discipline Designator
General	G
Demolition	D
Plan and Profile	PP
Civil	C
Instrumentation and Control	I
Landscape	L
Architectural	A
Structural	S
Process Mechanical	M
HVAC	H
Plumbing	P
Fire Protection	FP
Electrical	E

Drawing set should be arranged in this order

See individual discipline chapter in the CBPG for sheet order within the discipline

Sequence of General Sheets — Chapter 7 - Appendix 7A

General sheets should be arranged in this order:

- Cover / Title Sheet
- Location and Vicinity Map
- List of Drawings
- Symbol Sheet
- Abbreviations
- Process Flow Schematic
- Design Criteria
- Hydraulic Profile
- Piping Schedule
- Equipment Schedules

"D" Size Border and Title Block — Chapter 5

The current border has been modified to conform to company standards. The following was changed: Dsize Tags cell/block needs to be inserted on the border with project specific information, Dsize Tags cell/block needs to be inserted on each sheet with sheet specific information, Signature Block has been replaced by the STAMP-IFB stamp, and now there are two lines available for the Sheet Title (See the MWH_Common.cel/.dwg library and Appendix 6-2)

BORDER-ANSI-D & BORDER-ANSI-D-TAGS

Revisions / Addendum — Chapter 5

- Revision numbers are consecutive per drawing starting at "1"**
- All related changes should have the same date from sheet to sheet
- Short description

REV	DATE	BY	DESCRIPTION
4	2/29/99	MEF	CHANGE ORDER #8
3	10/22/98	CSL	CHANGE ORDER #5
2	7/25/98	CCT	ADDENDUM #3
1	5/7/98	GLW	REMOVED BYPASS PUMP 456

Job No: 0000000

- Initials of person making changes

Cloud area of revision (use rev clouds macro from MWH menu/apps)

REV — Add revision triangle with revision # next to cloud

** See Chapter 5 - Pages 14 - 16 for more information not supplied here.

Scale Box — Chapter 5

Drawings that are drawn to scale list it in this location. The following rules apply:

If the drawing is not to scale, or scaled 1:1, put NO SCALE in the box - use this in place of NTS and NONE.

If the drawing has multiple scales on the sheet, put AS SHOWN in the box and indicate the scale under the Section/Detail tag.

If the drawing has only one scale, indicate the scale, but do not indicate scale under the Section/Detail tags on the sheet.

Examples of preferred scales:

SITE PLANS:
- Preferred 1" = 20'
- Acceptable 1" = 40'
- Not Desirable 1" = 30'

BUILDING SECTIONS:
- Acceptable 3/4" = 1'-0", 3/8" = 1'-0", 1/2" = 1'-0"

BUILDING PLANS/ELEVATIONS:
- Preferred 1/4" = 1'-0"
- Acceptable 1/8" = 1'-0"

BUILDING DETAILS:
- Acceptable 3/4" = 1'-0", 1 1/2" = 1'-0"

PIPING & ROAD PROFILES/ SITE SECTIONS:
- Preferred 1" = 20' Horiz 1" = 5' Vert; 1" = 40' Horiz 1" = 10' Vert

Design Phase/Submittal Date/ Not For Construction Stamp Box — Chapter 5

PRELIMINARY DESIGN PHASE - DATE SUBMITTED

NOT FOR CONSTRUCTION

This document is an interim document and not suitable for construction. As an interim document, it may contain data that is potentially inaccurate or incomplete and is not to be relied upon without the express written consent of the preparer.

STAMP-PD-NFC

DESIGN DEVELOPMENT PHASE - DATE SUBMITTED

NOT FOR CONSTRUCTION

This document is an interim document and not suitable for construction. As an interim document, it may contain data that is potentially inaccurate or incomplete and is not to be relied upon without the express written consent of the preparer.

STAMP-DD-NFC

CONSTRUCTION DOCUMENT PHASE - DATE SUBMITTED

NOT FOR CONSTRUCTION

This document is an interim document and not suitable for construction. As an interim document, it may contain data that is potentially inaccurate or incomplete and is not to be relied upon without the express written consent of the preparer.

STAMP-CD-NFC

ISSUED FOR BID - DATE SUBMITTED

ANY PRINTS NOT BEARING THIS STAMP MAY HAVE BEEN PRINTED PRIOR TO ADVERTISING AND CANNOT BE CONSIDERED AS BID DOCUMENTS

STAMP-IFB
STAMP-IFC

STAMP-IFB is Issued for Bid. Use STAMP-IFC for all projects that are Design Build and considered Issued for Construction.

Conformed Drawings — Chapter 5

- Place CF in revision number area
- Date conformed drawings are being issued
- Remove all previous revisions from revisions box**

REV	DATE	BY	DESCRIPTION
CF	6/13/99	GGB	CONFORMED

Job No: 0000000

- Initials of person making changes

Remove ALL clouds, signatures,and stamps from drawings - please verify with the PM/PTL to capture client preferences.

Place conformed drawing note in the box to the left of the MWH Logo.

CONFORMED DRAWING

This drawing is a conformed drawing and is not a part of the contract documents. This drawing is provided as a courtesy to the contractor. In the event of a discrepancy between the conformed drawing and the contract documents, the contract documents shall govern.

STAMP-CONDWG

Record Drawings — Chapter 5

- Place an R in revision number area
- Date record drawings are being issued
- Remove all previous revisions from the revisions box

REV	DATE	BY	DESCRIPTION
R	9/10/00	JDJ	RECORD DRAWING

Job No: 0000000

- Initials of person making changes

Remove ALL clouds, signatures,and seals from drawings - verify with the PM/PTL and preferences made by the State.

Place record drawing note in the box left of the MWH Logo.

RECORD DRAWING

This record drawing has been prepared, entirely or in part on the basis of unverified information compiled and furnished by others to the preparer who is not responsible for any inaccuracies, errors or omissions which may have been incorporated into the document as a result

STAMP-RECDWG

Text — Chapter 6

Example and Application	Text Style*	Text Size (inches)
MAIN TITLE TEXT (Cover Sheets Only!)	MWH24pt*	1/4 or 0.24"
SUB-TITLE TEXT	MWH18pt*	3/16 or 0.18"
NOTES/DIMENSIONS TEXT	MWH12pt*	1/8 or 0.12"
STANDARD DETAILS/GENERAL SHEETS TEXT	MWH10pt*	3/32 or 0.10"

* See Chapter 5, for additional text styles - all text styles are defined by height and justification.

Font

True Type Arial Font is the current font of choice. Text should have equal height and width.

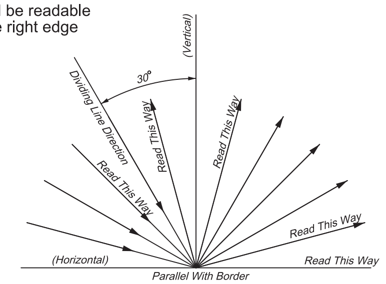
A B C D

All text should be uppercase and left justified with the exception of room names, structures, and area names.*

There should not be any periods for any abbreviations, including NO for number.

Reading Direction

All letters and figures should be readable from either the bottom or the right edge of the sheet.



General Sheet Notes — Chapter 6

- Notes in a numbered list
- Dock box in upper right corner of sheet border or under Key Plan

GENERAL SHEET NOTES

BLOCK-GENSHEET

1. TEXT FOR NOTE 1
2. TEXT FOR NOTE 2
3. TEXT FOR NOTE 3
4. TEXT FOR NOTE 4

The user should place this box down and edit the numbers and text. The box height should then be adjusted to accommodate the notes. DO NOT MODIFY THE WIDTH OF THIS BOX!

General sheet notes apply to everything on a sheet, but only the elements on that specific sheet. If you want your note to apply to all the discipline sheets, put it in the discipline general notes at the beginning of the General Discipline Sheets (i.e. GX-1)

This general note box should be placed in the upper right hand corner of the drawing, just below the keyplan box (if applicable).

Sheet Key Notes — Chapter 6

- Notes are in a lettered list
- Dock box in upper right corner of sheet border or under the General Sheet Notes

SHEET KEYNOTES

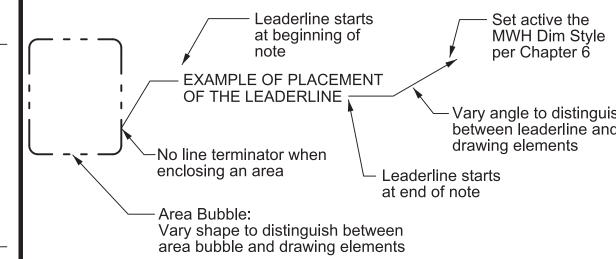
BLOCK-SHEETKEY

A. TEXT FOR KEYNOTE A
B. TEXT FOR KEYNOTE B
C. TEXT FOR KEYNOTE C
D. TEXT FOR KEYNOTE D

The user should place this box down and edit the letters and text. The box height should then be adjusted to accommodate the notes. DO NOT MODIFY THE WIDTH OF THIS BOX!

Sheet keynotes only apply to those items on the sheet that are specifically tagged withthe keynote symbol (hexagon). If you want your note to apply to all the discipline sheets, put it in the discipline general notes at the beginning of the General Discipline Sheets (i.e. GX-1) If your notes are general to the sheet, then use General Sheet notes.

Leaderlines — Chapter 6

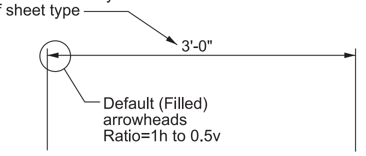


Example of Leaderlines to AVOID

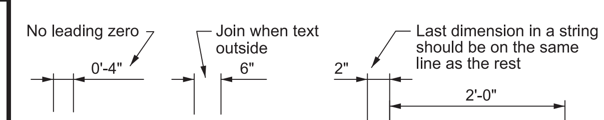
- EXAMPLE OF LEADERLINES TO AVOID
- AVOID CROSSED LEADERLINES
- AVOID HORIZONTAL LEADERLINES
- AVOID LEADERLINES THAT ARE TOO LONG
- AVOID CURVED LEADERLINES

Dimensions — Chapter 6

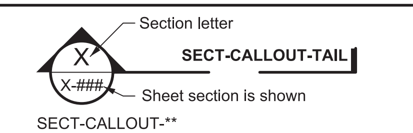
Text Size - See Chapter 6 and select MWH Dim Style based off sheet type



Example of Dimensions to AVOID



Section Cuts — Chapter 6



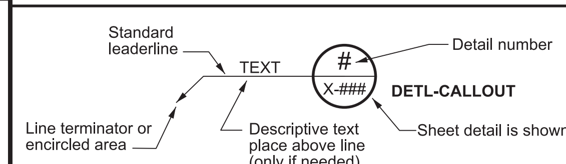
** See Chapter 6, Page 11 for the directions provided as cells and blocks.

Section letters should NOT be repeated in the same building.

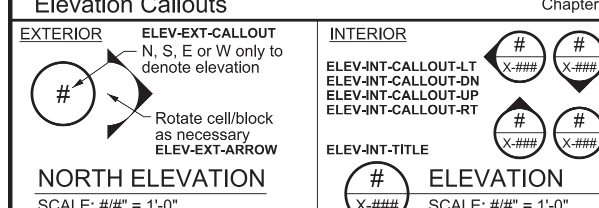
Keep Section tags in chronological order as much as possible from top to bottom and from left to right.

As much as possible align Section Callouts across the sheet.

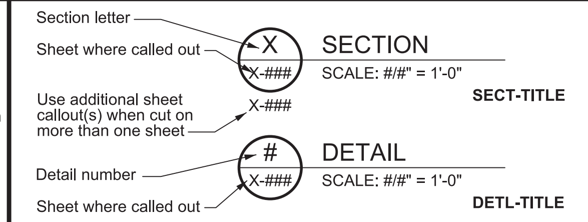
Detail Callouts — Chapter 6



Elevation Callouts — Chapter 6



Section and Detail Titles — Chapter 6



Standard Details — Chapter 6

Standard Detail Sheets

Details placed in order from left to right, top to bottom on discipline general sheets.

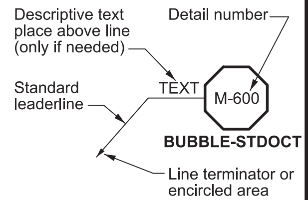
If modification of a standard detail is necessary for the job, the revision date should be removed from the detail.

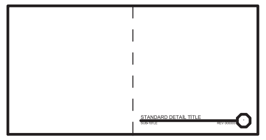
Job specific details that are common to more than one area and are going to be shown on the discipline general sheets should be given 9XX numbers and placed in order after the MWH standard details.

If creating 9XX series standard details - use BORDER-STDDTL for a template.

If the block isn't large enough, use multiples of this block, prefferably in a horizontal format not vertical.

DO NOT MOVE LOCATION OF THE TITLE TAG! IF USING MULTIPLE BLOCKS THE FURTHERS RIGHT LOCATION!!





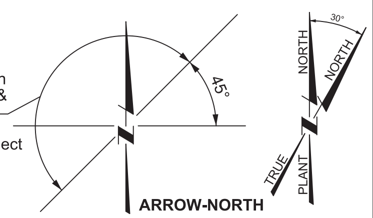
BORDER-STDDTL

North Arrow — Chapter 6

Locate north arrow in the upper left hand corner of ALL plans and maps.

North Arrow orientation to be in this quadrant (except for plan & profile drawings)

All north arrows should be project north arrows unless you note otherwise on the drawing.



ARROW-NORTH

Gridlines — Chapter 6

Structural discipline defines the grid - all other disciplines should reference if Structural sets the grid of a structure or building.

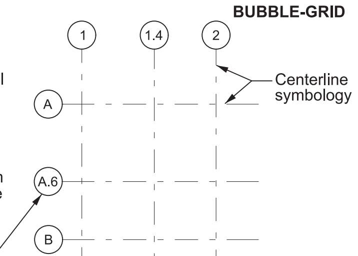
Repeat gridlines on plans, partial plans, sections and details.

Gridlines should match from discipline to discipline.

Top gridlines are numbered from left to right and side gridlines are lettered from top to bottom.

Once into a job, gridlines can be added by giving them a numerical suffix

BUBBLE-GRID



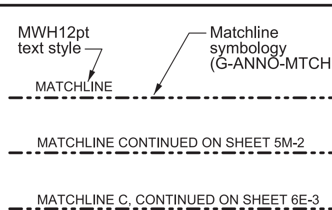
Matchlines — Chapter 6

Always label matchlines

If section or plan continues on next sheet, label matchline with that sheet number

Never dimension to a matchline

Clip drawing clean at matchline to prevent overlapping of elements with matchline label



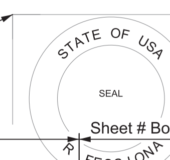
REV 1/1/16

Notes About This Sheet: ***Dynamic blocks for many of these are available now. See DYNAMIC BLOCK JAN 2016.pdf on CAD Knowledge Community Library for guidance.***

- *Text shown in the following type style:* **EXAMPLE** *are cell/block names.*
- *Across this sheet the CAD Best Practice Guide is abbreviated CBPG.*
- *For a PDF copy of the CBPG go to the link provided on the CAD Knowledge Community or Technical Library. This contains very useful guidance and includes examples and links to other locations for additional information.*
- *For more information/comments etc contact the following:* *CAD standards - CAD Project Lead or Quality and Standards Coordinator*; *CAD hardware and software - CSD and/or the ICE Team*; *Advanced applications - BIM Integration Leader*

CBPG Quick Reference Guide - General

Reserved space for stamp (adjust as necessary)



Revisions Box	Scale Box	Warning Box	Designed / Drawn Checked Box	Design Phase/Submittal Date/ Not For Construction/Signature Block Box	Logo Box	Client / Project Information Box	Drawing Title Box	Sheet # Box

- Use the BORDER-ANSI-D-TAGS cell/block to populate the titleblock information only
- First initial (space) last name (no periods)
- Discipline designator

REV	DATE	BY	DESCRIPTION	SCALE / SCALE	WARNING 0 ½ 1 IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE	DESIGNED F LAST / DRAWN F LAST / CHECKED F LAST	DESIGN PHASE/SUBMITTAL DATE NOT FOR CONSTRUCTION STAMP, ISSUED FOR BID STAMP, CONFORMED STAMP OR RECORD DRAWING STAMP (SEE MWHCOMMON.CEL) — STAMP-PD-NFC STAMP-DD-NFC STAMP-CD-NFC STAMP-IFB STAMP-CONDWG STAMP-RECDWG			PROJECT NAME DISCIPLINE BUILDING/FACILITY SHEET TITLE SHEET TITLE 2 (IF REQD)	SHEET #D-#

- Area number (No Leading Zero)
- Sequence number (No Leading Zero)
- Client number (if required by client)
- Job No.

THE FOLLOWING SYMBOLS SHEETS CAN BE FOUND IN THE NBC_COMMON.DWG BLOCK LIBRARY

A	AIR / AMPERE
A/C	AIR CONDITIONING
A/R	AIR RELEASE
AASHTO	AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
AB	ANCHOR BOLT
ABAN	ABANDON
ABND	ABANDONED
ABBR	ABBREVIATION
ABS	ABSOLUTE TEMPERATURE
AC	ACTIVATED CARBON / ASPHALTIC CONCRETE / ALTERNATING CURRENT
ACI	AMERICAN CONCRETE INTERNATIONAL
ACOUS	ACOUSTIC / ACOUSTICAL
ACP	ASBESTOS CEMENT PIPE / ASPHALTIC CONCRETE PAVEMENT
ADD	ADDITIONAL
ADH	ADHESIVE
ADJ	ADJUSTABLE
AFF	ABOVE FINISHED FLOOR
AISC	AMERICAN INSTITUTE OF STEEL CONSTRUCTION
ALT	ALTERNATE
ALUM	ALUMINUM / ALUM
AMB	AMBIENT
ANSI	AMERICAN NATIONAL STANDARDS INSTITUTE
API	AMERICAN PETROLEUM INSTITUTE
APPD	APPROVED
APPROX	APPROXIMATE
APPURTS	APPURTENANCES
ARCH	ARCHITECTURE
ASME	AMERICAN SOCIETY OF MECHANICAL ENGINEERS
ASPH	ASPHALT
ASTM	AMERICAN SOCIETY FOR TESTING AND MATERIALS
AT	ACOUSTICAL TILE
ATM	ATMOSPHERE
AV/AR	AIR VACUUM AND AIR RELEASE VALVE
AVE	AVENUE
AWPA	AMERICAN WOOD PRESERVERS ASSOCIATION
AWS	AMERICAN WELDING SOCIETY
AWWA	AMERICAN WATER WORKS ASSOCIATION
B&S	BELL AND SPIGOT
B/W	BACK OF WALL / BACK OF WALK
BC	BEGIN CURVE / BOLT CIRCLE / BETWEEN CENTERS / BACK OF CURVE
BCR	BEGIN CURB RETURN
BD	BOARD
BDRY	BOUNDARY
BF	BLIND FLANGE / BOTTOM OF FOOTING
BFP	BACK FLOW PREVENTER
BFV	BUTTERFLY VALVE
BHP	BRAKE HORSEPOWER
BLDG	BUILDING
BLK	BLACK / BLOCK
BLKG	BLOCKING
BLVD	BOULEVARD
BM	BEAM / BENCH MARK
BO	BLOW-OFF ASSEMBLY
BOD	BIOCHEMICAL OXYGEN DEMAND
BOP	BOTTOM OF PIPE
BOT	BOTTOM
BPV	BACK PRESSURE VALVE
BRK	BRICK / BREAK
BSMT	BASEMENT
BT	BOLT
BTU	BRITISH THERMAL UNIT
BV	BALL VALVE
BVC	BEGIN VERTICAL CURVE
BWV	BACK WATER VALVE
C	CENTIGRADE / CHANNEL / CEMENT
C&G	CURB AND GUTTER
CAB	CABINET / CRUSHED AGGREGATE BASE
CAP	CAPACITY
CATS	CASING TEST STATION
CATV	CABLE TELEVISION
CB	CATCH BASIN / CHALKBOARD / CURB
CC	CLOSED CIRCUIT TV / CENTER TO CENTER
CD	CEILING DIFFUSER
CEM	CEMENT
CF	CURB FACE / CUBIC FOOT
CFH	CUBIC FEET PER HOUR
CFM	CUBIC FEET PER MINUTE
CFS	CUBIC FEET PER SECOND
CHEM	CHEMICAL
CHG	CHANGE
CHKD	CHECKERED
CI	CAST IRON
CIP	CAST IRON PIPE / CAST IN PLACE
CIPP	CAST IN PLACE PIPE
CJ	CONSTRUCTION JOINT
CL	CENTERLINE
CL2	CHLORINE
CLF	CHAIN LINK FENCE
CLG	CEILING
CLOS	CLOSET
CLR	CLEAR / CLEARANCE
CMB	CRUSHED MISCELLANEOUS BASE
CMC	CEMENT MORTAR-COATED
CML	CEMENT MORTAR-LINED
CML&C	CEMENT MORTAR-LINED AND COATED
CMP	CORRUGATED METAL PIPE
CMU	CONCRETE MASONRY UNIT
CO	CLEANOUT
COL	COLUMN
COMM	COMMUNICATIONS CABLE
COMP	COMPRESSOR
CONC	CONCRETE / CONCENTRIC
COND	CONDENSER / CONDENSATE
CONN	CONNECTION
CONST	CONSTRUCT / CONSTRUCTION
CONT	CONTINUED / CONTINUOUS
CONTR	CONTRACTOR
COORD	COORDINATE
COR	CORNER
COTG	CLEANOUT TO GRADE
CPLG	COUPLING
CPVC	CHLORINATED POLYVINYL CHLORIDE
CS	CAST STEEL
CSP	CORRUGATED STEEL PIPE
CSTS	CURRENT SPAN TEST STATION
CT	CERAMIC TILE
CTR	CENTER
CTS	CORROSION TEST STATION
CTSK	COUNTERSUNK
CU	COPPER / CUBIC
CULV	CULVERT
CV	CHECK VALVE
CY	CUBIC YARD
CYL	CYLINDER
d	PENNY
DAD	DOUBLE ACTING DOOR
DAFT	DISSOLVED AIR FLOTATION THICKENER
DB	DIRECT BURY
DBL	DOUBLE
DC	DIRECT CURRENT
DEG	DEGREE
DET	DETAIL
DF	DRINKING FOUNTAIN / DOUGLAS FIR
DG	DOOR GRILL
DH	DOUBLE HUNG
DI	DUCTILE IRON
DIA	DIAMETER
DIAG	DIAGONAL
DIAPH	DIAPHRAGM
DIFF	DIFFUSER / DIFFERENTIAL
DIP	DUCTILE IRON PIPE
DIR	DIRECTION
DISCH	DISCHARGE
DISP	DISPENSER
DL	DEAD LOAD
DMH	DROP MANHOLE
DN	DOWN
DO	DISSOLVED OXYGEN / DITTO
DR	DOOR / DRAIN
DS	DRENCH SHOWER AND EYE WASH
DT	DRAIN TILE
DWG	DRAWING
DWLS	DOWELS
DWY	DRIVEWAY
E	EAST
E/O	EAST OF
EA	EACH
EB	EXPANSION BOLT OR ANCHOR
EC	END CURVE
ECC	ECCENTRIC
ECR	END CURB RETURN
EF	EACH FACE / EXHAUST FAN
EFF	EFFLUENT
EG	EXISTING GRADE / EDGE OF GUTTER / EXHAUST GRILLE
EGL	ENERGY GRADE LINE
EL	ELEVATION
ELEC	ELECTRICAL / ELECTRONIC
EN	EDGE NAILING
ENCL	ENCLOSURE
ENG	ENGINE
ENGR	ENGINEER
ENT	ENTRANCE
EP	EDGE OF PAVEMENT
EPT	ETHYLENE PROPYLENE
EQ	EQUAL
EQUIP	EQUIPMENT
ESMT	EASEMENT
ETB	EMULSION TREATED BASE
ETC	ET CETERA
EVAP	EVAPORATOR
EVC	END VERTICAL CURVE
EW	EACH WAY / EYE WASH
EX	EXISTING
EXC	EXCAVATION
EXH	EXHAUST
EX-HY	EXTRA HEAVY
EXIST	EXISTING
EXP	EXPANSION
EXT	EXTERIOR / EXTENSION
EXTR	EXTRUDED
F	FAHRENHEIT / FINISH
F TO F	FACE TO FACE
F&C	FRAME AND COVER
F&I	FURNISH AND INSTALL
FAB	FABRICATE / FABRICATION / FABRICATED
FAI	FRESH AIR INTAKE
FB	FLAT BAR / FLOOR BEAM / FIELD BOOK
FCO	FLOOR CLEANOUT
FD	FLOOR DRAIN
FDR	FEEDER
FE	FIRE EXTINGUISHER / FINAL EFFLUENT
FEM	FEMALE (PIPE THREAD)
FF	FLAT FACE / FAR FACE / FINISHED FLOOR
FG	FINISHED GRADE
FH	FIRE HYDRANT / FLAT HEAD
FIG	FIGURE
FIN	FINISHED
FIX	FIXTURE
FL	FLOWLINE / FLOOR
FLEX	FLEXIBLE
FLG	FLANGE / FLOORING
FLGD	FLANGED
FLOCC	FLOCCULATOR / FLOCCULATION
FLR	FLOOR
FLSG	FLASHING
FM	FACTORY MUTUAL (LAB APPROVED) / FORCE MAIN
FMH	FLEXIBLE METAL HOSE
FN	FIELD NAILING
FND	FOUNDATION
FOC	FACE OF CONCRETE / FIBER OPTIC CABLE
FOM	FACE OF MASONRY
FOS	FACE OF STUDS
FOW	FACE OF WALL
FPC	FLEXIBLE PIPE COUPLING
FPM	FEET PER MINUTE
FPS	FEET PER SECOND
FPTS	FOREIGN PIPE TEST STATION
FR	FRAME
FRP	FIBERGLASS REINFORCED PLASTIC
FS	FINISHED SURFACE / FAR SIDE / FLOOR SINK / FORGED STEEL
FT	FEET / FOOT
FTG	FOOTING
FUR	FURRING
FUT	FUTURE
FV	FIELD VERIFY
FWD	FORWARD
G	GAS
GA	GAGE / GAUGE
GAL	GALLON
GALV	GALVANIZED
GANC	GUY ANCHOR
GB	GRADE BREAK
GEN	GENERAL / GENERATOR
GFA	GROOVED FLANGE ADAPTER
GI	GALVANIZED IRON
GIP	GALVANIZED IRON PIPE
GL	GLASS / GROUND LINE / GRADE LINE
GLB	GLUE LAMINATED BEAM / GLULAM
GLV	GLOBE VALVE
GM	GAS METER
GP	GUY POLE
GPD	GALLONS PER DAY
GPH	GALLONS PER HOUR
GPM	GALLONS PER MINUTE
GR	GRADE
GRD	GRADE / GROUND
GRTG	GRATING
GSP	GALVANIZED STEEL PIPE
GV	GATE VALVE
GYP	GYPSUM
H	HIGH / HEIGHT
H&V	HEATING AND VENTILATING
H/B	HOSE BIBB
HC	HOUSE CONNECTION
HDR	HEADER
HDW	HARDWARE
HDWL	HEADWALL
HEX	HEXAGONAL
Hg	MERCURY
HGL	HYDRAULIC GRADE LINE
HGR	HANGER
HM	HOLLOW METAL
HORZ	HORIZONTAL
HP	HIGH POINT / HORSE POWER / HIGH PRESSURE
HPG	HIGH PRESSURE GAS
HR	HEAT RETURN / HOUR
HSL	HORIZONTALLY SLOTTED
HSS	HOLLOW STRUCTURAL SECTION
HTG	HEATING
HTR	HEATER
HV	HORIZONTAL AND VERTICAL CONTROL POINT
HVAC	HEATING, VENTILATION AND AIR CONDITIONING
HW	HOT WATER / HEADWORK
HWD	HARDWOOD
HWL	HIGH WATER LEVEL
HWO	HANDWHEEL OPERATED
HYD	HYDRAULIC / HYDRANT
I/O	INPUT/OUTPUT
I&O	INSIDE AND OUTSIDE
IBC	INTERNATIONAL BUILDING CODE
ID	INSIDE DIAMETER
IF	INSIDE FACE
IJTS	INSULATING JOINT TEST STATION
IN	INCH
INCL	INCLUDE / INCLUDING
INFL	INFLUENT
INSL	INSULATION / INSULATING / INSULATED
INSP	INSPECTION
INST	INSTRUMENT
INT	INTERIOR
INV	INVERT
IP	IRON PIPE
IPS	IRON PIPE SIZE
IRRG	IRRIGATION
JAN	JANITOR
JC	JUNCTION CHAMBER
JCT	JUNCTION
JS	JUNCTION STRUCTURE
JSTS	JOISTS
JT	JOINT
k	KILO
K	KELVIN / KARAT
kg	KILOGRAM
km	KILOMETER
kV	KILOVOLT
KVA	KILOVOLT AMPERE
kW	KILOWATT
kWh	KILOWATT HOUR
L	LITER / LENGTH / ANGLE
LAB	LABORATORY
LAM	LAMINATED
LAT	LATERAL
LAV	LAVATORY
LB	POUND
LCP	LOCAL CONTROL PANEL
LCS	LOCAL CONTROL STATION
LD	LOCAL DEPRESSION
LDG	LANDING
LEV	LEVEL
LF	LINEAR FOOT
LG	LENGTH / LONG
LH	LAMP HOLE / LEFT HAND
LL	LIVE LOAD
LLH	LONG LEG HORIZONTAL
LLV	LONG LEG VERTICAL
LOC	LOCATION
LOL	LAYOUT LINE
LONG	LONGITUDINAL
LP	LOW POINT / LOW PRESSURE / LAMP POST
LPG	LIQUID PETROLEUM GAS
LT	LEFT / LIGHT
LTS	LIME TREATED SOIL
LW	LOW WATER
LWL	LOW WATER LEVEL
LWR	LOWER
m	METER
M	MALE (PIPE THREAD)
mA	MILLIAMPS
MACH	MACHINE
MAG	MAGNETIC
MAINT	MAINTENANCE
MAN	MANUAL
MAS	MASONRY
MAT	MATERIAL
MAX	MAXIMUM
MB	MAIL BOX / MACHINE BOLT
MCC	MOTOR CONTROL CENTER
MCR	MIDDLE OF CURB RETURN
MEAS	MEASURE
MECH	MECHANICAL
MED	MEDIUM
MEMB	MEMBER
MFR	MANUFACTURER
MFRD	MANUFACTURED
MGD	MILLION GALLONS PER DAY
MH	MANHOLE / MAINTENANCE HOLE
MHT	MEAN HIGH TIDE
MHW	MEAN HIGH WATER
MI	MALLEABLE IRON / MILE
MICRON	1/1,000,000 METER
MIL	MILITARY / 1/1,000TH INCH
MIN	MINIMUM / MINUTE
MIR	MIRROR
MISC	MISCELLANEOUS
MK	MARK
MLW	MEAN LOW WATER
mm	MILLIMETER
MO	MOTOR OPERATED / MASONRY OPENING
MOD	MODEL
MON	MONUMENT
MOR	MORTAR
MS	MOP SINK
MSL	MEAN SEA LEVEL
MTC	MECHANICAL-TYPE COUPLING
MTD	MOUNTED
MTG	MOUNTING
MTL	METAL
MTR	MOTOR
N	NORTH
NaOCl	SODIUM HYPOCHLORITE
NaOH	SODIUM HYDROXIDE (CAUSTIC SODA)
NC	NORMALLY CLOSED
NEC	NATIONAL ELECTRICAL CODE
NEMA	NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION
NF	NEAR FACE
NFPA	NATIONAL FIRE PROTECTION ASSOCIATION
NG	NATURAL GRADE / NATURAL GAS
NIC	NOT IN CONTRACT
NO	NUMBER / NORMALLY OPEN
NOM	NOMINAL
NPS	NOMINAL PIPE SIZE
NPT	NATIONAL PIPE THREAD
NRCP	NON-REINFORCED CONCRETE PIPE
NRS	NON-RISING STEM
NS	NEAR SIDE
NTS	NOT TO SCALE
OBJ	OBJECT
OC	ON CENTER / OVER-CROSSING
OD	OUTSIDE DIAMETER / OVERALL DIMENSION
OE	OUTER EDGE
OF	OVERFLOW / OUTSIDE FACE
OFD	OVERFLOW DRAIN
OFF	OFFICE
OH	OVER HEAD
OHW	OVERHEAD WIRES
OPER	OPERATOR / OPERATING
OPNG	OPENING
OPP	OPPOSITE
ORIG	ORIGINAL
OS&Y	OUTSIDE SCREW AND YOKE
OSA	OUTSIDE AIR
OSHA	OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
OWG	OIL. WATER. GAS
OZ	OUNCE
P	POLE / PAGE / PIPE
P/S	POLE AND SHELF
PA	PLANTING AREA
PART	PARTITION
PAVMT	PAVEMENT
PB	POLYBUTYLENE / PULL BOX
PC	POINT OF CURVATURE / PRIMARY CLARIFIER / PORTLAND CEMENT
PCC	PORTLAND CEMENT CONCRETE / POINT OF COMPOUND CURVE
PCOTG	PRESSURE CLEANOUT TO GRADE
PCVC	POINT OF COMPOUND VERTICAL CURVE
PE	PLANT EFFLUENT / POLYETHYLENE / POLYELECTROLYTE POLYMER
PG	PRESSURE GAGE
pH	RECIPROCAL LOG OF HYDROGEN ION CONCENTRATION
PI	PLANT INFLUENT / POINT OF INTERSECTION
PK	PARKING
PL	PLATE / PROPERTY LINE / PLACE
PLAS	PLASTER / PLASTIC
PLT	PLANT
PLWD	PLYWOOD
PM	PRESSED METAL
PNEU	PNEUMATIC
PNL	PANEL
POB	POINT OF BEGINNING
POC	POINT OF CONNECTION
POT	POINT OF TANGENT
PP	POWER POLE / POLYPROPYLENE
PPD	POUNDS PER DAY
PPH	POUNDS PER HOUR
PPM	POUNDS PER MINUTE
PR	PAIR
PRC	POINT OF REVERSE CURVE
PRCT	PRECAST
PREFAB	PREFABRICATED
PRESS	PRESSURE
PROF	PROFILE
PRV	PRESSURE REGULATING, RELIEF OR REDUCING VALVE
PRVC	POINT OF REVERSE VERTICAL CURVE
PS	PRESSURE SWITCH
PSF	POUNDS PER SQUARE FOOT
PSI	POUNDS PER SQUARE INCH
PSIA	POUNDS PER SQUARE INCH ABSOLUTE
PSIG	POUNDS PER SQUARE INCH GAUGE
PT	POINT OF TANGENCY / PAINT / PRESSURE
PTFE	POLYTETRAFLUOROETHYLENE (TEFLON)
PV	PLUG VALVE
PVC	POLYVINYL CHLORIDE
PVDF	POLYVINYLIDENE FLUORIDE (KYNAR)
PW	POTABLE WATER
QT	QUARRY TILE
QTY	QUANTITY
QUAD	QUADRANGLE / QUADRANT
R	RADIUS / RISER / RATE OF SLOPE
R&O	ROCK AND OIL
R/W	RIGHT OF WAY
RAC	RECYCLED ASPHALT CONCRETE
RAG	RETURN AIR GRILLE
RAP	RECLAIMED ASPHALT PAVEMENT
RAS	RETURN ACTIVATED SLUDGE
RC	REINFORCED CONCRETE
RCP	REINFORCED CONCRETE PIPE
RD	ROAD / ROOF DRAIN / ROUND
RED	REDUCER / REDUCING
REF	REFERENCE / REFER / REFRIGERATOR
REG	REGULATING
REINF	REINFORCE / REINFORCED
REQD	REQUIRED
RESIL	RESILIENT
RET	RETAINING / RETURN
REV	REVISION
REW	RECLAIMED WATER
RF	ROOF / RAISED FOUNDATION / ROUGH FACE
RFG	ROOFING
RGE	REGISTERED GEOTECHNICAL ENGINEER
RH	REDHEAD / RIGHT HAND
RM	ROOM
RO	ROUGH OPENING
RPM	REVOLUTIONS PER MINUTE
RR	RAILROAD
RS	RISING STEM
RSL	RAW SLUDGE
RT	RIGHT
RTP	REINFORCED THERMOSETTING PLASTIC
RTU	REMOTE TERMINAL UNIT
RW	REDWOOD
RWL	RAINWATER LEADER
S	SOUTH / SCUM / SINK / SECOND / SLOPE /
S/O	SOUTH OF
SAM	SAMPLE
SAN	SANITARY
SBR	STYRENE BUTADIENE (RUBBER)
SC	SECONDARY CLARIFIER
SCCP	STEEL CYLINDER CONCRETE PIPE
SCD	SCREWED
SCFM	STANDARD CUBIC FEET PER MINUTE
SCH	SCHEDULE
SD	SANITARY DRAIN / SMOKE DETECTOR
SDR	STANDARD THERMOPLASTIC PIPE DIMENSION RATIO / STORM DRAIN
SEC	SECONDARY / SECTION
SER	SERIES
SETT	SETTING
SF	SQUARE FOOT
SH	SHOWER
SHELV	SHELVING
SHT	SHEET
SHTG	SHEATHING
SIM	SIMILAR
SL	SLUDGE
SLDG	SLIDING
SLG	SLUICE GATE
SOG	SLAB ON GRADE
SOLN	SOLUTION
SP	STATIC PRESSURE / SPARE CHEMICAL
SPEC	SPECIFICATION
SPK	SPIKE
SQ	SQUARE
SS	STAINLESS STEEL / SANITARY SEWER / SERVICE SINK
SSB	SELECT SUB-BASE
SSPWC	STANDARD SPECIFICATION FOR PUBLIC WORKS CONSTRUCTION
SSU	SECONDS SAYBOLT UNIVERSAL
ST	STREET / STATE
STA	STATION
STC	SLEEVE-TYPE COUPLING
STD	STANDARD
STK	STAKE
STL	STEEL
STM	STEAM
STR	STRAIGHT / STRUCTURAL
SU	STEAM LINE
SUCT	SUCTION
SV	SOLENOID VALVE
SW	SIDEWALK
SWD	SIDEWALK DRAIN
SWGR	SWITCHGEAR
SWR	SIDEWALL REGISTER
SY	SQUARE YARD
SYM	SYMMETRICAL / SYMBOL
SYS	SYSTEM
T	THERMOSTAT / TREAD OF STAIR / TANGENT
T&B	TOP AND BOTTOM
T&G	TONGUE AND GROOVE
TAN	TANGENT
TB	TACK BOARD
TBE	THREAD BOTH ENDS
TBM	TEMPORARY BENCH MARK
TC	TOP OF CURB
TCV	TEMPERATURE CONTROL VALVE
TEL	TELEPHONE
TEMP	TEMPERATURE / TEMPORARY
TF	TOP OF FOOTING
TH	TEST HOLE
THK	THICK / THICKNESS
THR	THRESHOLD
THR'D	THREADED
TK	TANK / TACK
TL	TRAVERSE LINE
TOC	TOP OF CONCRETE
TOE	THREAD ONE END
TOL	TOILET
TOM	TOP OF MASONRY
TOP	TOP OF PIPE
TOPO	TOPOGRAPHIC
TOS	TOP OF STEEL
TOW	TOP OF WALL
TP	TELEPHONE POLE
TR	TRACT
TRANS	TRANSMITTER / TRANSITION /TRANSMISSION
TS	TRAFFIC SIGNAL
TSB	TOP SET BASE
TSC	TRAFFIC SIGNAL CONDUIT
TV	THERMOSTATIC VALVE / TELEVISION
TW	THERMOMETER WELL /TRAVELED WAY
TYP	TYPICAL
UB	UNION BONNET
UBC	UNIFORM BUILDING CODE
UC	UNDER-CROSSING
UG	UNDERGROUND
UGC	UNDERGROUND CONDUIT
UH	UNIT HEATER
UL	UNDERWRITERS LABORATORIES
UNID	UNIDENTIFIED
UNO	UNLESS NOTED OTHERWISE
UOI	UNLESS OTHERWISE INDICATED
UPS	UNINTERRUPTABLE POWER SUPPLY
UR	URINAL
USA	UNDERGROUND SERVICE ALERT
USGS	UNITED STATES GEOLOGICAL SURVEY
UV	ULTRAVIOLET
UW	UTILITY WATER
V	VALVE / VERTICAL / VENT / VOLT / VOLUME
VAC	VACUUM
VAR	VARIES / VARIABLE
VB	VALVE BOX
VC	VERTICAL CURVE
VCP	VITRIFIED CLAY PIPE
VERT	VERTICAL
VOL	VOLUME
VPI	VERTICAL POINT OF INTERSECTION
VSL	VERTICALLY SLOTTED
VTC	VENT TO CEILING
VTR	VENT THROUGH ROOF
VWC	VINYL WALL COVERING
VWM	VERIFY WITH MANUFACTURE
W	WEST / WASTE / WIDTH / WIDE FLANGE / WATER
W/	WITH
W/O	WEST OF / WITHOUT
WC	WATER COLUMN / WATER CLOSET
WCO	WALL CLEANOUT
WD	WOOD
WDW	WINDOW
WH	WATER HEATER
WI	WROUGHT IRON
WM	WATER METER
WOG	WATER, OIL, OR GAS
WP	WATERPROOFING / WORKING PRESSURE / WORK POINT
WPJ	WEAKEN PLANE JOINT
WS	WATER SURFACE
WSTP	WATERSTOP
WT	WEIGHT
WWF	WELDED WIRE FABRIC
WWP	WATER WORKING PRESSURE
XCONN	CROSS CONNECTION
XS	EXTRA STRONG
XSEC	CROSS SECTION
XXS	DOUBLE EXTRA STRONG
YD	YARD
YR	YEAR
Z	ZERO / ZONE
ZN	ZINC
#	POUND
&	AND
@	AT

FOR ADDITIONAL ABBREVIATIONS SEE:

CIVIL - GENERAL CIVIL SHEETS
PIPING - PIPING SCHEDULE
ELECTRICAL - GENERAL ELECTRICAL SHEETS
INSTRUMENTATION - GENERAL INSTRUMENTATION SHEETS

OTHER ABBREVIATIONS CONFORM TO ANSI STANDARD ABBREVIATIONS Z32.2.3

REV 080115

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SCALE: NO SCALE

WARNING: 0 ½ 1 — IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

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DRAWN ____
CHECKED ____

SHEET-G-ABBRV

PROJECT: GENERAL APPENDIX 7A-2 ABBREVIATIONS

SHEET: G-#

JobNumber

GENERAL SYMBOLOGY

- NEW CONSTRUCTION
- EXISTING (SCREENED)
- FUTURE (PHANTOM)
- EXISTING TO BE REMOVED OR DEMOLISHED

MATERIAL SYMBOLOGY

- CONCRETE (PLAN AND SECTION)
- GROUT OR SAND (PLAN AND SECTION)
- BRICK (PLAN AND SECTION)
- CMU (PLAN AND SECTION)
- STEEL/METAL/FRP (SMALL SCALE SECTION)
- CHECKER PLATE OR SOLID FRP GRATING (PLAN)
- CHECKER PLATE (SECTION)
- GRATING (PLAN)
- GRATING OR SOLID FRP GRATING (SECTION)
- SAFETY GRATING (PLAN)
- SAFETY GRATING (SECTION)
- RAILING (PLAN)
- WOOD (PLAN OR ELEVATION)
- LUMBER/FRAMING - NOMINAL
- LUMBER - TRIMMED (BLOCKING OR SHIMS)
- OR — GLULAM (SECTION)
- GLULAM (ELEVATION)
- OR — PLYWOOD (SMALL SCALE)
- FINISHED GRADE
- GRAVEL/DRAINROCK/AGGREGATE BASE

VALVE AND GATE ACTUATORS

- DIAPHRAGM OPERATOR
- D — D = DIGITAL, E/H = ELECTROHYDRAULIC, P = PNEUMATIC, S = SOLENOID, T = TEMPERATURE
- HAND / MANUAL OPERATOR (ALSO SHOWN AS NO OPERATOR)
- M — MOTOR OPERATOR
- PISTON ACTUATOR
- PRESSURE BALANCED DIAPHRAGM ACTUATOR
- PRESSURE REGULATOR WITH EXTERIOR TAP
- PRESSURE REGULATOR (SELF CONTAINED)
- PRESSURE RELIEF OR SAFETY ACTUATOR
- WEIGHT BALANCED OPERATOR

VALVES

- 3 WAY MULTI-PORT VALVE
- 4 WAY MULTI-PORT VALVE
- AIR VACUUM, AIR RELEASE, OR AIR VACUUM AND AIR RELEASE ASSEMBLY
- ANGLE VALVE
- BACK-PRESSURE VALVE
- BACKFLOW PREVENTER VALVE
- BACKWATER VALVE
- BALL VALVE
- BUTTERFLY VALVE
- CHECK VALVE
- CHECK VALVE - ANGLE
- CHECK VALVE - BALL
- CHECK VALVE - SILENT
- CHECK VALVE - STOP
- CONE VALVE
- DIAPHRAGM VALVE
- FLAP VALVE
- GATE VALVE
- GLOBE VALVE
- HOSE BIBB VALVE FROM TOP, FRONT AND SIDE VIEW
- NEEDLE VALVE
- PINCH VALVE
- PLUG VALVE - ECCENTRIC
- PLUG VALVE - LUBRICATED
- OR — PRESSURE REGULATING VALVE
- PRESSURE RELIEF VALVE
- SLEEVE VALVE
- TELESCOPING VALVE

GATES

- SLIDE GATE (CAST IRON, ALUMINUM OR STAINLESS STEEL)
- STOP GATE OR SHEAR GATE

PUMPS & COMPRESSORS

- AIR DRIVEN DIAPHRAGM PUMP
- HORIZONTAL ANSI END SUCTION PUMP
- CENTRIFUGAL PUMP
- CENTRIFUGAL WET PIT PUMP OR TURBINE PUMP
- CHEMICAL METERING PUMP
- CIRCULATING PUMP
- DRUM PUMP
- GEAR PUMP OR ROTARY POSITIVE DISPLACEMENT BLOWER
- HORIZONTAL SPLIT CASED PUMP
- HOSE PUMP
- PISTON PUMP
- PROGRESSIVE CAVITY PUMP
- ROTARY LOBE PUMP
- SAMPLE PUMP
- SUBMERSIBLE PUMP
- SUBMERSIBLE TURBINE PUMP
- VERTICAL TURBINE PUMP
- PISTON DRIVEN COMPRESSOR
- COMPRESSOR

FLOW MEASUREMENT INSTRUMENTS

- DM — DENSITY FLOWMETER
- DISPLACEMENT FLOWMETER
- FLOW ORIFICE
- FLOW ORIFACE WITH QUICK CHANGE FITTINGS
- FLOW TUBE
- FLOW TURBINE
- FLOW VANE
- FLUME

FLOW MEASUREMENT INSTRUMENTS (CONTINUED)

- MM — MAGNETIC FLOWMETER
- PADDLE WHEEL METER
- PITOT TUBE METER (DOUBLE)
- PITOT TUBE METER (SINGLE)
- ROTAMETER / VARIABLE AREA FLOWMETER
- ULTRASONIC FLOWMETER
- VENTURI FLOWMETER
- VORTEX SHEDDING FLOWMETER
- WEIR METER

PIPING ENDS (SINGLE-LINE)

- BLIND FLANGE
- CAP - BREATHER
- CAP - SCREW / THREADED
- CAP - WELDED
- CAP - QUICK DISCONNECT
- EXPANSION JOINT
- FLANGED
- FLANGED COUPLING ADAPTER
- FLANGED COUPLING ADAPTER - RESTRAINED
- OR — FLEXIBLE CONNECTION - BELLOWS TYPE
- GROOVED END COUPLING
- MECHANICAL JOINT
- PIPE MATERIAL CHANGE
- PUSH-ON JOINT - BELL AND SPIGOT
- PUSH-ON JOINT - RESTRAINED
- REDUCER - CONCENTRIC
- REDUCER - ECCENTRIC
- REMOVABLE SPOOL PIECE
- SLEEVE TYPE COUPLING
- SLEEVE TYPE COUPLING - RESTRAINED
- UNION
- WELDED

REFERENCE SYMBOLS

SECTION IDENTIFICATION

SECTION LETTER — X — X-### — SHEET ON WHICH SECTION IS SHOWN

SECTION — SCALE: #/#" = 1'-0" — SHEET ON WHICH SECTION IS CUT

DETAIL IDENTIFICATION

DETAIL NUMBER — # — X-### — SHEET ON WHICH DETAIL IS SHOWN

DETAIL — SCALE: #/#" = 1'-0" — SHEET ON WHICH DETAIL IS CALLED-OUT

STANDARD DETAIL IDENTIFICATION

DETAIL NUMBER — C-302

DETAIL SUB-TITLE — C-302

STANDARD DETAILS ARE LOCATED ON DISCIPLINE GENERAL SHEETS, IN NUMERICAL ORDER

INTERIOR ELEVATION IDENTIFICATION

ELEVATION NUMBER — B, C, A, D — 6 — 1A-3 — OR — 6 — 1A-3 — SHEET ON WHICH ELEVATION IS SHOWN

6 — 1A-3 — ELEVATION — SCALE: #/#" = 1'-0" — SHEET ON WHICH ELEVATION IS CALLED-OUT

6A — 1A-3 — ELEVATION — SCALE: #/#" = 1'-0"

EXTERIOR ELEVATION IDENTIFICATION

X — N, S, E or W

NORTH ELEVATION — SCALE: #/#" = 1'-0"

EQUIPMENT IDENTIFICATION

SEE EQUIPMENT SCHEDULE/SPECIFICATIONS

EQUIPMENT DESIGNATOR — EQUIPMENT NUMBER — 12MAU-05 — AREA NUMBER

MISCELLANEOUS

4-12	ROOM NUMBER	###	COORDINATE POINT
2-16	DOOR NUMBER	Ø	ROUND OR DIAMETER
1-8	WINDOW NUMBER	@	AT
13	ACCESSORY NUMBER	∠	ANGLE
4	WALL TYPE NUMBER	℄	CENTERLINE
A	SHEET KEY NOTES		

DISCIPLINE SPECIFIC SYMBOLS ARE SHOWN ON THE DISCIPLINE GENERAL DRAWINGS.

FOR WELDING SYMBOLS USE AMERICAN WELDING SOCIETY STANDARD SYMBOLS.

REV 012216

REV	DATE	BY	DESCRIPTION	SCALE	WARNING		SHEET
				NO SCALE	0 ½ 1 — IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE	DESIGNED / DRAWN / CHECKED	

SHEET-GSYMB1

GENERAL
APPENDIX 7A-2
SYMBOLS - I

SHEET G-#

JobNumber

Plot Date: 01-FEB-2016 13:02
User: slbraat
PlotScale: 0.083333:1
DesignScript: MWH_Iplot_Pentable_2012i.pen
ColorTable: bw.ctb
Model: Layout1
File: _CBPG Chapter_07 - Appendix 7A-2 Symbols Sheets.dgn

PIPING ACCESSORIES

- ANNULAR SEAL
- ATMOSPHERIC VENT
- CHLORINE INJECTOR OR CHEMICAL EDUCTOR
- CONDENSATE TRAP (T)
- DIAPHRAGM SEAL
- DRAIN
- EXPANSION CHAMBER WITH RUPTURE DISK
- FLAME ARRESTOR (F/A)
- FLOOR CLEANOUT (FCO)
- FLOOR DRAIN
- FLOW SIGHT GLASS (FG)
- FLOOR SINK
- HUB DRAIN
- INLINE MIXER
- PIPE SUPPORT (PLAN)
- PULSATION DAMPENER
- RUPTURE DISK
- STRAINER - BASKET TYPE
- STRAINER - DUPLEX BASKET TYPE
- STRAINER - WYE TYPE
- TRAP (T)
- WALL CLEANOUT (WCO OR WCO)

WASTEWATER EQUIPMENT

- BELT FILTER PRESS
- CENTRIFUGE
- GRAVITY BELT THICKENER
- SHAFTED CONVEYOR
- SHAFTLESS CONVEYOR
- SLUDGE GRINDER

HVAC

- AIR CONDITIONING UNIT
- AIR FILTER
- AIR HANDLING UNIT
- AIR TURNING VANES IN DUCT
- CEILING RETURN OR EXHAUST AIR GRILLE OR REGISTER (SIZE IN INCHES, WIDTH X HEIGHT) (SIZE CFM)
- CEILING SUPPLY DIFFUSER (SIZE IN INCHES) (SIZE CFM)
- DAMPER
- DAMPER - DEFLECTING TYPE (DD)
- DAMPER - FIRE DAMPER WITH ACCESS DOOR (FD AD)
- DAMPER - MANUAL VOLUME (VD)
- DAMPER - MOTORIZED
- DEHUMIDIFIER
- DUCT (FIRST DIMENSION, DUCT SIDE SHOWN; SECOND DIMENSION, DUCT SIDE NOT SHOWN) (12x24)
- DUCT WITH ACOUSTICAL LINING
- DUCT SMOKE DETECTOR
- EVAPORATIVE COOLER
- EXHAUST OR RETURN AIR DUCT (FIRST DIMENSION, DUCT WIDTH) (24x12)
- EXHAUST OR RETURN AIR GRILLE OR REGISTER (SIZE IN INCHES, WIDTH X HEIGHT) (SIZE CFM)
- FIRE EXTINGUISHER (FE)
- FIRE HOSE CABINET (FHC)
- HEATER
- HVAC BOILER
- HVAC FAN
- HVAC LOUVER
- THERMOSTAT (T)
- STEAM GENERATOR
- SUPPLY GRILLE OR REGISTER (SIZE IN INCHES, WIDTH X HEIGHT) (SIZE CFM)
- SUPPLY OR OUTSIDE AIR DUCT (FIRST DIMENSION, DUCT WIDTH) (24x12)
- UNIT HEATER
- WATER HEATER

MISCELLANEOUS

- AERATOR (M)
- AFTER COOLER
- BLOWER
- BRIDGE CRANE
- CALIBRATION COLUMN
- CONTAINER SCALE
- DEMISTOR
- FILTER (F)
- GAS BOTTLE
- HEAT EXCHANGER - PLATE TYPE
- HEAT EXCHANGER - STRAIGHT TYPE
- HEAT EXCHANGER - U TUBE
- HORN
- MISCELLANEOUS EQUIPMENT
- MIXER
- MOTOR SYMBOL (M)
- PRESSURE GAUGE (G)
- PRESSURE GAUGE WITH DIAPHRAGM SEAL (G)
- PRESSURE SWITCH (S)
- PRESSURE SWITCH WITH DIAPHRAGM SEAL (S)
- PRESSURE VESSEL
- PIPE MATERIAL CHANGE
- RADIO ANTENNA
- REFRIGERATOR DRYER
- SAMPLE COOLER
- TANK WITH CONE SHAPED ROOF
- TANK WITH DOME ROOF
- TANK WITH FLOATING COVER
- TANK, VESSEL, OR BIN
- TEMPERING TANK
- WATER LEVEL

REV 040407

OTHER

REV	DATE	BY	DESCRIPTION

SCALE: NO SCALE

WARNING: 0 ½ 1 — IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

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SHEET-GSYMB2

GENERAL
APPENDIX 7A-2
SYMBOLS - II

SHEET G-#
JobNumber

CIVIL GENERAL NOTES

GENERAL

1. THE CONTRACTOR SHALL TAKE ALL PRECAUTIONARY MEASURES NECESSARY TO PROTECT EXISTING IMPROVEMENTS WHICH ARE TO REMAIN IN PLACE FROM DAMAGE. ALL IMPROVEMENTS DAMAGED BY THE CONTRACTOR'S OPERATIONS SHALL BE EXPEDITIOUSLY REPAIRED OR RECONSTRUCTED AT THE CONTRACTOR'S EXPENSE WITHOUT ADDITIONAL COMPENSATION.
2. THE CONTRACTOR SHALL PROPERLY DISPOSE OF ALL DEBRIS FROM DEMOLITION AT CONTRACTORS EXPENSE.
3. ALL BUILDING COORDINATES ARE TO OUTSIDE CORNER OF COLUMN OR BUILDING.
4. THE CONTRACTOR SHALL DISPOSE OF ALL NON-ORGANIC WASTES SUCH AS OLD GUNITE, PIPING, ROCK RUBBLE ETC... AT AN APPROVED LANDFILL OR, OTHER SUITABLE DISPOSAL SITES AT THE CONTRACTOR'S EXPENSE.
5. CONTRACTOR SHALL RESTORE ALL SURVEY MONUMENTS THAT ARE DAMAGED OR DESTROYED DURING CONSTRUCTION.

UTILITIES

1. PRIOR TO THE START OF CONSTRUCTION, THE CONTRACTOR SHALL LOCATE ALL EXISTING UTILITIES IN AND AROUND THE AREAS OF NEW CONSTRUCTION. THE CONTRACTOR SHALL POTHOLE FOR EXISTING UTILITIES PRIOR TO SUBMITTAL OF SHOP DRAWINGS, FOR POINTS OF CONNECTIONS.
2. THE CONTRACTOR SHALL PROTECT ALL REMAINING EXISTING UTILITIES.
3. LOCATIONS OF UNDERGROUND UTILITIES SHOWN ON THE DRAWINGS WERE OBTAINED FROM AVAILABLE RECORDS. THE CONTRACTOR SHALL VERIFY ALL LOCATIONS AND ELEVATIONS AND SHALL TAKE ALL PRECAUTIONARY MEASURES NECESSARY TO PROTECT UTILITY LINES WHETHER SHOWN OR NOT SHOWN.
4. PRIOR TO ANY CONNECTION TO AN EXISTING UTILITY, THE CONTRACTOR SHALL COORDINATE WITH THE UTILITY OWNER.
5. PRIOR TO ANY EXCAVATION IN THE VICINITY OF ANY EXISTING UNDERGROUND FACILITIES, INCLUDING ALL WATER, SEWER, STORM DRAIN, GAS, PETROLIUM PRODUCTS, OR OTHER PIPELINES; ALL BURIED ELECTRIC POWER, COMMUNICATIONS, OR TELEVISION CABLES; ALL TRAFFIC SIGNAL AND STREET LIGHTING FACILITIES; AND ALL ROADWAY, STATE HIGHWAY, AND RAILROAD RIGHTS-OF-WAY, THE CONTRACTOR SHALL NOTIFY THE RESPECTIVE AUTHORITIES REPRESENTING THE OWNERS OR AGENCIES RESPONSIBLE FOR SUCH FACILITIES NOT LESS THAN 3 DAYS NOR MORE THAN 7 DAYS PRIOR TO EXCAVATION SO THAT A REPRESENTATIVE OF SAID OWNERS OR AGENCIES CAN BE PRESENT DURING SUCH WORK IF THEY SO DESIRE. IN THE CASE OF THE UNDERGROUND UTILITY SERVICE ALERT CENTER, THIS NOTICE WILL GIVE THEM TIME TO MARK THE LOCATION OF THE UTILITIES. THE CONTRACTOR SHALL ALSO NOTIFY THE REGIONAL OR LOCAL UNDERGROUND SERVICE ALERT COMPANY AT LEAST 3 DAYS, BUT NO MORE THAN 7 DAYS, PRIOR TO SUCH EXCAVATION.

PIPING

1. THE CONTRACTOR SHALL COMPLY WITH THE STATE DEPARTMENT OF HEALTH SERVICES CRITERIA FOR THE SEPARATION OF WATER MAINS AND SANITARY SEWERS.
2. THE CONTRACTOR SHALL PROVIDE A MINIMUM OF [[[36]]] INCHES OF COVER ON ALL PIPELINES UNLESS OTHERWISE SHOWN OR DIRECTED.
3. STRAIGHT SLOPES SHALL BE MAINTAINED BETWEEN INVERT ELEVATIONS SHOWN OR SPECIFIED.
4. THE CONTRACTOR SHALL ADJUST ALL VALVE BOXES, PULL BOXES AND MANHOLES TO FINISHED GRADE UNLESS OTHERWISE SHOWN OR SPECIFIED. MANHOLES IN OPEN FIELDS SHALL BE SET ONE FOOT ABOVE GRADE. APPROXIMATE RIM ELEVATIONS ARE SHOWN ON DRAWINGS.
5. ALL PIPE TRENCHING AND BACKFILL SHALL BE IN ACCORDANCE WITH DETAIL C-602 FOR RIGID PIPE AND C-601 FOR FLEXIBLE PIPE. THE PIPING SHOWN ON THESE PLANS SHALL BE RESTRAINED JOINT DESIGN AT ALL SLEEVE TYPE COUPLINGS.
6. THE CONTRACTOR SHALL PROVIDE TWO FLEXIBLE SLEEVE TYPE COUPLINGS WITH RESTRAINED JOINTS FOR EACH PIPE PENETRATING A STRUCTURE. THE COUPLINGS AND FLEXIBLE JOINTS SHALL BE 3-FEET AND 8-FEET AWAY FROM THE STRUCTURE. ALL PIPING SHALL BE RESTRAINED JOINT DESIGN UNLESS INDICATED OTHERWISE. COUPLINGS AND RESTRAINED JOINTS SHALL BE PROVIDED WHETHER SHOWN ON THE DRAWINGS OR NOT. STEEL PIPE RESTRAINED HARNESS SETS SHALL BE PROVIDED IN ACCORDANCE WITH AWAA M-11. ALL OTHER PIPES, COUPLINGS AND RESTRAINED JOINTS SHALL BE APPROVED BY THE ENGINEER. ALL RESTRAINED JOINTS SHALL BE IN ACCORDANCE WITH THE PIPE MANUFACTURERS' RECOMMENDATIONS.

EROSION CONTROL

1. THE CONTRACTOR SHALL SUBMIT AN EROSION CONTROL PLAN FOR WORK DURING THE CONSTRUCTION, SIGNED AND STAMPED BY A REGISTERED CIVIL ENGINEER PRIOR TO THE START OF CONSTRUCTION.
   a. ALL SLOPES SHALL BE PROTECTED FROM EROSION DURING ROUGH GRADING OPERATIONS AND THEREAFTER, UNTIL INSTALLATION OF FINAL GROUNDCOVER (SEE LANDSCAPE PLANS FOR FINAL GROUNDCOVER).
   b. ALL SLOPE PROTECTION SWALES SHALL BE CONSTRUCTED AT THE SAME TIME AS BANKS ARE GRADED.
   c. THE CONTRACTOR IS RESPONSIBLE FOR IMPLEMENTATION AND MAINTENANCE OF EROSION CONTROL MEASURES CONTAINED WITHIN THE CONTRACT SPECIFICATIONS OR AS REQUIRED BY THE CITY, DISTRICT, OR OTHER REGULATORY AUTHORITY. THE CONTRACTOR SHALL ALSO PROVIDE ANY ADDITIONAL EROSION CONTROL MEASURES (E.G. HYDROSEEDING, MULCHING OF STRAW, SAND BAGGING, DIVERSION DITCHES, ETC.) DICTATED BY FIELD CONDITIONS TO PREVENT EROSION OR THE INTRODUCTION OF DIRT, MUD, OR DEBRIS INTO EXISTING PUBLIC STREETS, WATERWAYS, OR ONTO ADJACENT PROPERTIES DURING ANY PHASE OF CONSTRUCTION OPERATIONS.

CIVIL GENERAL NOTES - CONTINUED

SURVEY AND CONTROL

XXXXXX
XXXX

XXXXX
XXXXX

PERMITTING

XXXXXX
XXXX

XXXXX
XXXXX

DRAINAGE SYMBOLS

RIPRAP
HAY BALE
SILT FENCE

CORROSION CONTROL SYMBOLS

ETS — ELECTROLYSIS TEST STATION

T — CATHODIC TEST STATION

CTS	CORROSION TEST STATION
CATS	CASING TEST STATION
IJTS	INSULATING JOINT TEST STATION
FPTS	FOREIGN PIPELINE TEST STATION
CSTS	CURRENT SPAN TEST STATION

GENERAL CIVIL SYMBOLS

NEW
EXISTING
FUTURE
EXISTING TO BE REMOVED OR DEMOLISHED
CENTERLINE
EARTH (IN SECTION)
COMPACTED EARTH (IN SECTION)
S=0.0123 — SLOPE ON PAVED SURFACE
3:1 — BERM SLOPE (HORZ TO VERT)

TOPOGRAPHY AND MAPPING SYMBOLS

125 — MAJOR CONTOURS
MINOR CONTOURS
TOP OF SLOPE
TOE OF SLOPE
P/L — PROPERTY LINE
R/W — RIGHT-OF-WAY LINE
GB — GRADE BREAK
R — RIDGE LINE
ESMT — EASEMENT LINE
TEMP ESMT — TEMPORARY EASEMENT LINE
TRAIL OR DIRT ROAD
FLOW LINE
FLOOD HAZARD AREA
EDGE OF WETLANDS
RAILROAD
GUARDRAIL (PERMANENT)
GUARDRAIL (REMOVABLE)
VEGETATION
WELL

GEOTECHNICAL SYMBOLS

B-X — SOIL BORING LOCATION
TEST PIT LOCATION
XX — OBSERVATION HOLE
MW — MONITORING WELL

PIPING AND UTILITIES

UTILITIES (SINGLE LINE) SEE PIPE SCHEDULE FOR ADDITONAL PIPING INFO

G — UTILITIES (SIZE WHERE NOTED)
G — G — UNDERGROUND

G	NATURAL GAS LINE
HPG	HIGH PRESSURE GAS LINE
LPG	LIQUID PETROLEUM GAS LINE
W	WATER
PW	POTABLE WATER
FIRE	FIRE SUPPLY WATER LINE
REW	RECLAIMED WATER
UW	UTILITY / NON-POTABLE WATER
IRRG	IRRIGATION LINE
SDR	STORM DRAIN
SS	SANITARY SEWER
STM	STEAM LINE
TEL	TELEPHONE
COMM	COMMUNICATIONS LINE
FOC	FIBER OPTIC CABLE
CATV	CABLE TV
E	POWER
UNID	UNIDENTIFIED
ABND	ABANDONED UTILITY

BUMPED HEAD
PP — POWER POLE
BURIED ACCESS MANOLE (IN PLAN) LOCATE ON SIDE SHOWN
BURIED ACCESS MANHOLE (IN PROFILE)
AV/AR VALVE (IN PLAN)
AV/AR VALVE (IN PROFILE)
A/R VALVE (IN PLAN) LOCATE ON SIDE SHOWN
BLOWOFF (IN PROFILE) LOCATE ON SIDE SHOWN
BLOWOFF (IN PLAN)
BLOWOFF (IN PROFILE)
FH — FIRE HYDRANT (IN PLAN)
FH — FIRE HYDRANT (IN PROFILE)
MH — MANHOLE (IN PLAN)
MH — MANHOLE (IN PROFILE)
COTG PCOTG / COTG PCOTG — CLEANOUT TO GRADE OR PRESSURE CLEANOUT TO GRADE (IN PLAN)
COTG PCOTG — CLEANOUT TO GRADE OR PRESSURE CLEANOUT TO GRADE (IN PROFILE)
GATE VALVE
BUTTERFLY VALVE
ECCENTRIC PLUG VALVE
LUBRICATED PLUG VALVE

ROAD AND PAVING SYMBOLS

ASPHALT CEMENT PAVING
CONCRETE PAVING (HEAVY DUTY)
GRAVEL PAVING
CONCRETE PAVING (LIGHT DUTY) SIDEWALKS ETC...
CONCRETE CURB
CONCRETE CURB AND GUTTER
DROP INLET CATCH BASIN
CURBSIDE DROP INLET CATCH BASIN WITH LOCAL DEPRESSION
SIDE INLET CATCH BASIN WITH LOCAL DEPRESSION
CONCRETE WALK
DRIVEWAY/ACCESS RAMP

CONTROL SYMBOLS

BM-XX — BENCH MARK
— SITE COORDINATES (SEE TABLE ON DRAWINGS)
N XXXXXXX E XXXXXXX — SITE COORDINATES
EL XXXX.XX — MONUMENT
HORIZONTAL CONTROL POINT
VERTICAL CONTROL POINT
HORZ AND VERT CONTROL POINT
XXX.XX — FINISHED ELEVATION
(XXX.XX) — EXISTING ELEVATION
DELTA

STRUCTURES

SITE OR RETAINING WALL
x — x — FENCE (CHAINLINK)
FENCE (WOOD)
STRUCTURE
STRUCTURE (BELOW GRADE)
CB CB — CATCH BASIN

REV 050218

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Appendix B – Geotechnical and Environmental Investigation Work Plan Standards



The Narragansett Bay Commission

Phase III CSO Program

Geotechnical/Environmental

Investigation Work Plan Standards

Title:	**Geotechnical/Environmental Investigation Work Plan Standards**
To:	Narragansett Bay Commission
Author(s):	Simon J. McGrath, P.G., P.E. (Pare Corporation) Jeffrey M. Costa, P.E. (Pare Corporation) Brandon Blanchard, P.E. (Pare Corporation)
Date:	May 15, 2018
Reviewed by:	Christopher Feeney, Stantec Barry Doyle, Stantec

Stantec

PARE CORPORATION

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Revisions

Revision History

Date	Version	Description	Author(s)	Reviewer(s)	Date of Review(s)
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05.15.18	**1.0**	**Issued** **FINAL**	S. McGrath J. Costa B. Blanchard		

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LIST OF TABLES

APPENDICES

List of Abbreviations and Acronyms

ASTM	American Society for Testing and Materials
BOD	Biochemical Oxygen Demand
BVI	Blackstone Valley Interceptor
CM	Construction Manager
COD	Chemical Oxygen Demand
DC	Design Consultants
DO	Dissolved Oxygen
ESA	Environmental Site Assessment
FPSA	Fields Point Service Area
GEP	Geological Exploration Program
HASP	Health and Safety Plan
IDW	Investigation Derived Waste
JSA	Job Safety Analysis
NBC	Narragansett Bay Commission
NGVD	National Geodetic Vertical Datum
PCB	Polychlorinated Biphenyls
PID	Photo-Ionization Detector
PM	Project Manager
QA/QC	Quality Assurance/Quality Control
RQD	Rock Quality Designation
SAP	Sampling and Analysis Plan
SPT	Standard Penetration Testing
SVOC	Semi-Volatile Organic Compound
TKN	Total Kjeldahl Nitrogen
TPH	Total Petroleum Hydrocarbons
USCS	Unified Soil Classification System
VOC	Volatile Organic Compounds

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Section 1.0

Introduction and Purpose

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1.0 Introduction and Purpose

1.1 Introduction

The Narragansett Bay Commission (NBC) embarked on a three-phase Combined Sewer Overflow (CSO) control program in 1998, aimed at lowering annual CSO volumes and reducing annual shellfish bed closures in accordance with a 1992 Consent Agreement with the Rhode Island Department of Environmental Management (RIDEM). Phases I and II of this program, which focused on the Fields Point Service Area (FPSA) in Providence, were completed in 2008 and 2015, respectively. The program to date has succeeded in lowering annual CSO volumes and reducing annual shellfish bed closures to levels that are in keeping with a 1992 Consent Agreement between NBC and the RIDEM.

Phase III of the program (Phase III CSO Program), which began in 2016, is focused primarily on the Bucklin Point Service Area (BPSA) in the communities of Pawtucket and Central Falls. The final sub-phase of the program does address the final remaining outfalls in the FPSA. Its projected completion date is 2041. The Phase III CSO Program has been subdivided into four sub-phases, as follows:

- Phase IIIA: Pawtucket Tunnel
- Phase IIIB: Upper Blackstone Valley Interceptor (BVI) Relief Structure and OF-206 Sewer Separation
- Phase IIIC: Stub Tunnel to Control OF-220
- Phase IIID: West River Interceptor and OF-035 Sewer Separation

1.2 Purpose

The purpose of these work plan standards is to establish a guideline for design consultants (DCs) to follow in performing geotechnical and environmental investigations to promote consistency in all such activities performed for the Phase III CSO Program. It is the responsibility of the DCs to develop a site-specific work plan to detail required field investigations to support foundation design of permanent structures/features, design of temporary support of excavation, groundwater control, and soils management. The major topics covered in this plan include preparing for field activities, performing investigations, and reporting on findings and conclusions. DCs shall be required to prepare field investigation work plans for review and acceptance by the Program Manager/Construction (PM/CM), acting on behalf of the NBC, that satisfactorily address these major topics.

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Section 2.0

Field Investigation Work Plan Requirements

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2.0 Field Investigation Work Plan Requirements

DCs performing geotechnical and environmental field investigations shall be required to submit a work plan for review by the PM/CM prior to initiating field activities. The work plan shall provide a site-specific analysis of required geotechnical and environmental data necessary to support the design of temporary and permanent facilities. The DC shall establish the type and extent of investigations necessary to support their design activities, subject to review and acceptance by the PM/CM working on behalf of the NBC.

The overall intent of the work is to identify procedures for field investigation activities, inclusive of the following:

- Project coordination.
- Coordination and observation of exploration subcontractor operations and procedures.
- Investigation preparation.
- Performance of soil sampling and bedrock coring.
- Characterization of soil and bedrock.
- Performance of visual, olfactory, and field screening for environmental characteristics.
- Sample collection, handling, description, and geologic logging.
- Installation of groundwater monitoring wells (if applicable).
- Geotechnical laboratory testing to classify soil and rock and to establish engineering properties.
- Environmental laboratory testing to identify the chemical constituency of soils, rock, and groundwater.
- Groundwater level monitoring (if applicable).
- Data reporting.

An example outline for the DC's field investigation work plan is as follows:

1. Purpose of Investigation
2. Roles and Responsibilities
3. Preparation for Field Investigations
    a. Health and Safety
    b. Quality Assurance/Quality Control
    c. Investigation Locations
    d. Right of Entry
    e. Dig Safe Notification
    f. Traffic Control
4. Geotechnical and Environmental Field Investigations
    a. Geotechnical Drilling
    b. Test Hole Explorations
    c. Groundwater Monitoring
    d. Exploration Location Survey
    e. Geotechnical Laboratory Testing
    f. Environmental Investigations
5. Data Reporting

Field investigation activities shall be performed in general accordance with the Field Manual for Subsurface Exploration included as Appendix A, as applicable to the nature of work being carried out. Each DC shall prepare their work plan to be consistent with the Field Manual and additional requirements identified herein.

2.1 Purpose of Investigation

The DC's work plan shall include an introduction that identifies the scope and purpose of the field investigation. This section of the work plan should provide a general overview of the type and frequency of investigations proposed and how the investigation relates to project requirements and anticipated design deliverables.

2.2 Roles and Responsibilities

The DC's work plan shall identify the roles and responsibilities of key staff engaged in geotechnical and environmental field investigations. Staffing assignments are anticipated to include field engineers, health and safety personnel, a project manager, a technical manager, and quality assurance/quality control (QA/QC) reviewers. It is recognized that one party may perform multiple roles (e.g., project manager also serves as technical manager). Contact information should be provided for all key staff, and one person shall be identified as the emergency contact. The drilling (or test pit) subcontractor, and other key subcontractors (e.g., traffic management, analytical laboratories), shall also be identified along with their contact information.

2.3 Preparation for Field Investigations

2.3.1 Health and Safety

DCs shall prepare a project-specific health and safety plan (HASP) to be appended to their work plan. HASPs shall be developed by each firm anticipating field efforts during the proposed investigation. It shall include procedures related to geotechnical and environmental field investigations, establish minimum requirements for personal protective equipment (PPE), and establish procedures for the health and safety of their personnel. HASPs shall comply with Federal, State, and local regulations relating to job site safety. HASPs shall also include procedures for documenting safety on a daily basis, through job safety analysis (JSA) or similar methods.

Special considerations shall be given to subsurface work planned in areas of known or suspected contamination. Work planned on or near industrial properties, former or current landfills, gasoline/auto service stations, fuel oil depots, dry cleaners or other similar commercial operations should be considered suspect sources of contamination until known otherwise. In some cases, compliance with OSHA HazWOPER regulations set forth in 29 CFR 1910.120 may be applicable. The DC is expected to be aware of these conditions and to respond appropriately. This includes proper management of investigation derived waste such as excess soil cuttings, wash water from bedrock coring, and/or groundwater monitoring well development and sampling discharges.

2.3.2 Quality Assurance/Quality Control

DCs shall develop a QA/QC Plan as an appendix to their work plan that addresses quality assurance and quality control requirements relating to oversight of field activities, sampling and analysis procedures to be followed by field staff, and review of drafts and final deliverables. For environmental sampling, the QA/QC Plan shall outline the frequency and type of quality control samples such as trip blanks, field blanks, laboratory blanks and field duplicates to be collected to evaluate the accuracy and precision of the sampling program.

2.3.3 Investigation Locations

The work plan shall identify subsurface exploration locations (i.e. borings, test pits, and monitoring wells) on proposed alignment drawings based on the proposed plan and profile of design features. The subsurface exploration locations should be placed in areas of critical design importance and to establish baseline conditions, and at sufficient spacing and frequency to provide information to identify design constraints and or cost impacts relative to the project. The frequency, depth, and location of explorations shall be identified by the DC based on industry standards with consideration to the specific requirements of the project (e.g., exploration spacing along utilities no greater than 300 feet apart, borings located at all four corners of structures, test pits within the anticipated footprint of GSI infiltration systems, etc.).

The investigation locations shall be identified by their coordinates (RI State Plane) and assigned a unique identification number starting with the year of exploration. The DC shall make a field assessment of each subsurface exploration location and its surrounding area for suitability relative to drilling/excavation, potential constraints, etc. If a location appears to be unsuitable, an alternative subsurface exploration location shall be identified and verified with the PM/CM. DCs shall perform borings in areas where subsurface conditions are unknown or where subsurface conditions such as the presence of bedrock or contamination could present significant cost impacts during construction as well as to address design considerations.

The DC's work plan shall include a table summarizing the proposed scope of subsurface investigations to be performed, following field verification. The table shall include the following information:

- Investigation ID number.
- General investigation location (street address/intersection, site identification, etc.).
- Investigation coordinates.
- Figure indicating investigation locations.
- Anticipated total depth.
- Anticipated top of bedrock depth.
- Proposed groundwater monitoring wells, if applicable.
- Sampling interval.
- Proposed geotechnical testing (in-situ and laboratory).
- Environmental testing parameters planned at that location.
- Known or suspected contaminants present and procedures for handling investigation derived waste (IDW).
- Notes (e.g., proposed monitoring well location, unusual fill conditions).

Each boring and/or test pit location shall be field surveyed for survey grade accuracy for use in design and incorporation onto site plans. The survey data shall document x, y, and z data in the approved horizontal and vertical datum for the program.

2.3.4 Right of Entry

The DC's work plan shall identify the permits and access agreements anticipated to be required for the investigation program. DCs shall coordinate with PM/CM to identify permits and access agreements needed for the subsurface investigation points based on their proposed locations (e.g., public right-of-way, private property). Permits and access agreements on public property shall be obtained by the DC or their drilling/excavation subcontractor, such as from Pawtucket, Central Falls, Providence, and Rhode Island Department of Transportation (RIDOT), based on the right-of-way in which the work is to be performed. The PM/CM and NBC shall prepare right-of-entry letters to drill or excavate on private parcels. An example notice of entry letter is included in Appendix B.

Permits and right-of-entry access permission are to include provisions for installation of standpipe piezometers and a protective monument at each borehole location, where proposed. Additionally, permission shall be obtained from private land owners to obtain periodic access to monitor groundwater levels (via standpipe piezometers) at each location. DCs shall assist the PM/CM and NBC in obtaining access permission by providing a summary of the work, a description of the precise location of planned explorations, and an anticipated schedule and duration for incorporation into right-of-entry letters.

2.3.5 Dig Safe Notification

The DC's work plan shall identify the procedure and party responsible for field marking investigation locations and notifying Dig Safe in advance of field activities. Investigation locations shall be marked with white paint and notice shall be provided to Dig Safe at least 72 hours prior to initiating exploration activities at each location. Non-member utilities within the exploration area shall also be contacted. To avoid delay, multiple potential exploration areas should be marked (e.g. B18-1A, B, or C). The DC or its assignees shall keep telephone logs, emails or other records of communication with the utility companies, including the Dig Safe ticket number and name of utilities contacted, but the drilling subcontractor shall ultimately be responsible for clearing utilities prior to the work. The appropriate Dig Safe ticket number shall be provided to the PM/CM before drilling is initiated at that location. An example Dig Safe form is included as Appendix C.

2.3.6 Traffic Control

Traffic control shall be provided for boreholes located in public roadways. Traffic control requirements shall be determined by the DC, subject to approval by PM/CM. The DC's work plan shall identify the anticipated traffic control requirements and the procedure for coordinating such controls in advance of field activities, including the party responsible for implementing traffic controls.

Police details, where required, shall be paid for directly by the NBC in accordance with their current policy. Police detail slips shall be signed by authorized on-site personnel and the NBC contract number shall be written on each slip. DCs shall collect all slips and provide the original police slips to the PM/CM, so that they can be forwarded to NBC. DCs shall also prepare a log to correspond to the detail slips identifying: date, slip #, hours, etc. The log shall be updated monthly. The driller or excavation subcontractor shall schedule all police details.

2.4 Subsurface Explorations

The DC's work plan shall identify procedures for performing subsurface explorations for geotechnical and environmental investigation purposes. Procedures shall be provided for oversight of borings and test pits, monitoring well installation, sample handling and logging, and documentation of field activities. Procedures described in the DC's work plan shall be consistent with the requirements of Section 3 of this guidance document.

2.5 Data Reporting

The DC's work plan shall provide an outline and the anticipated content to be included in Geotechnical Data Reports and Environmental Sampling technical memoranda. Data reporting shall be in accordance with Section 4 of this guidance document.

Section 3.0

Geotechnical and Environmental Field Investigations

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3.0 Geotechnical and Environmental Field Investigations

3.1 Geotechnical Drilling

The following is a discussion of geotechnical drilling-related activities and methodology, sample logging and handling, rock core logging and handling, piezometer installation, grouting of borings, and disposal of cuttings.

3.1.1 Soil Drilling Procedures and Methodology

Prior to mobilizing to the site, the DC shall agree with the PM/CM on procedures for the following:

- classification system;
- field screening of soil samples for evidence of foreign materials and/or contaminants;
- boring and sampling location and protocol with field staff;
- health and safety procedures with field staff;
- jar, box, and core box labeling procedures;
- chain of custody procedures;
- rock core storage procedures; and
- soil and rock storage logging.

Exploratory drilling may include both overburden/soil drilling and rock coring based on the specific requirements to support design. Where possible, each boring shall be advanced using a track- or truck-mounted drill rig using drive and wash drilling techniques with 4-inch to 5-inch diameter steel casing. The drilling contractor is responsible for obtaining and transporting clean, non-contaminated water for use in drilling and coring activities. The drilling contractor shall obtain a fire hydrant meter, appropriate backflow prevention, and written permission where needed to access public water supplies.

Local soil types include urban fill, alluvium, and glacial deposits. Soil samples shall be collected in conjunction with Standard Penetration Testing (SPT) to provide preliminary information on soil properties. The SPT sampling shall be performed in general accordance with ASTM D1586 and at frequencies to be determined on a project by project basis. In some instances, 2-foot sampling intervals (i.e. continuous sampling) may be required based on the nature of construction for that project or specific location. Otherwise, 5-foot sampling intervals (i.e. semi-continuous) will be the minimum interval. Soil samples shall be logged and classified according to the terminology specified within the Field Exploration Manual in Appendix A to be consistent with previous investigations, and presented using gINT software similar to the example Boring Log within Appendix D.

Two-inch diameter split spoon samples shall be driven into soil using a 140-lb hammer dropping from a vertical distance of 30 inches. The DC or boring subcontractor shall arrange for the hammer height and weight to be certified by a third party prior to the start of drilling, and the DC shall provide this certification to PM/CM. Steel casings shall be seated into the bedrock to ensure an adequate seal in the boring where rock coring is proposed following soil drilling.

Prior to the start of drilling activities, the DC shall obtain the following from the drilling subcontractor:

- Casing, split spoon, and drill pipe dimensions in accordance with ASTM standards;
- Drill rig manufacturer and model;
- Driller's operating license; and
- All required permits and access agreements to allow drilling to proceed (unless otherwise obtained by PM/CM or NBC).

While on-site to observe the advancement of the borings, the DC's field engineer shall:

- Review drilling location and sampling depths with drillers.
- Monitor and record the drilling/coring activities.
- Review drilling process and drill rig performance with drilling subcontractor.
- Characterize subsurface soil conditions and field screening results.
- Collect soil samples and lab samples at appropriate intervals.
- Review drilling equipment to verify hammer drop height and hammer 'nameplate' weights and calibration.
- Review visitor requests and procedures for accommodating other design team members.

The DC will be responsible for properly documenting boring logs and samples and maintaining up-to-date records of the results of field investigations. It is anticipated that this shall include:

- Performing quality control review of boring logs on a daily basis.
- Periodically selecting samples from selected strata within the borings for classification testing upon reaching bedrock.
- Periodically submitting samples to environmental and geotechnical laboratories for classification testing and analysis.
- Periodically reviewing field descriptions against laboratory gradations and adjusting field classification procedures if necessary.

Where temporary demobilization is necessary, the steel casing shall be buried approximately 6 inches below grade, the top of the casing shall be covered with a steel cap and the void shall be filled with asphalt cold patch. The DC shall review the cold patch repair approximately 1 month after installation. The drilling contractor shall repair as necessary.

3.1.1.1 Soil Logging and Sampling

Sampling shall be performed using split spoons, at the specified frequency based on project conditions (i.e., 2-foot continuous, 5-foot interval sampling). A representation of each sample shall be collected and stored in clean glassware with screw-on lids and labels provided by the boring contractor or DC. The entire recovered sample shall be placed in jars. Samples collected for both geotechnical analysis and environmental sampling shall be split accordingly. Jars and boxes shall be clearly labeled, consistent with sample identification used in boring logs and chain of custody documentation provided to environmental sampling laboratories.

The DC's work plan shall specify the information to be recorded for each log, which at a minimum shall include the following:

- NBC project name and number
- Boring identification number
- Boring Location, ground surface elevation, and datum
- Starting and ending dates of each boring
- Names of onsite engineer and drilling foreman
- Drill rig make and model
- Sampling method and casing size
- Sample number and depth
- Blow count number
- Sample recovery and penetration
- Groundwater level, if observed
- Soil Description:
    - USCS symbol
    - Stratum
    - Density/consistency
    - Color
    - Soil type
    - Fabric
    - Moisture
    - Odor
- TVOC concentration measured with PID
- Remarks

Samples jars shall be labeled and stored in sample jar boxes at the DC's offices unless otherwise directed. Each jar of soil shall be labeled with the following minimum information:

- NBC project name and number;
- Boring identification number;
- Sample number and depth;
- Penetration and recovery depths;
- Name of onsite engineer collecting the sample; and
- Date and approximate time that sample was collected.

3.1.1.2 Hazardous Gas Monitoring for Health and Safety

Hazardous gas monitoring for volatile organic compounds, methane, and hydrogen sulfide shall be conducted by a field engineer during soil drilling operations to confirm safe working conditions and to obtain preliminary information for evaluating the potential impacts of hazardous gases on construction methods and costs. Measurements of hazardous gas levels shall be obtained periodically in the open borehole and within the covered borehole each morning prior to the start of drilling. The DC shall evaluate the frequency of gas monitoring required to ensure safe working conditions. Air monitoring shall be performed using a handheld photo-ionization device and a four-gas probe capable of detecting methane and hydrogen sulfide. The DC shall also evaluate the need for additional monitoring equipment (such as colorimetric tubes or dust meters) as may be needed.

3.1.2 Rock Coring

Bedrock shall be drilled using wire-line, triple barrel, HQ-sized rock coring methods where project requirements dictate a need for rock coring. The drilling shall be conducted in general accordance with the guidelines presented in ASTM D2113 – Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation. Rock cores shall be logged using the terminology specified within the Field Exploration Manual in Appendix A to be consistent with previous investigations. The exception to this is for describing very fractured zones of the rock core. In these cases, for rock core fractured to less than 0.75-inches, the joint spacing shall be described as extremely closely fractured or ECF. Where the rock core is fractured between 0.75 and 2.5-inches, the joint spacing shall be described as very closely fractured or VCF.

Rock cores shall be handled and transported in general accordance with the guidelines presented by ASTM D5079 – Standard Practices for Preserving and Transporting Rock Core Samples. When rock coring is required, drilling, sampling, and testing shall be managed by, and rock samples logged by, an experienced professional familiar with rock classification and rock core handling and logging practices. Rock cores shall be placed in 5-foot long wooden core boxes. Water for drilling and in-situ testing shall be provided by the driller and transported to the drill sites.

The following information shall be recorded for each core run:

- Depth
- Drill rate (minutes per foot)
- Run number
- Depth interval (measured after each core run)
- Elevation
- Length and percent core recovery
- Rock Quality Designation (RQD) (length and percentage)
- Discontinuities per foot

- Graphic Log
- Strata Depth
- Lithology and description (including rock texture)
    - Strength
    - Color
    - Rock Type
    - Bedding
    - Weathering
- Discontinuity information

    - Depth of each discontinuity
    - Type (joint, bedding, shear, fault, and mechanical break)
    - Aperture
    - Dip Angle (from core axis)
    - Roughness
    - Weathering
    - Infilling

The following drilling conditions related to drilling action and ground conditions shall also be recorded:

- Duration of core run (time of actual rock coring to evaluate penetration rate).
- Changes in drilling fluid circulation including the reduction of loss or gain of drill fluid.
- Change in cuttings or drilling fluid color.
- Flow of groundwater out of borehole casing.
- Change in drilling advance rate because of harder or softer conditions.
- Drilling difficulties including extremely hard drilling, core loss, bit damage, or “blocking-off” (inability for drill fluids to flow through core barrel).
- Rod drops due to voids.

3.1.3 Core Handling, Labeling, and Storage

Core samples shall be placed in wooden core boxes that hold 15 feet of rock core. Each tray shall be restricted to one 5-foot core run unless numerous short runs are obtained. If there is no evidence of a discontinuity at the end of a run, the core shall be labeled with “M” to indicate a mechanical break caused by placing core into the core box. Short runs shall be separated by wood blocks, pipe or another suitable spacer. Styrofoam, pipe, or wood spacers shall be placed in the tray to identify zones of no core recovery or locations where core samples have been removed for laboratory testing.

Each box shall be labeled on the exterior with the project name and number, date, borehole number, borehole location, box number, and core number. A stencil and spray paint shall be used to mark core boxes to maintain legibility. Sample depth and run number shall also be recorded along the left edge of the core box to identify the top and the bottom of the core run. The inside of the core box lid shall be labeled with core run number, depth, recovery, and RQD. Each core box shall be photographed using a high-resolution digital camera at a direct angle, in well-lit conditions, with the lid information visible, and the cores both in dry and wet condition. Digital versions of the core photographs shall be included in the Geotechnical Data Report. Files shall be labeled by boring number and depth below surface. Core samples identified for laboratory testing that are subject to slaking or degradation shall be wrapped in plastic for preservation after the box is photographed. Core boxes shall be transported to a core box storage area at an NBC storage facility and stored until construction is completed.

3.1.4 Soil and Rock Core Graphic Log Preparation

Borehole logs shall be prepared by the DC conforming to the requirements established in this document and in the Field Manual included as Appendix A. Borehole logs shall reflect information obtained from laboratory testing. Laboratory tests conducted on borehole samples shall be identified by depth on the logs. General drilling information and in-situ testing data and borehole instrumentation shall also be included.

3.1.5 Drilling Cuttings and Fluid Disposal

The DC shall determine disposal requirements for drilling cuttings and fluids. In most instances, drill cuttings can be placed directly into the borehole. If grouting of boreholes is required, it is anticipated that sand or silt-sized drilling spoils shall be disposed of, to the extent possible, by mixing with the grout.

At boring locations, both the drillers and on-site staff shall monitor cuttings, fluids, and samples for odors or sheens that suggest petroleum or solvent contamination. The DC shall stipulate requirements for handling of investigation derived waste (IDW) in areas of known or suspected contamination. The DC's work plan shall also include provisions for adding measures to the investigation program to properly handle IDW should contamination be encountered during the work.

3.1.6 Groundwater Acquisition

Groundwater encounters shall be recorded for each boring during and at the end of the drilling process. A water meter level shall be on-hand and used for accurate groundwater depth. The minimum time of stabilization is 20 minutes at the end of each borehole. The onsite engineer and boring subcontractor foreman shall track casing depth to account for groundwater level.

3.1.7 Field Activity Documentation

Daily Field Activities shall be documented to provide a written record of drilling events and site conditions. Daily drilling activity information shall be recorded on boring logs as well as within Field Activity Logs. Sample boring logs and Field Activity Logs are provided in Appendix D. Daily drilling information includes the following:

- Project name and number
- Date
- Borehole number and site-specific location description
- Recorder's name
- Drilling personnel (name of driller, number of drilling personnel)
- Field logger
- Visitors to site
- Daily safety meeting summary, if applicable
- Summary of daily drill-related activities by time interval. These activities include mobilization, site preparation, casing installation, soil sampling, rock coring, in-situ testing, borehole conditioning, piezometer installation, grouting records, equipment breakdowns, standby time, and other delays.

3.1.8 Drilling Documentation Deliverables

The following field drilling information shall be provided following the completion of drilling activities, as applicable:

- Preliminary field borehole logs.
- Instrumentation (piezometer) and monitoring well as-built drawings.
- Field permeability testing data.
- Borehole wireline logging results.
- Investigation location sketches.
- Investigation location survey data.
- Chain of custody forms from environmental and geotechnical testing laboratories.
- Additional field notes, as required.

3.2 Test Hole Explorations

Test holes shall be performed where relatively shallow subsurface explorations are preferred to support design activities, such as for GSI projects where soil permeability and depth to groundwater are important design considerations. Subsurface conditions shall be logged on forms provided by DC as required to facilitate their design. Hazardous gas monitoring and field screening of soil and groundwater encountered in test holes shall follow the procedures identified above.

The DC shall procure the services of an excavation contractor to perform test hole investigations as well as to restore areas disturbed during the investigation, immediately following field activities. The DC's work plan shall include procedures for documenting and logging subsurface conditions as well as restoring disturbed areas following the completion of investigations.

3.3 Groundwater Monitoring

DCs shall evaluate whether groundwater monitoring is required to facilitate their design requirements, and their work plan shall identify the locations and frequency that groundwater monitoring is proposed. Groundwater monitoring data shall be summarized and presented in the DC's Geotechnical Data Report along with conclusions drawn from the monitoring program.

3.4 Exploration Location Survey

Following the completion of explorations, borehole, monitoring well, and test hole locations shall be surveyed by a licensed surveyor to obtain location and elevation data. Exploration location survey data, including elevation and coordinates, shall be included on the final borehole logs, well as-built sketches, and test hole logs produced by the DC. Elevations shall be expressed in NBC's vertical datum standard (NGVD 29).

3.5 Geotechnical Laboratory Testing

A program of geotechnical laboratory testing shall be completed to provide information for engineering and material properties of the soil and rock necessary to inform design and construction. Table 3-1 summarizes typical geotechnical laboratory tests that might be conducted on soil, along with the standard test method. The DC shall determine the analyses required and expand or decrease from this list in their work plan, as applicable based on the specific requirements of the project.

Table 3-1 Geotechnical Laboratory Testing (Soil)

Analysis	Test Method
Atterberg Limits	ASTM D4318
Density (Unit Weight)	ASTM D2937 or ASTM D7263
Grain Size – Sieve & Hydrometer	ASTM D6913
Grain Size Analysis (Sieve only)	ASTM D6913
Moisture Content	ASTM D2216
Unconfined Compressive Strength	ASTM D2166 or ASTM D2850

Table 3-2 summarizes typical geotechnical laboratory tests that might be conducted on rock, along with the standard test method. Each DC shall determine the analyses required and expand or decrease from this list in their work plan, as applicable based on the specific requirements of the project.

Table 3-2 Geotechnical Laboratory Testing (Rock) (If Applicable)

Analysis	Test Method
CERCHAR Abrasivity Index (CAI)	ASTM D7625
Unconfined Compressive Strength of Rock	ASTM D7012
Unconfined Compressive Strength with Elastic Moduli	ASTM D7012
Splitting Tensile Strength	ASTM D3967
Punch Penetration Index	Handewith Method
Point Load Index	ASTM D5731

Laboratory test samples shall be obtained at the DC's discretion based on the requirements of their design. In general, the number of tests performed on each soil or rock type should be proportional to its abundance. Strength tests shall be performed on both weaker and stronger samples to obtain a representative range of strength values.

Rock core shall be selected for laboratory testing as quickly as possible after drilling to prevent core degradation (desiccation or slaking) from reducing core strength, where rock coring is necessary for project requirements. Potential strength test samples shall be wrapped and sealed in plastic in the field to maintain the natural moisture content. Test samples shall be a minimum of 6 inches long, include only sound rock, and be free of incipient discontinuities and/or healed joints. Bedding or foliation in the test sample shall be oriented perpendicular to the long axis of the core (if possible) to mitigate against low strength structural breaks.

3.6 Environmental Investigations

The purpose of the environmental investigation is to collect soil and groundwater samples for chemical analysis to determine if special handling and/or disposal requirements are required. The results of the investigation will be incorporated into a soils management plan for each project and methodology for the disposal/treatment for groundwater. It shall be the responsibility of each DC to include in their work plan investigation requirements to characterize the potential for contamination and/or anthropogenic activity that may impact soils and groundwater. The proposed investigation shall consider the number of samples to define areal and vertical extent of potential impacts.

3.6.1 Soil Sampling

Environmental soil sampling shall be performed at investigation locations where soil displacement is anticipated as part of construction. Environmental soil sampling shall be performed to evaluate health and safety concerns for workers and/or the public as well as to evaluate whether disposal of contaminated soil shall be required during construction. Soil samples for laboratory analysis shall be collected as grab samples from excavations or from split-spoon samples recovered from drilling operations. Samples shall be transferred into clean, laboratory-provided glassware. The environmental samples shall be temporarily stored within an on-site portable cooler with ice until they are collected by the environmental testing laboratory. The environmental samples shall be collected by the laboratory on the same or next working day that they are gathered.

Environmental soil samples collected during the geotechnical investigation shall be screened for overt evidence of contamination. Screening shall include visual and olfactory screening for discoloration, sheen, ash, cinders, fill, and odors. Each environmental sample shall also be field screened with a photo-ionization detector (PID) for the presence of total volatile organic compounds (TVOCs) using jar headspace protocols. The DC's work plan shall specify a procedure for field screening. The results of field screening shall be recorded in the sampler's field log.

It is anticipated that environmental sampling shall be performed continuously through fill materials; typically for sample intervals 0-2 feet, 2-4 feet, 4-6 feet, and 6-10 feet though the sample depth and interval shall be as determined by the DC. Field conditions and/or screening results may warrant modification to this sampling frequency or additional sample testing. Sampling shall be prioritized within specific soil strata thought most likely to be impacted based on data collected as part of the environmental data review and the results of the field screening efforts described above. Similarly, native soils/non-impacted soils should be tested beneath suspected impacted strata to limit unnecessary disposal or handling costs.

Samples shall be transported with chain-of-custody documentation to a Rhode Island licensed laboratory to perform chemical analyses. Samples shall be handled in a manner to minimize disturbance to split spoon recovery for geotechnical sampling purposes.

Chemical analysis shall be performed for the following minimum parameters listed in Table 3-3. DCs shall evaluate the need to perform additional analyses if conditions warrant due to a specific contaminant of concern or to obtain additional waste characterization data. Some disposal facilities may have permit specific testing in addition to these parameters, such as pesticides/herbicides, pH, conductivity, asbestos or biological testing.

Table 3-3 Environmental Laboratory Testing (Soil)

Analysis	Method
Priority Pollutant (PP-13) Metals	EPA 6010B
Total Petroleum Hydrocarbons (TPH)	EPA 8100M
Volatile Organic Compounds (VOCs)	EPA 8260B
Semi-Volatile Organic Compounds (SVOCs)	EPA 8270D
Polychlorinated Biphenyls (PCBs)	EPA 8082A

The analytical data shall be tabulated and evaluated against applicable RIDEM Direct Exposure Criteria for soil and disposal facility acceptance criteria. The results of the soil sampling program shall be summarized in a technical memorandum prepared by the DC.

3.6.2 Groundwater Sampling and Analysis

Groundwater sampling shall be performed at piezometer and monitoring well locations determined by the DC to be points of interest to determine potential impacts to dewatering operations. Groundwater should be considered a point of interest if there is a significant likelihood that construction dewatering will be needed and to determine what if any treatment and/or permits will be required to discharge groundwater from within the work area. Groundwater should also be characterized to evaluate health and safety concerns for workers and/or the public.

Groundwater samples for laboratory analysis shall be collected from monitoring wells installed in accordance with RIDEM guidelines and standard practices. The samples shall be collected in a manner that represents in-situ characteristics. Low flow sampling techniques shall be employed unless the DC has a compelling technical reason to alter from this approach. Groundwater samples are to be collected into clean, laboratory-provided glassware and preserved in accordance with EPA standard guidelines and practices. The environmental samples shall be temporarily stored within an on-site portable cooler with ice until they are collected by the environmental testing laboratory. The environmental samples shall be collected by the laboratory on the same or next working day that they are gathered.

Groundwater samples shall be screened for overt evidence of contamination. Screening shall include visual and olfactory screening for discoloration, sheen, odor, or presence of foreign materials. Each groundwater sample shall also be field screened with a PID for the presence of TVOCs by screening the monitoring well headspace.

Samples shall be transported with chain-of-custody documentation to a Rhode Island licensed laboratory to perform chemical analyses. Chemical analysis shall be performed for the following minimum parameters listed in Table 3-4. The DC shall evaluate the need to perform additional analyses if conditions warrant due to a specific contaminant of concern or to obtain a local, state or federal discharge permit. Some discharge permits may need permit specific testing depending on site conditions.

Table 3-4 Environmental Laboratory Testing (Groundwater)

Analysis	Method
Metals (TBD by discharge permit)	EPA 6010B
Total Petroleum Hydrocarbons (TPH)	EPA 8100M
Volatile Organic Compounds (VOCs)	EPA 8260B
Semi-Volatile Organic Compounds (SVOCs)	EPA 8270D
Polychlorinated Biphenyls (PCBs)	EPA 8082A
Permit Specific Criteria (e.g. pH, TSS, BOD, COD, DO, TKN, etc.	To be determined by DC through discussions with authorizing agency

The analytical data shall be tabulated and evaluated against applicable RIDEM Groundwater Objective Criteria and the applicable discharge permit limitations for the area. The results of the groundwater sampling program shall be summarized in a technical memorandum prepared by the DC and presented under separate cover.

Section 4.0
Data Reporting

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4.0 Data Reporting

4.1 Geotechnical Investigation Report

4.1.1 Overview

A Geotechnical Investigation Report shall be prepared at the conclusion of geotechnical investigations. At a minimum, the report shall provide the following:

- A summary of the type of geotechnical investigations performed.
- A description of subsurface conditions (soil, rock, and groundwater) encountered.
- Laboratory (geotechnical) testing results.
- Boring and/or test hole logs.
- Groundwater level data.
- A site plan showing final borehole and test hole locations.
- Monitoring well/piezometer as-built sketches (if installed).

4.1.2 Anticipated Geotechnical Investigation Report Content

The Geotechnical Investigation Report shall include the following major sections, as applicable:

1. Introduction and Purpose
2. Existing Conditions
3. Subsurface Explorations
4. Groundwater
5. Laboratory Testing
6. Summary of Findings
7. Appendices and Figures

4.2 Environmental Technical Memorandum

A technical memorandum summarizing environmental sampling procedures and results shall be prepared at the conclusion of environmental investigations performed at borings and test holes.

The Environmental TM shall include the following:

1. Introduction and purpose;
2. Description of the environmental sampling program performed;
3. Tables summarizing the results of field screening;
4. Tables summarizing laboratory testing results;
5. Findings and conclusions from the sampling program;
6. Final exploration location plan with sample locations at various depths (appended to report); and
7. Certificates of Analysis and chain of custody documentation (appended to report).

Appendix A

Field Manual for Subsurface Exploration

Stantec

FIELD MANUAL
FOR SUBSURFACE EXPLORATION
for
Narragansett Bay Commission
Pawtucket Tunnel Project

Ver. 2.3: 09/21/2017

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Chapter 1 INTRODUCTION

PURPOSE

This manual describes basic procedures to be followed by Stantec/Pare field engineers and geologists in performing subsurface exploration for design and construction of water conveyance tunnels and shafts. Principal responsibilities of the field engineer/geologist are to ensure quality in the driller's execution of the work, to direct the exploration, and to monitor and accurately record all information obtained. Field work and its documentation establish the level of detail and reliability that can be achieved in interpreting subsurface conditions. This manual is intended to assist field staff in achieving efficiency, quality, reliability, and safety in exploration and record-keeping.

LIMITATIONS

This manual was written for exploration programs for design of tunnels and subsurface structures in soils and sedimentary rocks of the Narragansett basin. Soil and rock classification systems described herein are consistent with standard practice, but are limited to the subject geology. Other procedures may be more appropriate in some cases. The field engineer/geologist should not deviate from these procedures without prior approval by the lead geotechnical engineer. The field engineer/geologist is expected to have a basic understanding of drilling methods and equipment, field testing procedures, data reduction and analysis, regional geology, and methods that may be employed in constructing the subject project. These subjects are addressed in basic geotechnical engineering and geology texts and are not repeated here.

Chapter 2 AUTHORITY AND RESPONSIBILITY OF THE FIELD ENGINEER / GEOLOGIST

INTRODUCTION

This chapter describes the role of the field engineer/geologist in administering the drilling contract. In this chapter, the term “engineer” refers to the field engineer/geologist assigned to observe the drilling work, to prepare records, and to ensure the drilling firm's conformance with the technical conditions of the contract. The term "contractor" refers to the drilling firm.

AUTHORITY OF THE ENGINEER

The engineer has the authority to approve materials and workmanship that meet contract requirements, and he should give his approval promptly, when necessary.

The engineer does not have the authority to stop work.

The engineer does not have the authority to approve deviations from contract requirements, though he can alter quantities of unit price items within the original work plan.

The engineer should not require the contractor to furnish more than that required by the contract.

The engineer should not attempt to direct the contractor’s work; doing so may relieve the contractor of responsibility under the contract.

Instructions are to be given to the contractor’s senior representative (generally the driller), not to his assistants or subcontractors.

RESPONSIBILITY OF THE ENGINEER

The engineer is to be thoroughly familiar with the plan and intent of the investigation, and the contract specifications as they apply to the work to be inspected.

The engineer is to notify the contractor if any material portion of the work does not conform to the requirements, to tell the contractor why it does not conform, and to record it in the daily log.

Materials should be checked as soon as possible after they are delivered. Work should be inspected as it progresses.

The engineer is to observe the work continually.

A realistic tolerance is to be applied to interpretations of the specifications.

The engineer must be capable of differentiating between items that are essential and those that are not, as defined by the lead geotechnical engineer.

When work is to be corrected by the contractor, the engineer is to follow it up daily, lest it be forgotten.

The engineer is to perform his duties in a manner that will promote the progress of the work, and will endeavor to maintain good relations with the contractor. An attempt should be made to anticipate problems in advance. The engineer should avoid hasty decisions, by investigating the situation and possible consequences.

The engineer is to stand behind any decision made regarding acceptability of the contractor’s work.

The lead geotechnical engineer should be notified in the event of problems that cannot be resolved between the inspector and the contractor.

Daily reports should record the day’s activities, instructions given to the contractor, and agreements made.

The engineer should be safety-minded, and if he observes a potentially dangerous condition, it is his responsibility to call it to the attention of the contractor, note it in the daily log, and stay out of harm's way.

The engineer has a responsibility to be alert and observant, and should report to the senior geotechnical engineer any situation that may delay completion of the project.

Adapted from “Recommended Standards for the Responsibility, Authority, and Behavior of the Inspector,” Committee on Inspection of the Construction Division, ASCE Journal of the Construction Division: Vol. 101, No. CO2, 1975.

Chapter 3 SOIL DRILLING AND SAMPLING

GENERAL

The principal objective in soil sampling is to recover a complete series of samples representative of the major strata penetrated by the boring. Information from recovered samples is to be supplemented by observations of drill tool and drilling fluid behavior.

Sampling intervals are usually set at some multiple of 5 feet (2.5-ft, 5-ft, 10-ft) for compatibility with drill rod lengths (5-ft, 10-ft, and 20-ft). A sampling interval of 2.5 feet is common for planning deep excavations in soil.

For more information on drilling methods and equipment, see the guide “Soil Sampling” (ASCE 2000); or “Geotechnical Investigations; EM 1110-1-1804” (Army Corps of Engineers 2001).

SAMPLE PREPARATION

SPLIT SPOON SOIL SAMPLES

Upon opening the split spoon, wipe the sample free of drilling fluid. Discard cuttings from the top of the sample, which consist of disturbed soils from the bottom of the borehole. Cuttings typically appear soft or loose, highly disturbed, mixed with drilling mud, or washed clean of fines if drilling with clear water.

Take hand penetrometer readings on cohesive samples. Make two or three trials on a sample, and record a representative value, to the nearest 0.25 tsf. Include readings on the ends of the sample, parallel to it’s axis. Disregard readings influenced by gravel particles or severe sample disturbance.

A split-spoon sampler tends to smear the surface of cohesive samples, obscuring its composition and fabric. To observe the sample clearly, split the sample lengthwise with a stiff-bladed spatula to about half its diameter, and spread open. Details such as trace amounts of sand, and thin layers of silt, will become apparent. Layering details may be enhanced by allowing a portion of the sample to partially dry.

In layered granular soils, avoid mixing silt layers with sand and gravel. To do so will result in a composite grain size curve and an inappropriately low estimation of horizontal permeability. Place dissimilar soils from a single sample into different jars, to avoid their becoming mixed.

Retain two full jars per sample if recovery permits. When placing a sample in two or more jars, add the suffix “A”, “B”, “C”, and so on to the sample number, beginning with the lowest

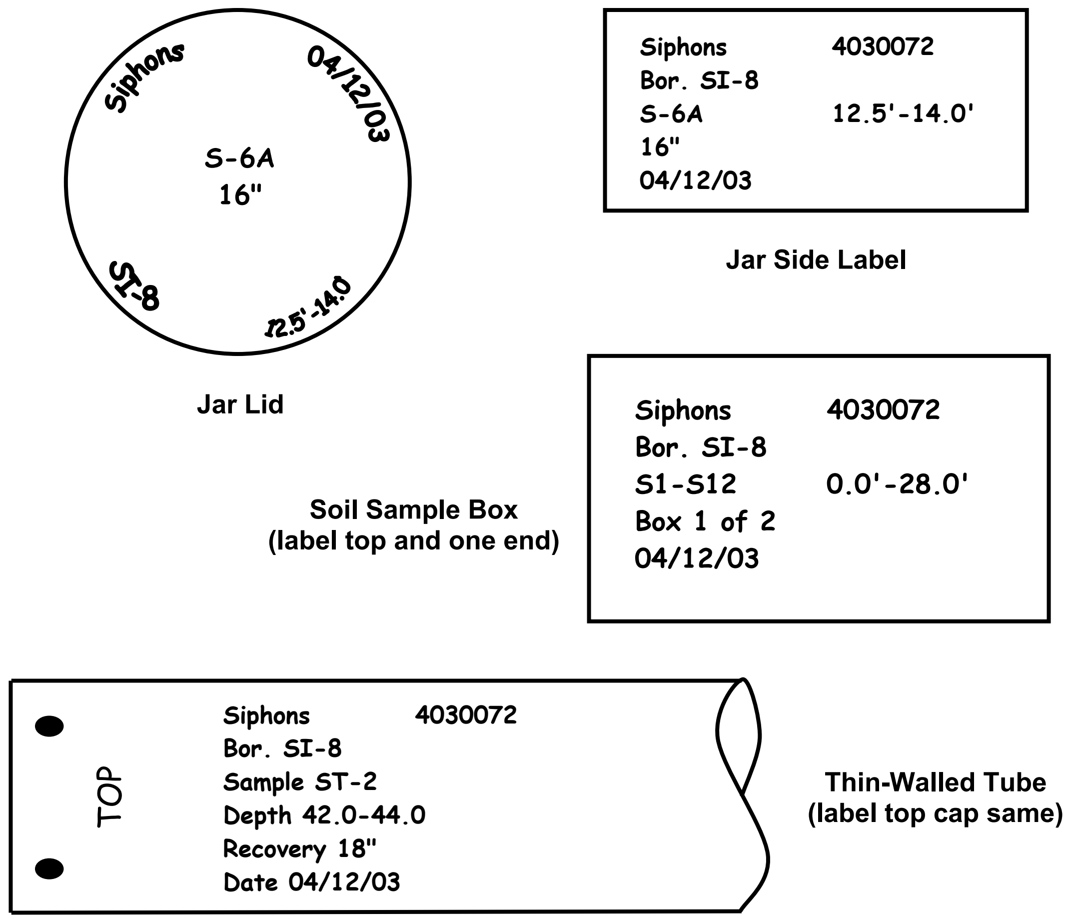

Figure 3-1. Soil sample container labels.

portion of the sample. For example, if placing sample S-2 in two jars, label the lower portion S-2A and the upper portion S-2B.

Affix a gummed label to the jar, and also label the jar lid. At least one label (jar or lid) is to include the project name, project number, boring number, sample number, depths to top and bottom of sample, recovery, and date. The other label shall include boring number and sample number, as a minimum. Label the jar and lid as shown in Figure 3-1.

Every sampling attempt must be numbered on the boring log, so if recovery is zero, either label an empty jar and lid to account for the attempt, or accept a gap in the sequence of jars.

Begin each boring with a new box of jars. Return jar samples to their box in order of recovery. When full, close the box and label the top and one end with the project name and number, boring number, sample numbers contained, and depth range of samples contained. When the boring is completed and the total number of boxes is known, add the box number in series (for example, 1 of 3). See Figure 3-1. Where multiple borings are being drilled, the bottom few samples from different boreholes may be consolidated into a single box, properly labeled. Count this box as part of the series of boxes for each boring.

Keep the box dry and in serviceable condition. Reinforce the bottom with tape if necessary. If jar samples are to be stored temporarily on site, protect from water, excessive heat, and freezing temperatures.

THIN-WALLED TUBE SAMPLES

The purpose of thin-walled tube sampling is to retrieve samples with the least amount of disturbance possible. Take special care in recovering, handling, packaging, and transporting these samples.

Thin-walled tube samples are normally taken in cohesive soils less than 2 tsf in unconfined compressive strength. If split-spoon sampling encounters a soft layer of unknown thickness, the borehole should be cleaned to the bottom of the split-spoon sample and a tube taken. In thick cohesive strata, a tube can be taken at the next sampling interval, in lieu of a split-spoon sample.

Upon retrieving the tube, measure and record the length of soil recovered, excluding cuttings from the top of the sample. Remove cuttings and clean an additional ½ inch of soil from each end, and square off. Take a hand penetrometer reading in bottom end of sample. Seal each end of the sample with melted sealing wax, at least ½ inch thick. Fill any remaining void space in the tube with tightly balled newspaper or other filler material, to prevent the sample from breaking the end seals during handling and shipping. Cap the ends of the tube and wrap the seams with tape. Alternatively, tubes can be sealed with other devices such as expandable packers or pre-waxed circular wooden blocks.

Label the tube and top cap with an indelible marker or by affixing a label. If possible, locate all labeling in the top 1 foot of the tube. Record the project name, project number, boring number, sample number, depths to top and bottom of sample, recovery, and date, in that order. In addition, mark the tube "top". See Figure 3-1.

In thick strata of stiff clay, some drillers prefer to extrude the sample on the rig to re-use the tube. This is acceptable provided the character of the clay is such that the sample remains intact, and provided the driller supplies sample boxes specifically designed to protect and transport tube samples. Extrude the sample out the top of the tube, to avoid reversing stresses on the sample. Wrap the sample in foil or plastic immediately, to prevent drying. Label the sample wrap with a permanent marker or adhesive label.

DRILLING OBSERVATIONS

Supplement sampling data with observations of drill tool and drilling fluid behavior. Make these observations even when blind drilling (drilling without sampling) part or all of a borehole in soil.

DRILLING ACTION

Drilling action can give some indication of ground conditions. A change in rate of bit penetration can indicate a contact between different strata. Drill tool chatter can indicate cobbles or boulders, which cannot be recovered in a split spoon. Smooth, hard drilling may indicate penetration of a large boulder, or top of bedrock. The drill fluid can be strained for rock cuttings to determine if the rock igneous or sedimentary. Ask the driller to interpret changes in drilling action.

FLUID BEHAVIOR

Describe drilling fluid behavior and other indications of groundwater. When drilling fluids are not being used to advance the boring, the first indication of free water on samplers or drilling equipment should be recorded as the water level. Note the depth at which drilling water is lost, and the depth at which lost water is regained. Loss of borehole water could indicate a perched water table. Note any increase in the quantity of drill water, a rise in water level in the borehole, or change in color of drill water. A rise in borehole water level could indicate an artesian condition.

Measure the water level in the boring at the end of each work day, again prior to continuing drilling the following day, and at other opportune times. Record the date and time of each reading. These readings often differ considerably from the true water table level at the boring location, particularly when drilling mud is being used to advance the boring, in low permeability ground, and in areas of perched groundwater. Nevertheless, borehole water level readings can provide useful information on ground conditions when considered in context with other information.

On rare occasions an artesian discharge from the borehole may occur. The hydrostatic head on the discharge can be determined by extending the drill casing above ground surface, allowing the water level to stabilize, and measuring the height of the water column from ground surface.

OBSTRUCTIONS

Obstructions are natural or man-made objects that impede normal drilling progress through the overburden, or are too large to enter the sampling device. They include buried utilities, building rubble, buried pavements, timber piles, cobbles and boulders. Obstructions are often indicated only by drilling action, as they are difficult to sample. Obstructions can have serious consequences on project design, and may require changes in the investigative approach. Record all indications of drilling obstructions, including depths first encountered and finally cleared, and evidence of composition. *See the chapter on Site Safety for precautions regarding buried utilities*.

Whenever drilling through surface pavement, record the thickness and composition of the pavement, and depth of base material.

COMPACTED TILLS

Some glacial tills can be heavily compacted, hard to drill, and hard to sample with blow counts from 75 to well over 100 blows per 6 inches. Their compacted nature is attributed to a wide particle size gradation from gravel to clay, combined with pressure from overlying ice. Compacted tills are difficult to retrieve in a split spoon due to low penetration and a tendency to fall out of the sampler. Make every effort to obtain a representative sample of compacted till. Ask the driller to hammer the sampler with as many blows as necessary to advance the spoon at least 2 to 3 inches. If the compacted till is gravelly, an oversize spoon sampler may be effective.

SOIL/ROCK CONTACT

The soil/rock contact can be particularly difficult to sample. Often the soils are too hard or contain too much fragmented rock to retain in a split-spoon, or the rock may be too soft or broken to core. It is important to know the condition of this transition zone for sound planning of shaft excavation and support methods. The soil/rock contact is often an avenue of groundwater movement, which will be of interest in planning groundwater control measures. Some drillers tend to blind drill through this zone for expediency. Direct the driller to attempt to recover representative samples. An oversize spoon sampler may be more effective than a standard spoon in this zone. Pay close attention to drilling action and drilling fluid when drilling through this zone. The less distinct the transition from soil to rock, the more important that conditions be accurately characterized.

SOIL LOG PREPARATION

An example of a completed soil boring log is shown in Figure 3-2 for reference. A blank field log is included in Appendix C.

Heading: Fill out completely for each sheet of log:

- Project Name & Project Number
- Client & Contractor
- Driller: First and last name
- Field Engineer/Geologist: First and middle initial, and full last name
- Rig: Type of drill rig. For example, CME-55.

Boring Number: Use complete boring number as assigned by lead geotechnical engineer.

If boring is sampled to partial depth, then abandoned and offset a short distance due to encountering an obstruction, note the relocation distance and direction in Remarks, and continue the log on the same sheet. Alternatively, start a new log, retain the original boring number, and differentiate the borings with “A” and “B”. If working with boring location diagrams, mark the changed location on the diagram.

Sheet number: For each boring, begin with 1 and number consecutively for the entire boring. If rock coring is performed subsequent to soil drilling, continue numbering pages through the rock log. Include a soil log even if overburden is blind-drilled to rock.

MWH MONTGOMERY WATSON HARZA

SOIL BORING LOG
-FIELD-

BORING NO. SI-8

Project Name Siphons
Sheet 1 **of** 2
Project Number 403 0072
Date Began 4-12-03
Field Engr/Geol RJ Lange
Date Completed 4-13-03

Scale (ft)	Depth (ft)	Sample No.	Blow Count	Recovery (in)	q_u (tsf)	U.S.C.S.	Description	Graphic	Remarks
							asphalt pvmt. 0.8		Roller bit through pavement.
	2.5								
	4.0	S-1	3 4 6	14	–	sm	loose brown silty fine sand, moist (fill)		H.S. auger. Automatic hammer
5	5.0								
	6.5	S-2	4 3 9	16	–	sm	med. dns. lt. br. silty c-f sa., some c-f gravel, brick frag., moist 6.5		
	7.5								
	9.0	S-3 B/A	6 6 7	18	–	ml	med. dns. gray silt, wet		
10	10.0						10.0		— began wash boring
	11.5	S-4	8 10 10	16	–	sw-sm	med. dns. c-f sa., some f. grvl., tr. silt, wet		
	12.5								
	14.0	S-5	4 5 9	12	–	sm	med. dns. f. gravelly sand, some silt, wet		
15	15.0								
	16.5	S-6 B/A	4 8 6	16	1.25	sm / cl	as above 15.5 / stiff brown silty clay, laminated, moist		
	17.5								
	19.0	S-7 B/A	3 6 9	18	2.5	cl	as above, very stiff		
20	20.0						20.0		
	21.5	S-8 B/A	7 8 10	18	3.0	cl	v. st. br. silty clay, tr. c-f sand, moist		
	22.5								
	23.5	S-9	6 50/3	7	4.0	cl	as above, piece brkn. gravel in shoe		— drill tool chatter
25	25.0								
	26.5	S-10	15 15 15	8	4.5+	cl	as above, some c-f sand 27.2		— roller bit 1' into top of rock, set casing, began coring.
							Top of Rock		
30									

Contractor R&S Drilling **Driller** Dan Simpson **Rig** CME-55

General Notes

Figure 3-2. Example soil log.

Scale: For sampled borings, scale the depth at one mark per foot. Establish ground surface as zero depth. When drilling over water, establish water surface as zero depth. When drilling off a platform, do not show void space at the top of the log. Use a continuous and uniform depth scale throughout the soil log. A break line may be introduced for long lengths of unsampled soil, or deep water columns. For borings blind drilled to rock, use any convenient scale.

Depth: Mark the top and bottom depths of sampler penetration by drawing a horizontal line through this and the next five columns up to the Description column. Mark numerically the top and bottom depths of sampler penetration. In general, record depths to the nearest 0.5 foot.

Sample Number: For each sample type, number samples consecutively (1, 2, 3 etc.) starting with 1 for each boring. Identify sample type using the codes on the boring log form. Each sample type constitutes a unique series of samples. For example, three consecutive standard split-spoon samples followed by a tube would be numbered S-1, S-2, S-3, and T-1.

Blow Count: Number of blows required to drive the sampler for each 6 inches of advancement. Typically, this is for the standard penetration test, in which a standard split-spoon sampler is driven 18 inches with blows from a 140-pound hammer falling 30 inches. For example, 9-15-26 for full penetration.

Blow count refusal is generally defined as 50 blows to advance 1 inch or less. If refusal is encountered, record the number of blows and the interval driven (for example, 60/3). It is important to recover a sample, and in very hard soils (as some tills) it may be necessary to drive the sampler beyond "refusal" to do so.

Recovery: Length of sample recovered, excluding cuttings.

USCS: Unified Soil Classification System symbol. System definitions are included in the Appendix B.

Description: Record a description for every sample recovered. Follow format described in the following article, SOIL DESCRIPTION. If sample appearance is same as previous sample, record "As above." If sample differs in small degree to previous sample, record "As above," followed by notation of difference.

At each major change in strata, draw a horizontal line through the Description and Graphic columns. Mark the depth on the right side of the stratification line in the Description column. Drop-down lines may be used in this column to provide additional space for describing thin layers.

Any portion of the rock surface penetrated by roller bit should generally be shown on the rock log. There should be no gaps or overlaps in information shown on the Soil Boring Log and Rock Coring Log.

Graphic: Draw a symbol depicting major soil types. Use symbols shown in Figure 3-3. Irregular constituents such as boulders and thin layers need not be shown in the graphic.

Remarks: Record drilling procedures, drilling action, driller's observations, type of SPT hammer used (automatic hammer, safety hammer, etc.), and other information relevant to interpreting the log and conditions encountered in the borehole. If the boring requires more than one day to complete, record the date where drilling resumed. Record casing advances, size, and depth to bottom of casing. Record water levels measured in borehole. Record changes in field staff.

If no rock drilling will be performed, at the bottom of the last log sheet, indicate how borehole was completed, for example "piezometer installed". If grouted, indicate mix composition and placement procedure, for example "Borehole sealed with cement-bentonite grout pumped down a 1" tremie pipe inserted to bottom of hole. Pumping continued until clean grout returned to surface. Mix composition per specification".

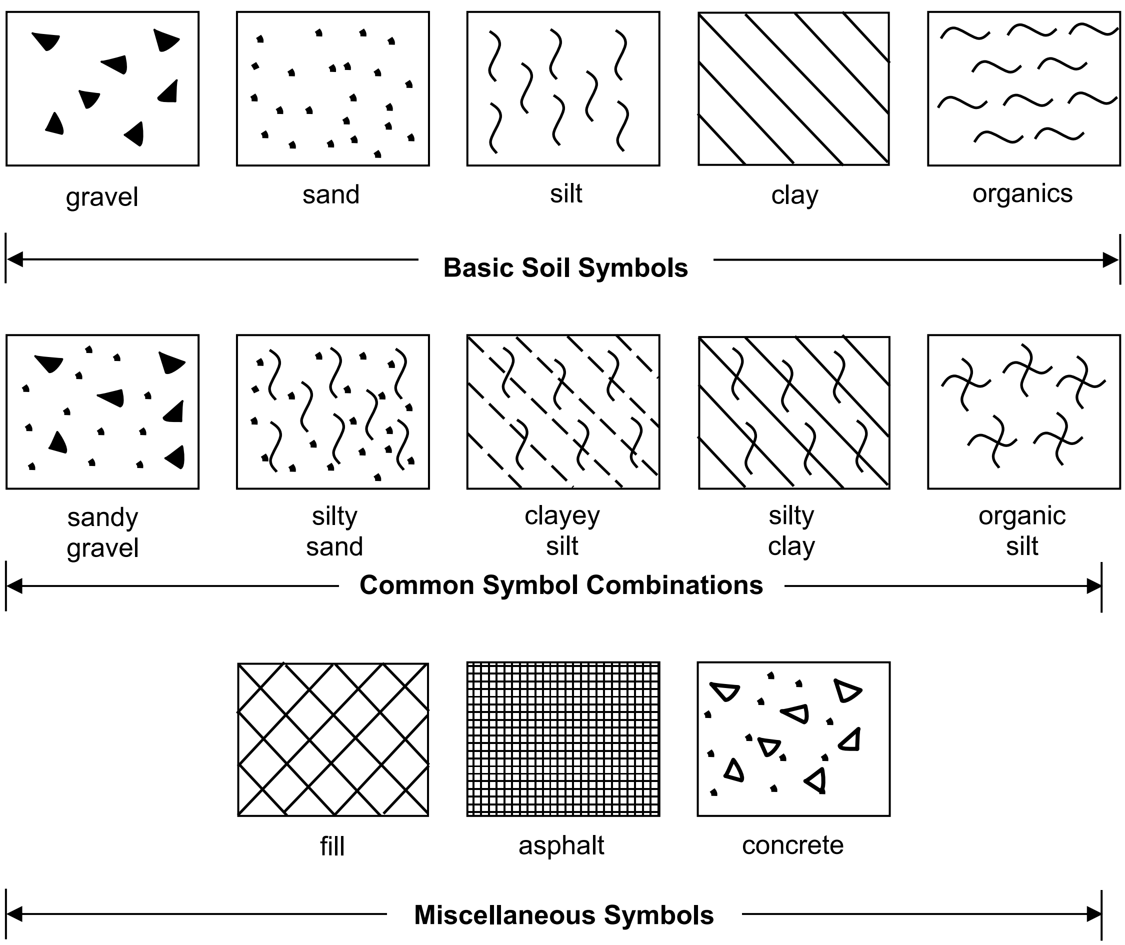

Figure 3-3. Soil symbols.

SOIL DESCRIPTION

Soils are generally comprised of only four constituents—gravel, sand, silt, and clay—in an infinite number of combinations. The method of identifying soils described herein is based on relative proportions of granular constituents, and plasticity of cohesive constituents. This method incorporates USCS symbols, but does not follow the naming conventions of ASTM D2487 and D2488 which lack definition in particle size and proportion. The latter standard contains useful field procedures for identifying soils.

Record the soil description parameters in the following order, in general:

- Density/Consistency
- Color
- Soil Type
- Fabric
- Wetness
- Odor

See the example boring log in Figure 3-2 for application of this method. Terms may be abbreviated to save space or time, but do so in a manner that makes the meaning apparent.

DENSITY/CONSISTENCY

Describe density of cohesionless (granular) soils and consistency of cohesive soils in accordance with Tables 3-1 and 3-2. Determine consistency of cohesive soils in the field using a hand penetrometer. If the consistency value borders two alternative terms (such as 0.5 tsf), use the blowcount to select the alternative.

Table 3-1. Relative Density of Granular Soils

Relative Density	No. Blows Per Foot, N
Very Loose	0-4
Loose	4-10
Medium Dense	10-30
Dense	30-50
Very Dense	>50

Ref. Terzaghi, Peck, and Mesri 1996, p. 60.

Table 3-2. Consistency of Cohesive Soils

Consistency	q_u (tsf)	N	Characteristics
Very Soft	< 0.25	<2	Sample will sag or slump under own weight.
Soft	0.25 to 0.5	2 to 4	Sample can be pinched in two between fingers.
Medium Stiff	0.5 to 1.0	4 to 8	Sample can be easily imprinted with fingers.
Stiff	1.0 to 2.0	8 to 15	Sample can be imprinted with considerable effort.
Very Stiff	2.0 to 4.0	15 to 30	Readily indented by thumbnail.
Hard	> 4.0	> 30	Indented with difficulty by thumbnail.

Ref. Terzaghi, Peck, and Mesri 1996, p. 63.

COLOR

Soils are commonly some shade of brown or gray, but may include tint of red, yellow, green, or blue. Modify color names using "light" or "dark", and combine as in "gray brown". Note if colors appear mottled (common in fill), iron-stained, or exhibit other variations. Color often changes rapidly with exposure to air, so record soon after soil is removed from sampler.

Color is a useful but seldom critical parameter for identifying soils for engineering purposes. If precise identification is necessary, use a Munsell soil-color chart for reference.

GRANULAR SOILS

Granular soils include *boulders*, *cobbles*, *gravel*, *sand*, and *silt*. The terms are defined by particle size, as shown in Figure 3-4. Particle sizes larger than about 2 inches will be excluded from a standard split-spoon sample, though their presence may be inferred from drilling action. Fine sand may be distinguished from silt by sand's gritty texture, whereas silt feels like flour. Saturated silt may initially appear cohesive due to surface tension of water, but silt particles disperse easily if submerged in water, and will not hold together well enough to roll into a 1/8-inch diameter thread.

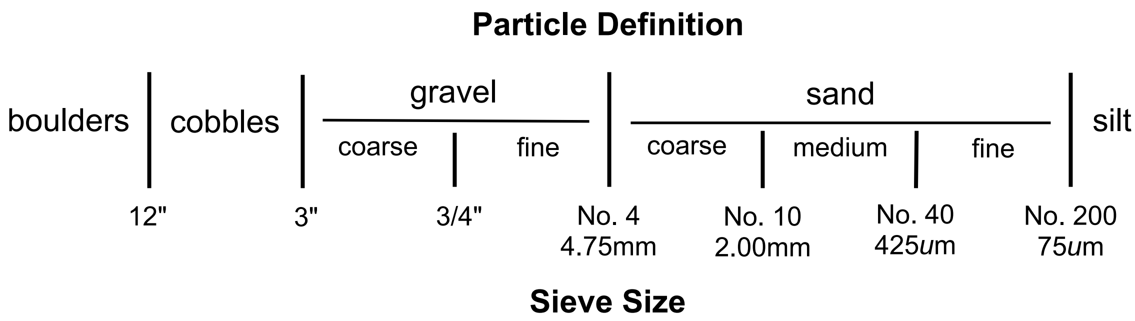

Figure 3-4. Particle size definitions for granular soils. Ref. ASTM D 2487.

To describe a granular soil, identify the major component, and indicate the proportion of secondary components using appropriate identifying terms from Table 3-3.

Examples: 55% gravel, 35% sand, 10% silt → gravel, some sand, trace silt
60% sand, 25% gravel, 15% silt → sand, some gravel, little silt

For granular soils, as well as cohesive soils containing sand and gravel, include the textural attribute of particle size in the description, in order of decreasing particle size. Omit if particle size range can be inferred.

Table 3-3. Naming Granular Soils

Identifying Term	Content by Weight Percent
Trace	up to 10
Little	10 to 20
Some	20 to 35
And	35 to 50

It is generally not necessary to record the textural attributes of particle shape and roundness. These details can be retrieved by examining samples in the laboratory. Terms used to describe shape are equant (spherical), prolate (oblong), oblate (disk), and bladed (uneven disk). Terms used to describe roundness are angular, subangular, subrounded, and rounded.

If granular soils are cemented, describe the degree of cementation using the terms weak (breaks with handling or little finger pressure), moderate (breaks with considerable finger pressure), and strong (does not break with finger pressure). Cementation, however, is usually destroyed in the split-spoon sampling process.

INORGANIC CLAYEY SOILS

Inorganic clayey soils are comprised mainly of clay and silt, in varying proportions. The descriptive term is based on plasticity, as shown in Table 3-4.

Where cohesive soil occurs in combination with granular soil, the name is derived from the plasticity of the combination passing the #40 sieve (fine sand or smaller particles), and the total percentage by weight of granular material.

Examples: 40% sand, PI = 30% → sandy silty clay
60% sand, PI = 5% → clayey silty sand

Table 3-4. Naming Silt-Clay Combinations

Identifying Term	Plasticity Index	Degree of Plasticity	USCS
Clayey Silt	>0 to 7	low	ML for PI<4; CL-ML for PI = 4 to 7
Silty Clay	7 to 40	medium to high	CL, CH
Clay	> 40	high	CH

Some clays, in addition to being highly plastic, may exhibit considerable toughness and a tendency to adhere to metal surfaces. These should be identified using the term *sticky*, as in "clay, sticky".

ORGANIC SOILS

Soils containing severely decomposed organic material in sufficient amounts to affect overall appearance or behavior are described as organic. The identifying term is based on plasticity, as shown in Table 3-5. In this table, the USCS symbols most commonly associated with the identifying term are shown in bold, though laboratory testing may indicate that another term is more accurate. Some organic clays can exhibit a tendency to adhere to metal surfaces, and should be identified using the term *sticky*, as for inorganic clays above.

Table 3-5. Naming Organic Soils

Identifying Term	Plasticity Index	Degree of Plasticity	USCS Symbols
Silt with organics	1 to 7	low	**ML** or **OL**
Organic Silt	7 to 40	medium to high	**OL**, ML, **OH**, MH, CL, CH
Organic Clay	> 40	high	**OH**, CH

Material consisting of semi-decomposed, identifiable plant fiber, and having a mineral content of less than 20 percent, is called *peat* (USCS symbol **Pt**). Several methods have been developed for describing peats and their degree of decomposition, and should be applied if a significant amount of peat will be encountered.

NON-SOIL MATERIALS

Samples may include non-soil material such as shells, wood fibers, or waste products (organic or inorganic). Waste materials may indicate the depth of man-made fill, or suggest types of larger waste products that may be present. Vertically oriented wood may indicate foundation piles. Horizontally oriented wood may indicate abandoned ground support walls from prior construction, or ancient buried trees. Indicate the degree of decomposition of wood using the terms in Table 3-6, or other equally descriptive terms. Distinguish timber from identifiable twigs and branches.

Table 3-6. Degrees of Decomposition of Wood

Term	Definition
Fresh	Little to un-decomposed, retains properties of sound wood.
Fibrous	Somewhat decomposed, visual appearance of wood, but fibers soft, pull apart easily by hand.
Particulate	Well to severely decomposed, little or no fibrous characteristics remaining.

Record all non-soil materials present, and retain in sample jars. The fact that non-soil material is present is more important than the relative amount, which may be minor. If the relative amount is indeterminate, include in the description using the term "with", as in "with small shells". *See the chapter on Environmental Monitoring and Safety for procedures regarding chemical contaminants*.

FABRIC

Fabric is a property of aggregates rather than particles. A description of fabric aids in determining depositional mode, stress and climatic history, and mass behavior characteristics of a deposit. Describe soil fabric using the terms in Table 3-7.

Depositional fabric features are often regular in nature and result from alluvial (flowing water), lacustrine (quiescent water), loessal (windblown), or mass transport (glacial) mechanisms. Beds are a common depositional fabric feature. Beds are tabular or lenticular layers of sediments having characteristics that distinguish them from strata above and below. Beds are range widely in thickness. Beds displaying internal layers deposited at a distinct angle to the bounding surfaces are *cross-bedded* or *cross-laminated*.

Environmental fabric features are generally irregular, and may result from desiccation (due to lowering of lake levels), stress release (melting of overlying glacial ice), organic activity, and groundwater infiltration. These features include fractures, fissures, root holes, and mottling.

Table 3-7. Soil Fabric Terminology

Term	Sedimentary Structure	Characteristic Soil Unit
massive	Without internal structure; obscurely layered.	lodgment till
bedded	Sequential layers.	reworked till, outwash, lacustrine deposit
layer	Distinctly defined tabular body of sediment.	reworked till, outwash, lacustrine deposit
interbedded	Alternating layers of differing composition	outwash, lacustrine deposit, alluvial deposit
well bedded	Beds are numerous and clearly defined.	outwash, lacustrine deposit, alluvial deposit
laminated	Small scale sequence of layers.	lacustrine deposit
varved	Regularly alternating thin beds of silt and clay, of seasonal sedimentary origin.	lacustrine silt and clay deposit
mottled	Spotted or variations in color.	Soils near or above the water table.
few	One or less occurrences per foot.	
occasional	One to twelve occurrences per foot.	
frequent	More than 12 per occurrences foot.	

WETNESS

The description of wetness helps to locate the capillary fringe, and the water table, and can indicate the relative porosity of soils. Terms are shown in Table 3-8. All granular soils below the water table are *wet* and most clayey soils below the water table are *moist*.

Table 3-8. Degree of Wetness

Term	Definition
Dry	Soil contains no free water.
Moist	Soil feels damp, but does not wet palm.
Wet	Soil readily wets palm of hand.

ODOR

Some soil samples give off an odor of decaying vegetation, hydrogen sulfide, gasoline, fuel oil, or various chemicals. Record any odor noted during sampling. *Do not attempt to decipher a chemical smell if noticed. See section on Man-Made Contaminants, in chapter on Environmental Monitoring and Sampling, for appropriate action to be taken.*

GEOLOGIC SOIL UNITS

A geologic soil unit is a stratum of soil, comprised of one or more layers, that originates from a particular geologic process. Soil units are characteristic of a physiographic region. In the Narragansett basin, the region on which this manual is focused, the most common soil units originate from glacial and fluvial processes. The soil unit concept is useful in developing subsurface profiles through a series of borings because soil units, as opposed to individual soil layers, tend to be laterally extensive. A profile is developed by interpolating soil units between adjacent borings, in a manner consistent with what is known about the area geology. Soil units accommodate compositional variability among samples of the same origin.

The field engineer/geologist should be familiar with the characteristics of geologic soil units likely to be present at the site being investigated. Attempt to develop soil descriptions and stratification lines in a manner consistent with the soil unit concept and the local geology, while avoiding over-interpretation of the available evidence. In some cases, it requires careful examination of samples from several borings to identify a soil unit, requiring time not available to the field engineer/geologist. Common geologic soil units and their characteristics are described in Table 3-9. Other soil units may be defined to suit local geologic conditions or project needs.

Table 3-9. Common Geologic Soil Units

Soil Unit	Origin	Characteristics
Fill	Deposited by man.	Any composition, highly variable. In lowland areas, may be comprised of soil from nearby highlands or dredge material from a river channel or harbor. In metropolitan areas, frequently includes waste material and building debris.
Alluvial channel deposits	Deposited in post-glacial stream channel.	Sorted. Silt to coarse sand. May exhibit laminations, cross-bedding, upward fining, mud pebbles, organic matter.
Alluvial flood basin deposits	Deposited in channel belt bordering an alluvial channel, during times of overbank flood.	Typically fine grained, comprised of clay, silt, fine sand, or organics. Laminated. Soft.
Lacustrine deposits	Deposited in meltwater lakes formed between retreating continental ice front and end moraine.	Highly sorted. Fine sand, silt, or clay, with very little mixing of grain sizes. May be laminated or varved. Rarely, may include coarse sand or gravel dropped from melting ice floe.
Outwash	Deposited in meltwater streams of variable flow rate.	Sorted. Coarse sands to gravels, trace to no silt. May exhibit frequent layering.
Till	Mainly lodgment till deposited at base of an advancing ice sheet. May also include ablation till accumulated through melting of stagnant ice.	Unsorted. Grain sizes in a single sample may range from clay to gravel. Commonly exhibits massive structure (without internal structure, obscurely bedded, or thick homogeneous beds). May include thin layers silt, sand, or gravel deposited by subglacial meltwater. Silty till may exhibit horizontal structure, or “fissility”, a result of shearing at base of ice. Consistency may range from very soft to hard.

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Terzaghi, K., R. B. Peck, and G. Mesri 1996. *Soil mechanics in engineering practice*. 3rd ed. New York: John Wiley & Sons.

Chapter 4 ROCK CORING

GENERAL

The principal objective in rock coring is to recover core samples representing the rock in place, including soft or highly fractured rock, while inducing a minimal number of mechanical breaks to the core.

CORE PREPARATION

Upon opening the core barrel's split inner sleeve, the rock core may be left in a half-sleeve for logging, or carefully rolled into a PVC half-round for logging.

In preparation for logging, tightly refit the ends of any pieces that have become separated. Mark the full length of the core with two continuous lines of red and blue indelible ink spaced about 1 inch apart. Place the red line on top and the blue line on the bottom, as viewed on a boxed section of core. These lines will serve as reference for orienting core pieces as they are placed in the core box and later during handling. (Others color pairs can be used, the important thing is to be consistent.)

Mark mechanical breaks originating from drilling with an "M" or a slash in indelible black ink. Mechanical breaks are usually oriented perpendicular to the core, and tend not to follow natural rock discontinuities or bedding. Edges of the break may be chamfered due to spinning of the core during drilling.

Starting at a full 1-foot depth, mark the core at ½-foot intervals, and label depths at 2-foot intervals, using a lumber crayon or indelible ink sharpie. After marking, log as described below.

The bottom few inches of a core run may break off above the bit and remain in the hole, not to be recovered until the following run. If this occurs, the values for recovery and RQD cannot be calculated until the next run has been retrieved.

Cored materials subject to slaking or alteration due to drying should be triple-wrapped with heavy duty plastic wrap. This includes some shales, and thick clayey fillings in joints or faults.

In winter work, do not allow core to freeze in the steel split sleeve. If this occurs, thaw with a heat source. Do not hammer the core free.

PLACING CORE IN COREBOX

After logging, carefully transfer the core to a core box, and label the box. A correctly labeled core box is shown in Figure 4-1. Place core in the box in the manner of lines of text on a page, from left to right, starting in the upper left corner and ending in the lower right. Fit the ends of individual pieces as tightly together as possible. Fit long lengths of core into the box by breaking the core cleanly with a sharp blow from a rock hammer. Mark hammer break with an "H" in indelible ink.

Place a spacer block at the end of each core run. Fix the spacer to the core box by nailing. Mark the visible edge of the block with the depth to end of the core run.

If portions of the core run have not been recovered (excluding the bottom few inches likely to be recovered in following run), place spacer blocks at the top and bottom of the lost core section (as best can be determined), to partition a length equal to that lost. Nail the blocks in place, and mark with the depth to top and bottom of the lost core section. If the location of lost core cannot be determined, place it at the end of the run, and note the location as "Inferred" in the Remarks column of the log.

Label core boxes with indelible marker on the inside and outside of the lid, and on each end. Mark the outside of the lid with the project name, project number, boring number, box number in coring sequence, depths covered, and date. Mark the inside of the lid with the information noted above, and the following additional information in tabular form: run numbers, depths covered in each run, recovery as linear measure and as percent, and RQD (rock quality designation). Label the box ends as shown.

Place core from one boring only in a core box. Under no circumstances transfer core to another box without the approval of the lead geotechnical engineer.

Core is commonly photographed as part of the project record, so the core and the information printed on the inside of the box lid must present a full and legible record.

DRILLING OBSERVATIONS

Supplement information provided by core samples with observations of drilling action and drilling fluid behavior. Rod drops may indicate a solution feature or very soft rock. Changes in the rate of bit penetration can indicate differences in rock hardness. Note the depth at which drilling water is lost, and the depth at which lost water is regained. Note any increase in the quantity of drill water, a rise in water level in the borehole, or change in color of drill water.

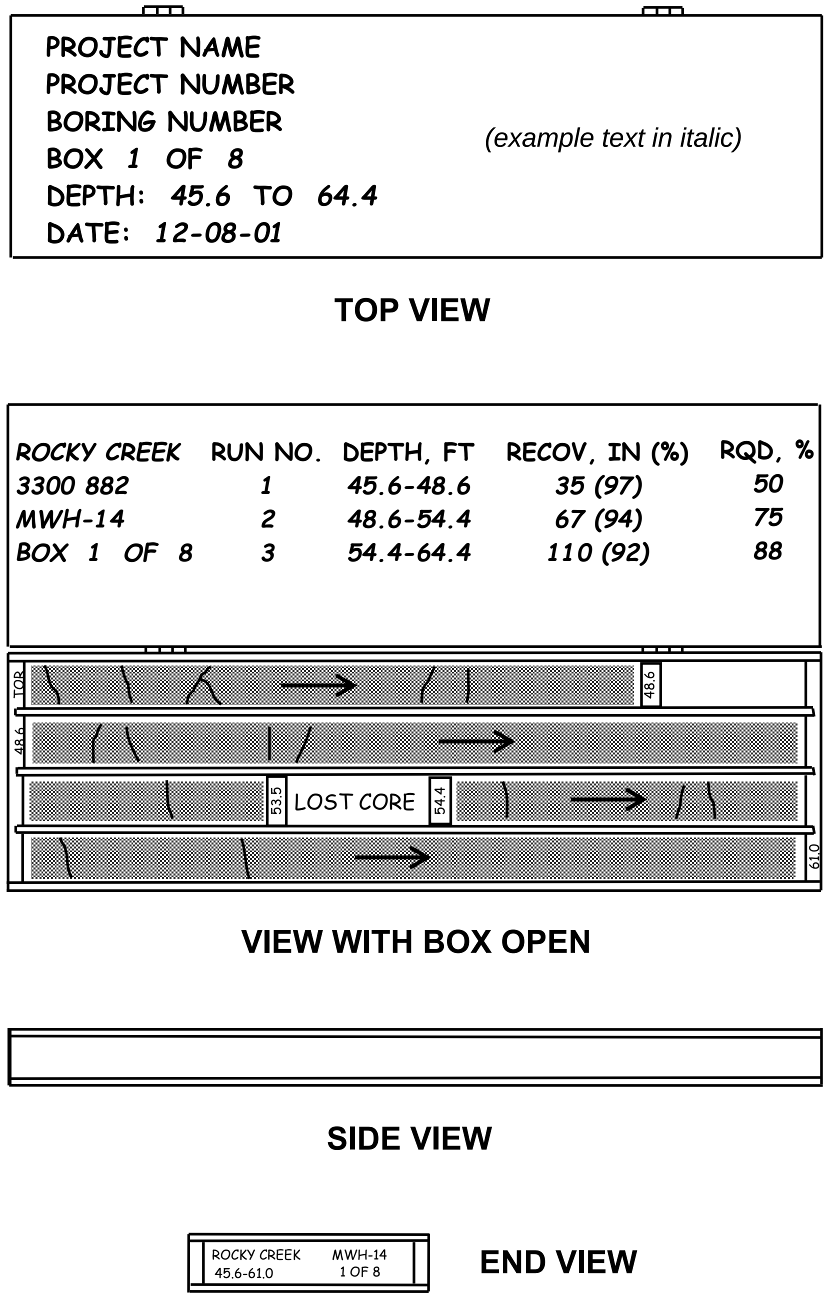


Figure 4-1. Labeled core box.

ROCK LOG PREPARATION

Begin rock log at top of rock. An example of a completed rock log is shown in Figure 4-2 for reference. A blank field log is included in Appendix C.

Heading Information: Fill out completely for each sheet of log. Same format as for soil log, including:

- Core size, for example NQ, or HQ
- Core barrel type. For example, wireline or conventional (a conventional core barrel attaches to drill rods and is retrieved by pulling the rod string); double tube or triple tube.

Sheet Numbers: Continue page numbering from soil log.

Scale: Scale the depth from surface at one mark per foot. A gap of up to 5 feet may be placed at the top of the first rock core log, so that major tic marks correspond to multiples of 5 feet. Use a continuous and uniform depth scale throughout the rock log.

Run Number: Number individual runs consecutively, beginning with 1.

Depth: Mark the top and bottom of the core run by drawing a horizontal line through this and the next several columns up to the Description column. Mark numerically the top and bottom depths of the core run, to nearest 0.1 foot.

Recovery: Indicate length of core recovered, to nearest 0.1 foot. Also indicate recovery as a percentage of core run length [(length of core recovered / length of core run) × 100], and display under measured length.

RQD (rock quality designation)**:** Sum the cumulative length of core recovered as intact, sound pieces more than 4 inches in length, divide by the length of the core run, and multiply by 100.

For the purpose of computing RQD, a core run can be defined in three ways (ASTM D 6032): 1) a core run is equal to a drill run, 2) the end of a core run could be established at a formation change, 3) a core run can be a selected zone of concern. Use definition 1 routinely. Use definitions 2 or 3 as appropriate to characterize significant or abrupt changes in core quality.

Measure core pieces in the manner shown in Figure 4-3. Measure along the core centerline to avoid over-penalizing vertically fractured core. Consider only natural fractures for RQD purposes; exclude mechanical breaks. If in doubt whether a break is natural or mechanical, count as a natural fracture. Pieces of core that are highly weathered, highly vuggy, friable, or a combination thereof should not be included in the summation of <u>sound</u> pieces greater than 4 inches for the determination of RQD. The qualitative terms for RQD shown on Figure 4-3 are included for information only, and are not generally incorporated in the general description.

If a portion of the core run remains in the borehole, consider that length of core left as part of the run in which it was cored, rather than the run in which it was retrieved.

Breaks: Mark joints and bedding plane breaks, exclusive of mechanical breaks, to show their distribution, frequency, and true inclination. Blacken to indicate lost core.

Graphic: Where the boring log format includes a graphic column, depict major rock types using the symbols shown in Figure 4-4. Thin layers may be disregarded. If only one rock type would appear, this column may be left blank, or only variations from principal rock type shown.

Description: Record a description for every core run. Follow format described in the following article, ROCK DESCRIPTION.

At each major change in strata, draw a horizontal line through the Description column. Mark the depth on the right side of the stratification line in the Description column. Where core consists of closely interbedded layers of differing rock types (for example shale and sandstone), it is unnecessary to depict individual thin layers on the log. Indicate the range of bed thickness and approximate percentage of the lesser constituent. Marker beds or other formation contact indicators should be explicitly shown on log.

In the description column, also record drilling procedures, drilling action, driller's observations, and other information relevant to interpreting the log and conditions encountered in the borehole. In the event that coring requires more than one day to complete, record the date where drilling resumed. Record water levels measured in borehole. Record changes in field staff. Remarks pertaining to coring should indicate the depth of borehole when the event occurred.

At the bottom of the last log sheet, indicate how borehole was completed, for example "piezometer installed". If grouted, indicate mix composition and placement procedure, for example "Borehole sealed with cement-bentonite grout pumped down a 1" tremie pipe inserted to bottom of hole. Pumping continued until clean grout returned to surface. Mix composition per specification".

MWH MONTGOMERY WATSON HARZA

ROCK CORING LOG
-FIELD-

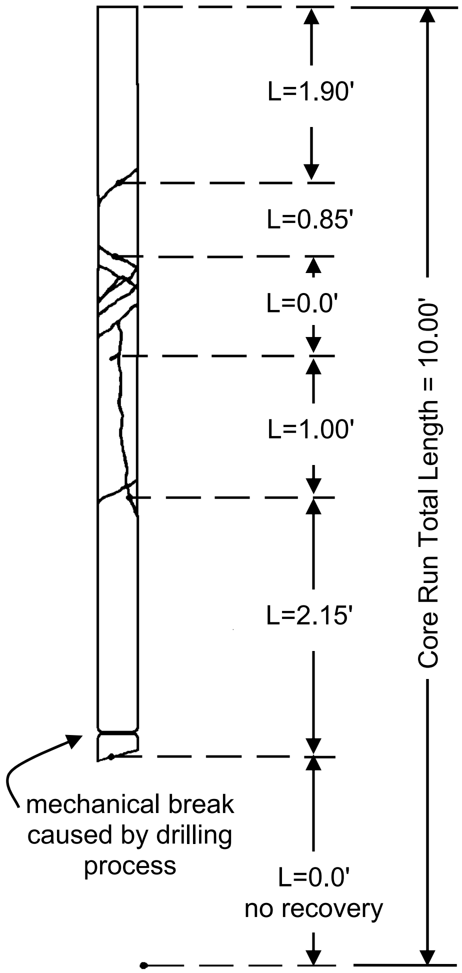
Project Name: Siphons
Project Number: 403 0072
Field Engr/Geol: RJ Lange

BORING NO. SI-8
Sheet 2 of 2
Date Began 4-12-03
Date Completed 4-13-03

Scale (ft)	Depth (ft)	Run No.	Recovery (Ft) / (%)	RQD	Breaks	Description	Graphic	Remarks
	27.2					Top of Rock 27.2		- roller bit
	28.2							- began coring
30	32.0	1	3.04 / 80	18		Moderately strong to strong brown gray to gray dolomite, calcareous in places, low content fine to medium vugs, occasional shale layers to 0.8' thick, slight to moderate weathering.		
35	37.0	2	4.90 / 98	32		As above		
40						As above 42.0		
45	47.0	3	10.0 / 100	92		Moderately strong to weak brown gray to gray, medium content medium to coarse vugs, highly weathered, sandy texture 45' to 46'.		
50	52.0	4	4.64 / 92.8	100		As above 52.0		- Grouted borehole to surface, 8 gal water per bag cement, 6 bags total.
55						Bottom of Boring		

Core Size: NX
Core Barrel Type: double-tube
General Notes:

Figure 4-2. Example rock log.



$$RQD = \frac{\sum Length\ of\ Core\ Pieces > 4\,in}{Total\ Length\ of\ Core\ Run}$$

$$RQD = \frac{1.90 + 0.85 + 1.00 + 2.15}{10.00} \times 100 = 59\,\%$$

RQD (Rock Quality Designation)	Description of Rock Quality
0 - 25%	Very Poor
25 - 50%	Poor
50 - 75%	Fair
75 - 90%	Good
90 - 100%	Excellent

Figure 4-3. RQD logging. Ref. ASTM D 6032.

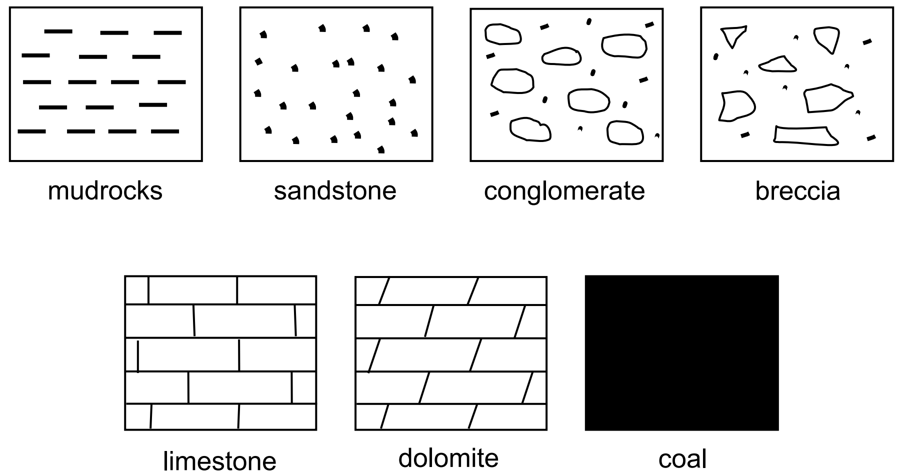


Figure 4-4. Rock symbols.

ROCK DESCRIPTION

The method of rock description presented here was developed for sedimentary rocks of the Rhode Island Formation of the Narragansett basin. These rocks include mainly clastics (mudrocks, sandstones, and conglomerates) and carbonaceous rocks (coal and graphitic shales).

Record the description parameters in the following order, in general:

- Compressive Strength
- Color
- Rock Type
- Sedimentary structure
- Weathering
- Discontinuities

See the example boring log in Figure 4-2 for an application of this method. Terms may be abbreviated to save space or time, but do so in a manner that makes the meaning apparent.

The field rock description should be detailed enough to identify cored formations from published literature on regional geology, and should record characteristics that may deteriorate or change with handling, drying, or transportation of the core. Matters of most interest are 1) general material characteristics, 2) unique characteristics that identify the formation or unit, including marker beds, and 3) discontinuity characteristics (frequency, width, filling, weathering, etc). If more details are needed the core can be examined in the laboratory or storage facility.

COMPRESSIVE STRENGTH

Compressive strength is related to hardness. Large differences in strength are important, subtle differences are not. Describe compressive strength for each rock type, using the terms in Table 4-1.

COLOR

Rocks are commonly some shade of white, brown, gray, or black, but may include tint of red, yellow, green, or blue. Modify color names using “light” or “dark”, and combine as in “gray brown”. Note if colors appear mottled, iron-stained, or exhibit other variations. Color often changes rapidly with drying or with exposure to oxygen. Identify color when rock core is wet, preferably when first removed from the corehole.

Color is a useful but seldom critical parameter for identifying rock for engineering purposes. For precise identification, use a Munsell rock-color chart for reference.

Table 4-1. Field Estimation of Rock Compressive Strength

Strength description	Approximate Compressive Strength (ksi)	Properties of hand specimen
Very weak	1.5 to 3.5	Brittle or tough, may be broken in hand with difficulty.
Weak	3.5 to 15	Crumbles under firm blows of sharp end of hammer.
Moderately weak	15 to 35	
Moderately strong	35 to 140	5 mm indentations with sharp end of hammer.
Strong	140 to 290	Hand-held specimen can be broken with single blow of hammer.
Very strong	>290	More than one hammer blow required to break specimen.

Source: Geological Society Engineering Group Working Party, 1977; Tbl. 4.

MUDROCKS

Mudrock is a general term for lithified siliciclastic sediments composed mainly of silt- and clay-sized particles. Mudrocks are classified on the basis of texture and structure as shown in Table 4-2.

- *Siltstones* are massive rocks (visible bedding is absent). Grains can generally be seen with hand lens.
- *Mudstones* are massive rocks having the appearance of claystone, but the gritty feel of siltstone.
- *Claystones* are massive rocks having a smooth waxy aspect when cut or scraped with a knife, especially when moist.
- *Shales* are mudrocks exhibiting the tendency to split easily into thin layers along closely spaced, roughly planar, and approximately parallel bedding surfaces.

Table 4-2. Mudrock Nomenclature

Silt & Clay Content	*Massive Mudrock*	*Fissile Mudrock*
>2/3 silt, <1/3 clay	siltstone	silt shale
1/3 to 2/3 silt	mudstone	mud shale
<1/3 silt, >2/3 clay	claystone	clay shale

Source: Blatt 1992; Tbl. 6-1.

Mudrock colors may range through red, brown, yellow, green, light gray, and dark gray to black. Color is a function mainly of carbon content, and of oxidation state of iron in the rock.

- Thermally mature organic-rich mudrocks may range from dark gray (0.5% to 1.5% carbon), to gray black (1.5% to 3.0% carbon), to black (>3% carbon) (Potter, Maynard, and Pryor 1980).
- Thermally immature organic-rich shales tend to be more brown than black (Arthur and Sageman 1994).
- Variations in color from red through purple to green gray correlate with decreasing ratios of Fe^{3+}/Fe^{2+} (Fe^{3+} gives red, Fe^{2+} gives green).

Mudrocks commonly contain nodules of calcite, dolomite, siderite, chert, or pyrite. Fossils are common in some formations.

SANDSTONES

Sandstones are composed of a framework of sand- and coarse silt-sized particles, with varying amounts of matrix and cement within the interstitial pore space. Framework grains of most sandstones are composed principally of quartz, feldspar, and rock fragments. The matrix commonly consists of clay minerals and silt-grade quartz. Cement is precipitated around and between grains; common cementing agents are quartz and calcite.

Textural classification of sandstone is sufficient for field work. Describe sandstones on the basis of predominant grain size (coarse, medium, fine, or combination thereof), and grain shape (subangular to well-rounded). Sandstone having a matrix of silt or clay is described as silty sandstone.

CONGLOMERATES AND BRECCIAS

Conglomerates and breccias are composed of rock fragments of any type, held together in a matrix of silt and clay, or by a mineral cement. They are the consolidated equivalent of gravel. *Conglomerates* are composed of rounded to subangular rock fragments. *Breccias* are composed of angular rock fragments. A particle size classification for conglomerates and breccias is shown in Figure 4-5. As for sandstones, also grain shape as subangular to well-rounded.

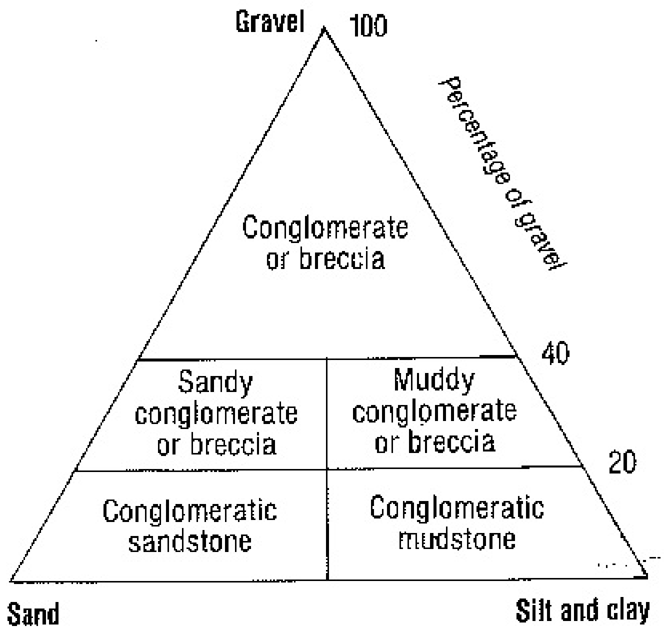


Figure 4-5. Conglomerate and Breccia Nomenclature
Source: Compton, 1985, p. 57.

COAL

Coal is a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material. True coals include humic coal and sapropelic coal.

Humic coals are products of thermal maturation of peat under deep burial. Humic coals are identified by degree of thermal maturation, or *rank*. Coals of the Rhode Island Formation consist of anthracite or meta-anthracite, which appears hard, dense, bright, and shiny, and breaks with conchoidal (smoothly curving) fracture like glass.

Sapropelic coals are derived from particulate organic matter generated within or washed into shallow lakes, ponds, and coastal lagoons and preserved in anoxic muds. Sapropelic coals are generally dull and massive. They may occur with humic coals or separately.

Describe coals using the following nomenclature:

Humic (banded) coal descriptors:

- bright
- bright with dull bands
- bright and dull
- mainly dull with numerous bright bands
- dull with minor bright bands
- dull

Sapropelic (non-banded) coal descriptors:

- dull with conchoidal fracture surfaces
- shaley (silt and clay is disseminated throughout)

GRAPHITIC ROCKS

Graphite appears lustrous, iron black to steel gray crystals, flakes, scales, laminae, or grains. It can occur in layers or disseminated in metamorphic rock. Where disseminated, describe host rock as "graphitic," as in "graphitic shale."

SEDIMENTARY STRUCTURE

Sedimentary structure is defined as a primary depositional feature that is small in scale yet large enough to be seen without a hand lens. Terms to describe sedimentary structure features of interest in the fluvial sandstones and mudrocks of the Rhode Island Formation include the following:

- laminations - layering on a scale of 1 to 2 mm (±)
- beds - layering on a scale of 1 to 5 cm (±)
- other thicknesses - include thickness dimension
- massive - absence of sedimentary structure
- flat-bedded - horizontal layering
- cross-bedded - inclined layering; common dip angles are 20º to 25º
- laminated - horizontal layering
- cross-laminated - inclined layering

WEATHERING

Weathering refers to chemical or mechanical degradation of rock. The effects generally decrease with depth below ground surface. Differential weathering can occur within a single rock unit along discontinuities (joints, faults) through which groundwaters penetrate deeply into the rock mass. It can occur along unconformities such as an erosion surface, and between rock units due to compositional or textural differences. Weathering is unlikely to occur randomly within a rock mass, so be cautious about attributing a decrease in rock strength to weathering. Describe degree of rock weathering using the terms in Table 4-4.

Table 4-4. Terms to Describe Degree of Weathering/Alteration

Term	*Description*
Fresh	Unchanged from original state.
Slightly weathered	Slight discoloration, slight weakening.
Moderately weathered	Considerably weakened, penetrative discoloration. Large pieces cannot be broken by hand.
Highly weathered	Large pieces can be broken by hand. Does not readily disaggregate (slake) when dry sample immersed in water.
Completely weathered	Considerably weakened. Slakes in water. Original texture apparent.
Residual soil	Soil derived by *in situ* weathering but having lost original texture and fabric.

Source: Geol. Soc. Eng. Group Working Party, 1995; Tbl. 2.

FAULTS

Faults may be filled with a clayey silt to silty clay material, called *gouge*, which may include breccia. Describe gouge using the procedures for soil. Preserve fault gouge by wrapping the core in plastic wrap.

DISCONTINUITIES

Discontinuities are physical breaks in the rock mass, including joints and bedding plane discontinuities. In most rock excavations within a few hundred feet of ground surface, rock mass behavior is controlled by the frequency, orientation, and condition of discontinuities, so it is important to record their frequency and condition accurately.

Mark each discontinuity on the rock log at its correct depth and orientation. Label mechanical breaks from drilling or handling with “M”; no further description of mechanical breaks is required. Working from the discontinuities graphic, record the breaks per foot.

Where time allows, describe each natural discontinuity in the field using the following nomenclature:

<u>Condition of discontinuities:</u>

Type:
B bedding
J joint
S shear
F fault

Aperture:
Record the separation in mm. N for none.

Roughness:
VR very rough (near-vertical steps and ridges)

R rough (ridges, side-steps, and asperities evident, abrasive to touch)
SR slightly rough (asperities can be felt)
SM smooth (smooth to touch)
SL slickensided (smooth glassy finish with visible striations)

Infilling:
Record material type and thickness in mm. Leave blank for none.

Use the following abbreviations for common infill (define any other abbreviations used):
CL clay
SI silt
SA sand
PY pyrite
QZ quartz
GR graphite

Weathering:
Describe using standard abbreviations for weathering.

PHOTOGRAPHING ROCK CORE

High resolution rock core photographs can be an informative supplement to core log descriptions. Core photographs are best taken after the boring is completed, when the entire sequence of core boxes can be photographed under conditions of uniform lighting and consistent camera position.

Consider the following suggestions for obtaining useful rock core photographs:

- Use a digital camera with sufficient resolution to pick up all visible detail in the core.
- Assemble broken core in the box as close to natural conditions as practical.
- Label the core box lid completely, and in a legible manner.
- Photograph outdoors in full natural sunlight, or indoors with at least two photographic lamps on the subject, to eliminate shadows. The use of a flash only in low light conditions is insufficient.
- Using a spray bottle, wet the core slightly to enhance natural colors.
- Position the camera for a near-direct view into the box, within about 15º to 20º of perpendicular of the plane of the box. The box and lid may be propped slightly to improve the angle.
- Place a measuring tape or folding scale along top or bottom of core box.
- Fill the camera frame with the core box and open lid.
- Remove distracting objects from any remaining background, including the prop on the box lid, and the photographer's feet.
- Photograph sequential boxes in as close to the same position as practical, from first to last box. This can be accomplished using a camera tripod, and positioning marks on the ground for locating each box.
- In addition to core box photos, consider taking close-up photos to record both typical and anomalous features such as layering, texture, and formation contacts.

REFERENCES

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Chapter 5 HYDRAULIC CONDUCTIVITY TESTING IN BOREHOLES

INTRODUCTION

Borehole tests to determine hydraulic conductivity include the falling head test, the rising head test, and the constant head test. These are performed in cased boreholes drilled using clean water as drilling fluid. Boreholes drilled using mud cannot be tested using these procedures, regardless of amount of flushing proposed. The test section should be a well-defined stratum of permeable soil or rock exposed in the borehole, not multiple layers. The shape of the test section is accounted for in analyzing the data, by use of shape factors. Test section configurations and corresponding shape factors are shown in Figure 5-1.

These tests are inherently inaccurate, but can be useful for obtaining rough approximations of hydraulic conductivity, and as a guide to deciding if pump testing is justified (Powers 1992, p. 194). It is important they be carefully performed if the results are to have value. Sources of error include leakage along the casing, clogging of pores due to sloughing of fines into the test water, air locking due to gas bubbles in the soil or water (Cedergren 1989, p. 50), and smearing of fines along borehole walls. The borehole should be carefully cleaned prior to testing. Avoid excessive bailing or pumping that may disturb soils below the casing, or erode discontinuity fillings in rock. Allow the groundwater level to equilibrate in the borehole before starting the test. Given the inaccuracy of these tests, it is preferable to test the stratum of interest at multiple locations.

FALLING HEAD TEST

Begin the falling head test by measuring the initial water level in the casing. Then pour water into the casing, filling it to the top or to some arbitrary height above static groundwater level, and record the start time. Measure the fall in water level over time, noting either the real time or elapsed time from start. Time intervals of 1 to 5 minutes between readings are appropriate for the early portion of the test, but may be increased as the test progresses. Continue the test until the water level has fallen close to its initial level. Attempt to take at least five readings through the duration of the test to establish a consistent trend. Repeat the test if necessary to obtain reliable results. If the borehole water level cannot be raised significantly due to high take, record the approximate rate of inflow and the result.

Test water must be clean and without visible turbidity. Water that contains even small amounts of suspended silt and clay will plug pores and fine fractures, resulting in hydraulic conductivity values that are too low. Test water should be warmer than ground temperature to prevent air bubbles from forming in the test section, as this may also reduce the hydraulic conductivity.

Plot the data on semilog paper, with time on the arithmetic scale versus head ratio on the log scale. Head ratio is the height of the water column above static water level at any time t, divided by the initial height at t_o. The semilog plot should be linear (Cedergren 1989, p. 61).

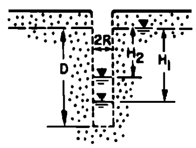
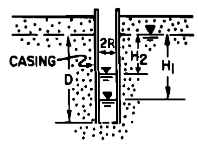
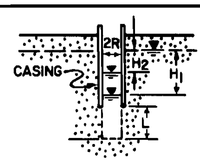
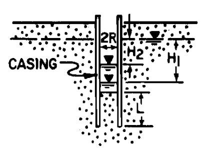
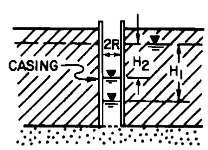
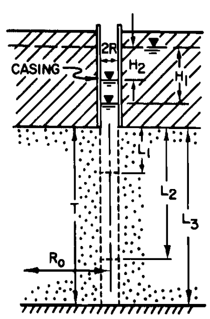
	CONDITION	DIAGRAM	SHAPE FACTOR, F	PERMEABILITY, K BY VARIABLE HEAD TEST	APPLICABILITY
OBSERVATION WELL OR PIEZOMETER IN SATURATED ISOTROPIC STRATUM OF INFINITE DEPTH				(FOR OBSERVATION WELL OF CONSTANT CROSS SECTION)	
	(A) UNCASED HOLE		$F = 16\pi DSR$	$K = \frac{R}{16DS} \times \frac{(H_2-H_1)}{(t_2-t_1)}$ FOR $\frac{D}{R} < 50$	SIMPLEST METHOD FOR PERMEABILITY DETERMINATION. NOT APPLICABLE IN STRATIFIED SOILS. FOR VALUES OF S, SEE FIGURE 13.
	(B) CASED HOLE, SOIL FLUSH WITH BOTTOM.		$F = \frac{11R}{2}$	$K = \frac{2\pi R}{11(t_2-t_1)} \ln\left(\frac{H_1}{H_2}\right)$ FOR $6'' \leq D \leq 60''$	USED FOR PERMEABILITY DETERMINATION AT SHALLOW DEPTHS BELOW THE WATER TABLE. MAY YIELD UNRELIABLE RESULTS IN FALLING HEAD TEST WITH SILTING OF BOTTOM OF HOLE.
	(C) CASED HOLE, UNCASED OR PERFORATED EXTENSION OF LENGTH "L".		$F = \frac{2\pi L}{\ln\left(\frac{L}{R}\right)}$	$K = \frac{R^2}{2L(t_2-t_1)} \ln\left(\frac{L}{R}\right) \ln\left(\frac{H_1}{H_2}\right)$ FOR $\frac{L}{R} > 8$	USED FOR PERMEABILITY DETERMINATIONS AT GREATER DEPTHS BELOW WATER TABLE.
	(D) CASED HOLE, COLUMN OF SOIL INSIDE CASING TO HEIGHT "L"		$F = \frac{11\pi R^2}{2\pi R + 11L}$	$K = \frac{2\pi R + 11L}{11(t_2-t_1)} \ln\left(\frac{H_1}{H_2}\right)$	PRINCIPAL USE IS FOR PERMEABILITY IN VERTICAL DIRECTION IN ANISOTROPIC SOILS.
OBSERVATION WELL OR PIEZOMETER IN AQUIFER WITH IMPERVIOUS UPPER LAYER				(FOR OBSERVATION WELL OF CONSTANT CROSS SECTION)	
	(E) CASED HOLE, OPENING FLUSH WITH UPPER BOUNDARY OF AQUIFER OF INFINITE DEPTH.		$F = 4R$	$K = \frac{\pi R}{4(t_2-t_1)} \ln\left(\frac{H_1}{H_2}\right)$	USED FOR PERMEABILITY DETERMINATION WHEN SURFACE IMPERVIOUS LAYER IS RELATIVELY THIN. MAY YIELD UNRELIABLE RESULTS IN FALLING HEAD TEST WITH SILTING OF BOTTOM OF HOLE.
	(F) CASED HOLE, UNCASED OR PERFORATED EXTENSION INTO AQUIFER OF FINITE THICKNESS: (1) $\frac{L_1}{T} \leq 0.2$ (2) $0.2 < \frac{L_2}{T} < 0.85$ (3) $\frac{L_3}{T} = 1.00$ NOTE: R_0 EQUALS EFFECTIVE RADIUS TO SOURCE AT CONSTANT HEAD.		(1) $F = C_sR$	$K = \frac{\pi R}{C_s(t_2-t_1)} \ln\left(\frac{H_1}{H_2}\right)$	USED FOR PERMEABILITY DETERMINATIONS AT DEPTHS GREATER THAN ABOUT 5FT. FOR VALUES OF C_s, SEE FIGURE 13.
			(2) $F = \frac{2\pi L_2}{\ln(L_2/R)}$	$K = \frac{R^2 \ln\left(\frac{L_2}{R}\right)}{2L_2(t_2-t_1)} \ln\left(\frac{H_1}{H_2}\right)$ FOR $\frac{L}{R} => 8$	USED FOR PERMEABILITY DETERMINATIONS AT GREATER DEPTHS AND FOR FINE GRAINED SOILS USING POROUS INTAKE POINT OF PIEZOMETER.
			(3) $F = \frac{2\pi L_3}{\ln\left(\frac{R_0}{R}\right)}$	$K = \frac{R^2 \ln\left(\frac{R_0}{R}\right)}{2L_3(t_2-t_1)} \ln\left(\frac{H_1}{H_2}\right)$	ASSUME VALUE OF $\frac{R_0}{R}$ = 200 FOR ESTIMATES UNLESS OBSERVATION WELLS ARE MADE TO DETERMINE ACTUAL VALUE OF R_0.

Figure 5-1. Shape factors for falling head and rising head tests in boreholes. From Naval Facilities Engineering Command, 1982; pp. 7.1-105 to 106.

RISING HEAD TEST

A rising head test can be performed provided the static water level is several feet above the bottom of the casing. The test is similar to the falling head test. Draw the water level in the casing below static level by bailing or pumping. Then measure the rise in water level over time. Take care not to draw the water level so far down as to destabilize the bottom of the borehole, or to aerate the zone being tested. This test is more reliable than the falling head test because it avoids the plugging problems caused by fines or air bubbles in the test water.

Rising head tests may not be feasible in rock because of the difficulty of obtaining reliable water level measurements below the bottom of the casing. Groundwater cascading down the borehole walls onto the water level indicator probe tends to produce false readings. To minimize false readings, and if the borehole diameter permits, insert a ¾-inch PVC pipe into the borehole and measure the water level from inside the pipe.

CONSTANT HEAD PUMP TEST

Constant head pump tests are subject to the same limitations as falling head and rising head tests. After the hole is cleaned, water is added or removed through a controlled pumping system to maintain a constant head above or below static groundwater level. The flow rate and amount of head on the test section are measured.

To run a constant head pump-out test, position a variable speed pump several feet below the borehole static groundwater level. To avoid pumping sediment, position the pump at least 2 to 3 feet above the bottom of casing when testing in soil, or the same distance above the bottom of borehole in rock. Start the pump and set at a medium to high rate to draw down the borehole water level. Where testing an unconfined aquifer, pump water from the borehole for at least 2 hours to approach a steady-state condition, prior to commencing measurements.

When the water discharge stream changes from steady flow to faltering, this indicates that the borehole water level has reached the pump intake. Reduce the pump rate in small to medium increments until a steady flow has been re-established. Avoid running the pump dry for more than 2 to 3 minutes, to prevent overheating. When steady flow has been re-established, measure the discharge rate using a stopwatch and a 5-gallon pail or other small container of known volume. If the discharge rate has remained steady for the duration of measurement, increase the pump rate slightly and repeat the measurement. If flow rate falters before the container is filled, terminate the measurement and calculate discharge rate based on the volume of water in the partially-filled container. Then decrease the pump rate in small increments until steady flow is re-established, and repeat the measurement. Continue until acquiring at least five measurements showing comparable results.

If the borehole recharge rate exceeds the pump capacity such that borehole water level cannot be drawn all the way down to the pump screen, measure borehole water level at steady state condition using a water level indicator inside the casing, taking care not to entangle the probe and cable with the pump discharge hose. As an alternative to measuring water level inside the borehole, raise the pump in increments of 5 feet or so until pumping rate can be matched to borehole recharge rate. If the pump has been raised an indeterminate height from the bottom of the boring, mark the supporting cable at the top of the casing with a piece of tape or indelible marker, and use this mark to measure pump depth after retrieving the pump and laying out the assembly on the ground.

Record the following information for each test: type of pump, distance from bottom of pump to intake screen, size of discharge hose, depth to bottom of pump in borehole, open borehole diameter, length of open borehole, depth to bottom of casing, size of casing, duration of pumping prior to measuring flow rate, volume pumped and duration of pumping for each trial, and flow rate for each trial. Record this information along with other related field notes on a lined note pad, properly labeled.

Do not attempt the pump-out test in highly fractured rock that may dislodge from the borehole walls and entrap the pump.

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Powers, J. P. 1992. *Construction dewatering: New methods and applications*. 2nd ed. New York: John Wiley & Sons.

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Chapter 6 HYDRAULIC PRESSURE TESTING IN ROCK

INTRODUCTION

Hydraulic pressure testing, also known as packer testing, is a down-hole test for estimating the hydraulic conductivity of rock. The test is performed by isolating a portion of the borehole using gas-inflated packers, pumping water under constant pressure into the test zone, and measuring the rate of flow into the rock. Hydraulic pressure testing may be performed above or below the water table.

The simplest form of pressure testing utilizes a single packer to isolate a test zone some distance above the bottom of the borehole (20 feet for example). A pressure test is run following each core run as the borehole is advanced, for the full depth of the borehole. The single packer method is time-consuming because it requires alternating coring and pressure testing equipment in the borehole. Single packers offer an advantage in highly fractured or heavily weathered rock which may deteriorate as drilling progresses.

A more efficient method of pressure testing employs a double packer assembly to isolate a test zone of fixed length (20 feet for example) anywhere along the borehole. Pressure tests are run after coring is completed, in a continuous series either from bottom to top of the corehole (upstaging), or from top to bottom (downstaging). This manual describes double packer testing, though the procedures for single packer testing are similar.

THEORY AND ASSUMPTIONS

Pressure testing data are used to estimate the hydraulic conductivity of rock surrounding the borehole, using the equation:

$$K = \frac{Q}{2\pi LH} \ln \frac{L}{r} \qquad \text{for } \frac{L}{r} \geq 10$$

where K is hydraulic conductivity, Q is constant rate of water flow into the test zone, L is length of test zone, H is water head acting on test zone above piezometric (pre-test) conditions, and r is radius of borehole (U.S. Dept. of the Interior, 1974, p. 576). The equation is based on assumptions of homogeneous and isotropic permeability of the rock mass, a semi-ellipsoidal pattern of water flow around the test zone, and steady-state laminar flow through rock discontinuities. The thickness of the stratum tested should be at least $5L$.

The equation above can be expressed in more general terms by:

$$K = \frac{Q}{H} C_p \qquad for\ C_p = \frac{1}{2\pi L} \ln \frac{L}{r}$$

where C_p is a constant based on test zone dimensions. In the pressure test, H and C_p are set as test conditions, and Q is measured.

Pressures generated by the test dissipate within a few feet of the borehole wall (Bliss and Rushton, 1984), so the results are valid only for the immediate vicinity of the borehole. Tests performed above the water table do not yield entirely accurate results, because the procedure does not account for capillary forces which tend to draw water from saturated rock near the test zone into surrounding unsaturated rock.

APPARATUS

The hydraulic pressure testing system includes a water pump, water flow meter, hydraulic pressure gage, packer assembly, and associated plumbing. A general arrangement for double packer testing is shown in Figure 6-1. Configurations vary among contractors. Specific equipment requirements are described in the technical conditions of the drilling contract.

PACKER ASSEMBLY

A common type of packer is the inflatable packer, incorporating a sleeve of high-strength reinforced rubber secured at each end to a cylindrical end cap. A conductor pipe passes through the sleeve and end caps to allow water to be pumped past the packer. Single and double packer assemblies are shown in Figure 6-2. As a rule of thumb, the length of the inflated packer should be at least 5 times the diameter of the boring to minimize leakage; for an NX core size this is 15 inches. Some packer designs feature one of the end caps fixed to the conductor pipe and the other free to slide up and down with inflation and deflation of the packer, to minimize stress on the rubber sleeve.

In a double-packer arrangement the packers are separated by a length of perforated pipe. To minimize friction losses the perforations should be at least 1/4 inch in diameter, and total an area at least twice the internal area of the pipe. The length of the test zone, including end caps and perforated pipe, is usually set at a convenient interval such as 10 or 20 feet.

Packers are inflated using bottled gas, commonly nitrogen, fed through a regulator and a high-pressure inflation tube. In a double packer assembly, a short length of inflation tube connects the upper packer to the lower packer. The "seating pressure" is the pressure necessary to inflate the packer and seat it firmly against the borehole wall, absent external hydrostatic pressure. Seating pressures may range from 50 to 150 psi for various packers. The packer manufacturer's recommended maximum inflation pressure may be in the range of 100 to 200 psi, or higher.

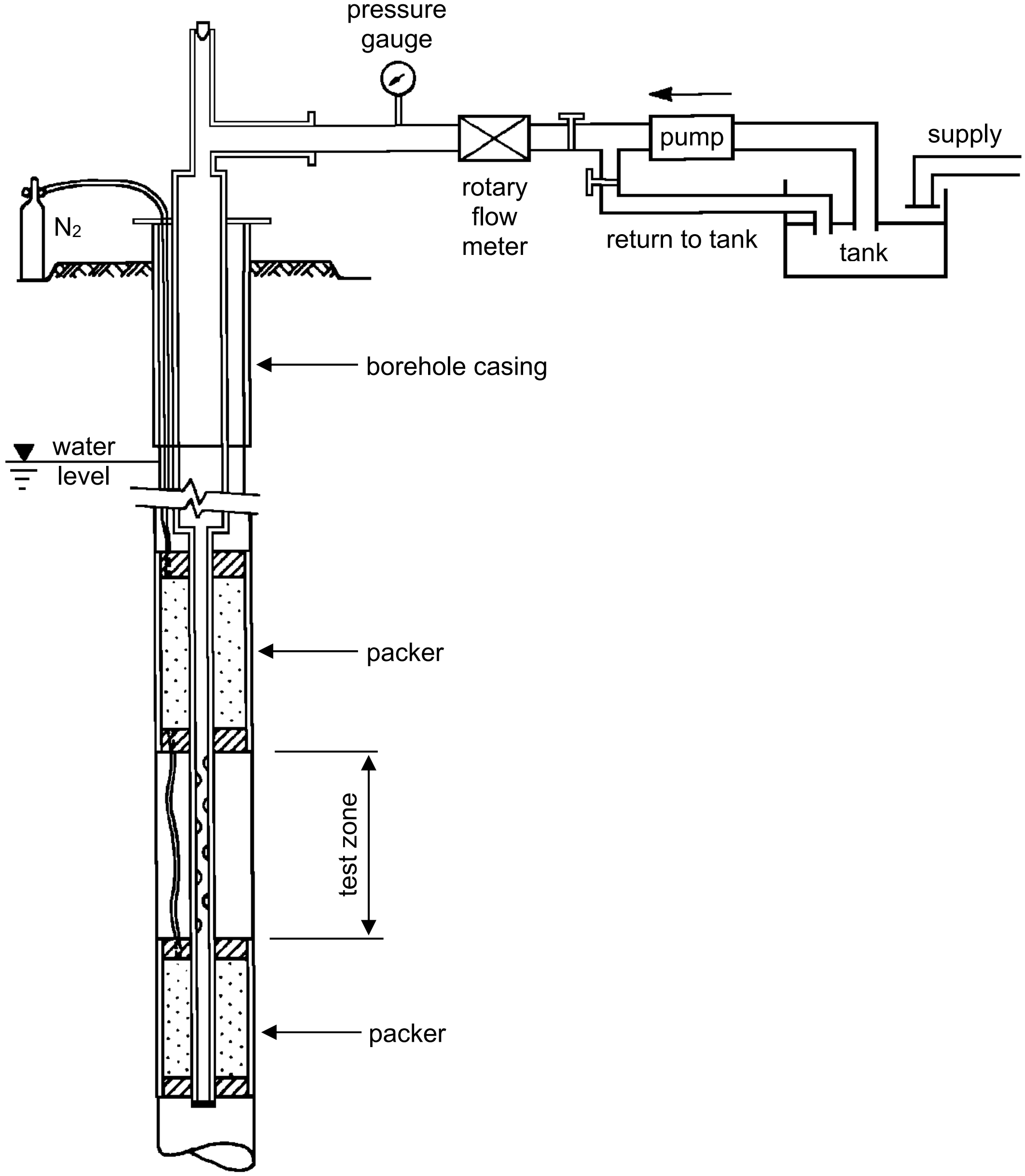


Figure 6-1. General packer testing arrangement.

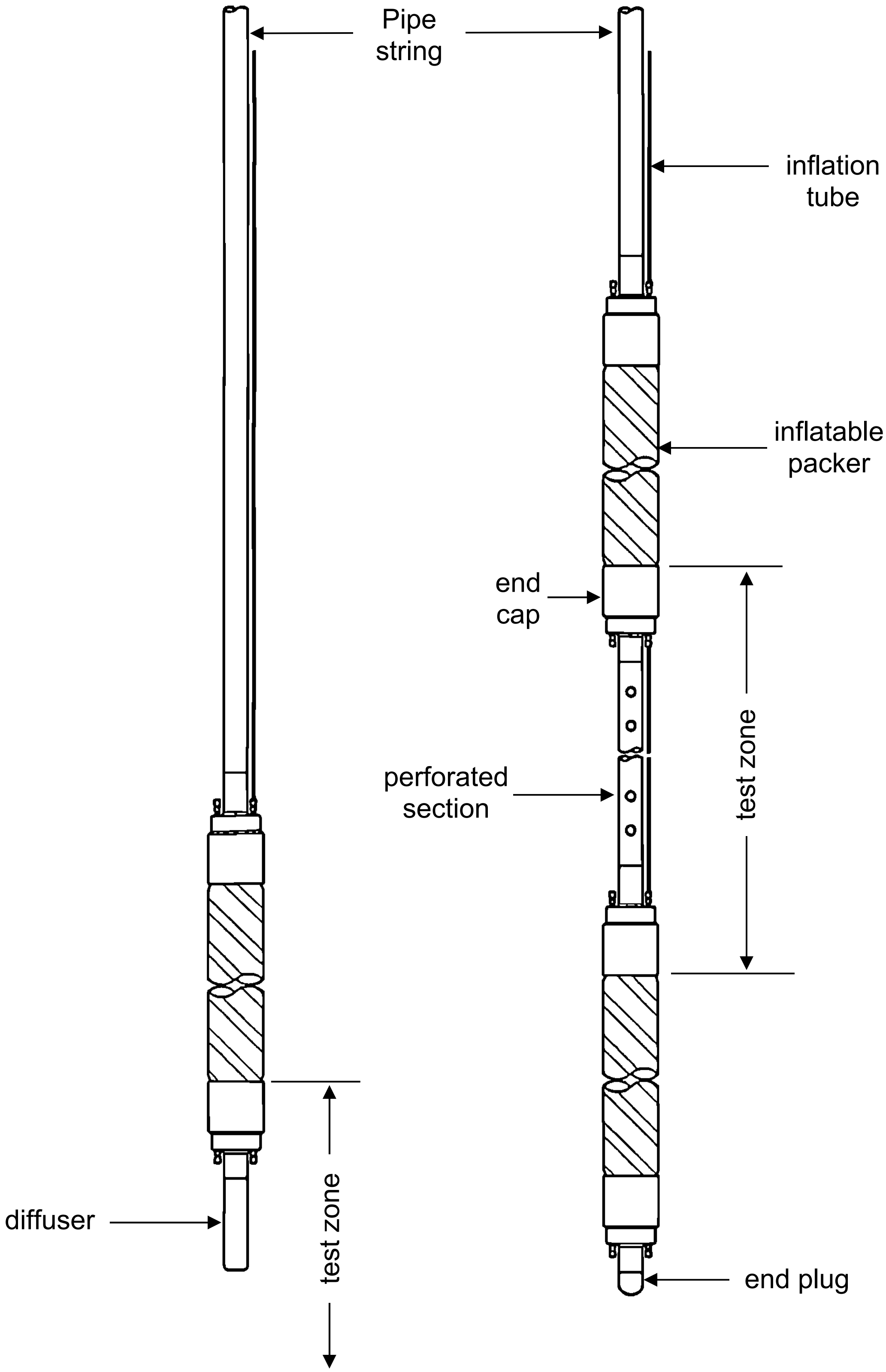


Figure 6-2. Single and double packer assemblies.

The rubber sleeves of inflatable packers are vulnerable to puncturing or tearing on rough projections when being moved in the borehole, so spares should be kept available on site during testing.

COMPRESSED GAS SYSTEM

Packers are best inflated with an inert gas, such as nitrogen. Gas that can heighten a fire hazard, such as oxygen, should never be used. Compressed air is not recommended. Toxic or flammable gases should never be used.

The compressed gas system includes the gas cylinder, a regulator, and the inflation tube. The regulator attaches directly to the cylinder, and controls gas delivery pressure. A 1/4-inch nylon tube connects the regulator to the packers. It is convenient to place a valve in the tubing at the regulator, to release pressure in the packers on completing each test. This avoids having to repeatedly detach and reattach the tubing at the regulator, which can damage the connectors. Tubing is subject to damage during testing, so extra unions, ferrules, and compression nuts should be kept available for making repairs.

WATER PUMP

The pump should be capable of delivering water to the test zone faster than it can escape through rock discontinuities, at the specified maximum test pressure. For rock of low to medium permeability the pump mounted on the drill rig may be sufficient. For highly permeable rock a larger pump will likely be necessary. Centrifugal pumps and progressing cavity (Moyno) pumps are preferred over piston pumps, as the former can deliver a constant discharge at constant back pressure.

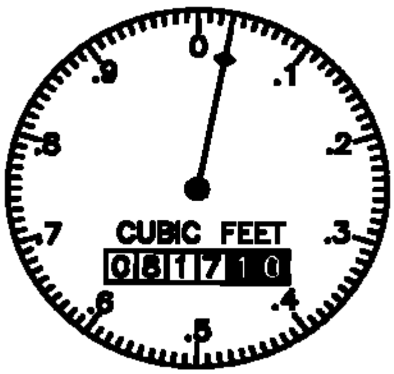
WATER METER

A water meter is used to measure the flow rate, or "take", of water into the test zone. A residential-type water meter is generally adequate. A meter that reads in gallons is preferred, but one reading in cubic feet is satisfactory. Reading a water meter is explained in Figure 6-3.

A sight-flow indicator features a visible rotor or propeller that spins when water is moving through the piping. It may be incorporated into the water meter, or may be separate and mounted in line. The sight-flow indicator can be helpful when testing low-take zones to verify that the meter is not stuck.

PIPE STRING

The pipe string carries water down the borehole to the test zone. It commonly consists of 1- to 1-1/4-inch diameter standard steel water pipe. Drill rods are commonly used. Packers have also been suspended on 2-inch diameter thermo-plastic water well casing, its light weight offering an advantage (Brassington and Walthall, 1985). Pipe sections between joints should be of uniform length, except for the top section which may vary in length to suit testing needs.



The meter reading is taken from the figures shown under the words CUBIC FEET, and the sweep hand. This meter reads 81710.03 cubic feet.

On most meters the final digit will "turn over" once the sweep hand has passed the 0.6 mark. On this meter the final number has turned over, and the correct reading is 2425.92 cubic feet.

The small triangle is the low flow indicator. It will spin if water is flowing through the meter.

Figure 6-3. Reading water meters.

SURFACE PLUMBING

Surface plumbing includes the piping, valves, gages, fittings, and hoses used to control water flow rate and pressure to the pipe string. A schematic of a surface plumbing arrangement is shown in Figure 6-4. Surface plumbing should be set up to minimize friction losses. Pipe diameter should be equal to or larger than the inlet/outlet diameters of the water meter, and hose diameter should be equal to or larger than the pipe diameter. Piping commonly consists of 1-1/2 to 2-inch diameter standard steel water pipe. Connections should be made short and straight, with a minimum number of changes in diameter.

A surge tank may be desirable to dampen pressure surges, though it may not be necessary with a steady-acting pump. The performance of the water pressure gage will indicate whether or not a surge tank is necessary. The tank can be made with a 3-foot length of pipe, oriented vertically as shown.

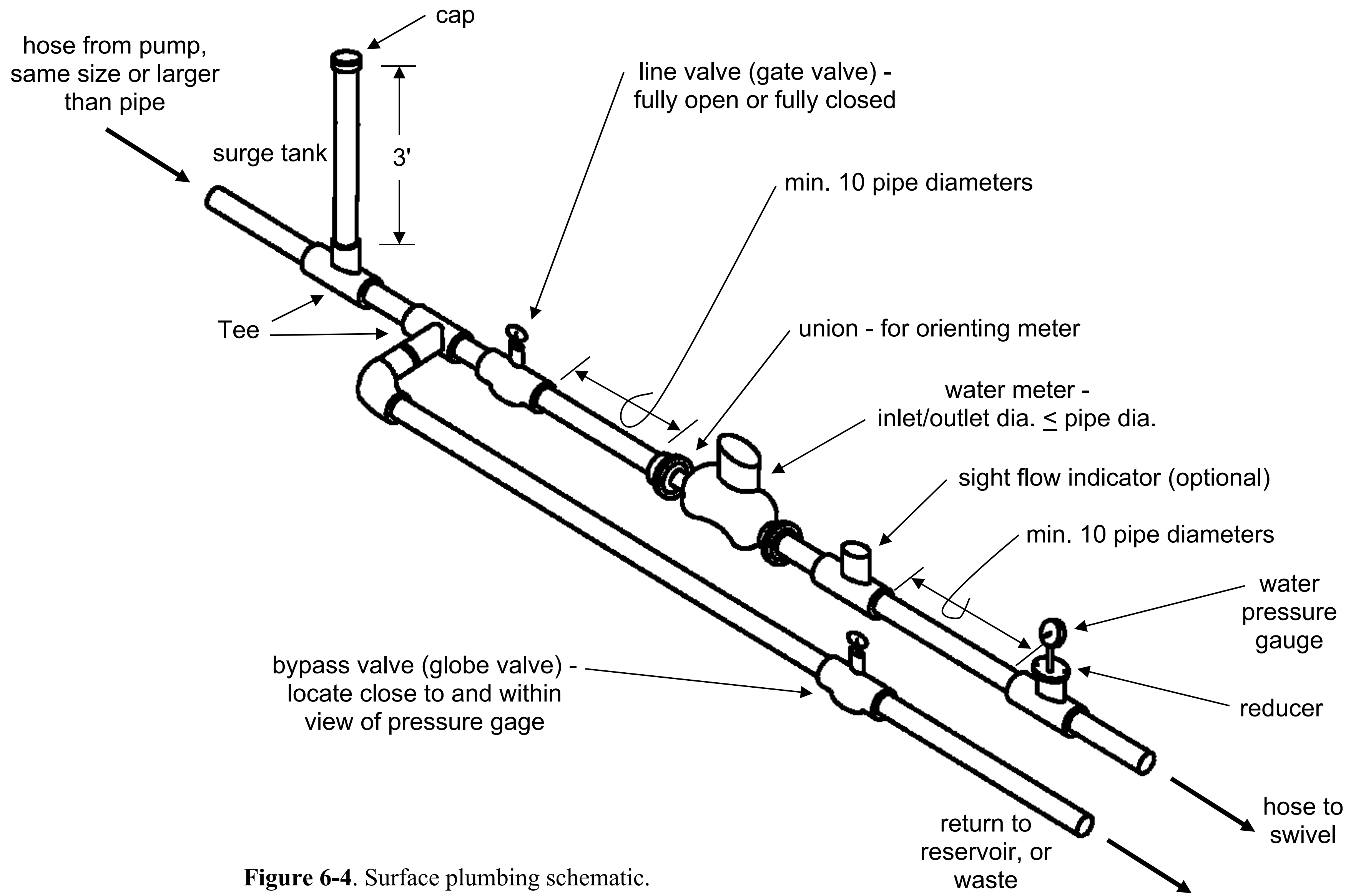


Figure 6-4. Surface plumbing schematic.

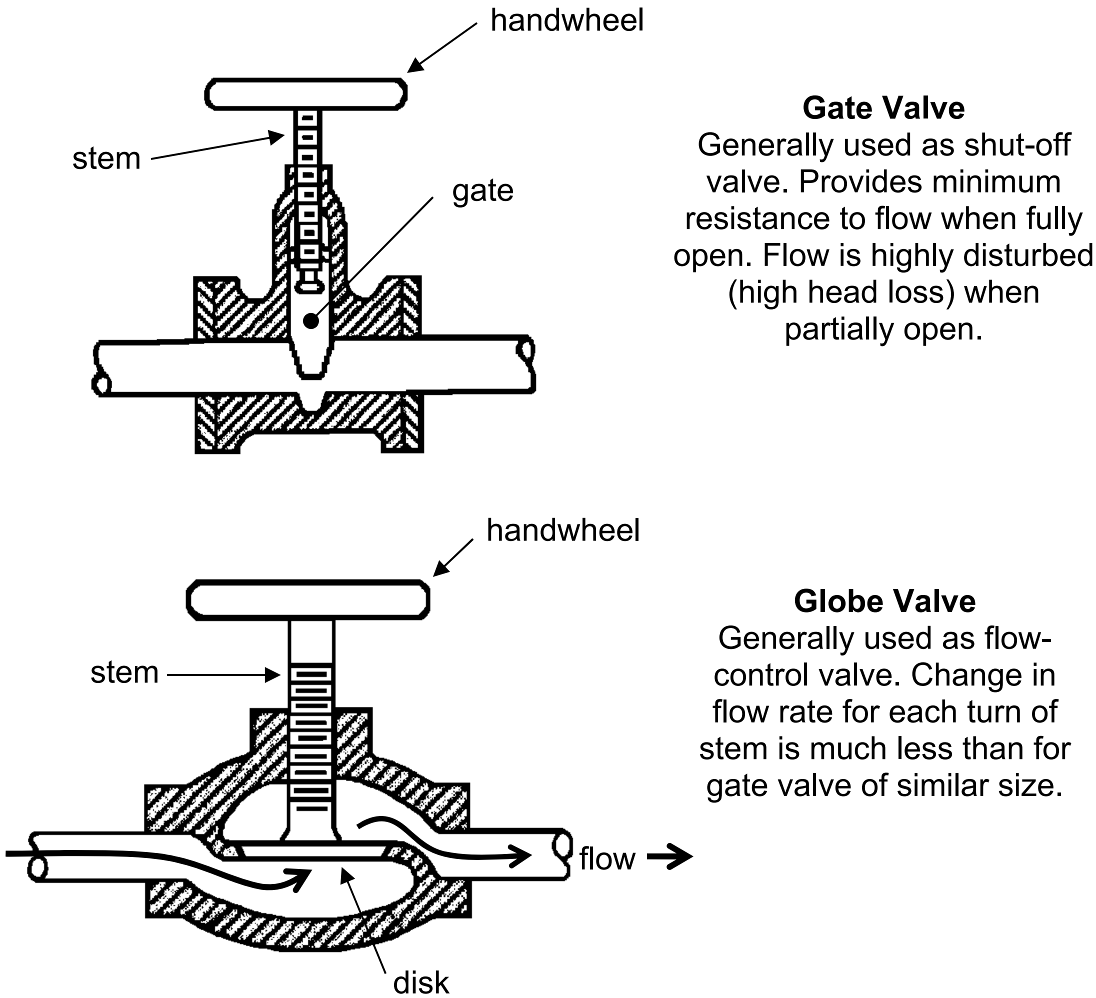


Figure 6-5. Valve schematics.

Two valves are used to regulate water flow and pressure. The *line valve* releases water to the test zone. A valve designed to operate fully open or fully closed, such as a gate or ball valve, is normally used. The *bypass valve* is used to regulate flow rate and pressure by releasing excess water. A valve designed to control flow, such as a globe valve, is used. Valve schematics are shown in Figure 6-5. In installing a globe valve it is desirable that water flows upward through the orifice and that the disk is screwed down against the pressure in shutting the valve.

TEST WATER

Test water must be clean and without visible turbidity. Water that contains even small amounts of silt, clay, or organic matter will plug rock pores and fine fractures, resulting in hydraulic conductivity values that are too low. Test water should be slightly warmer than ground temperature to prevent bubbles from forming in the test section and plugging rock pores. Test water is commonly produced from a tank truck or fire hydrant.

PREPARING THE BOREHOLE

After completing coring and prior to removing the drill rods, thoroughly wash the borehole, and surge to remove cuttings trapped in fractures and pores. Then remove drill rods.

Allow some time for water level in the borehole to stabilize, then periodically measure the depth to water. When subsequent readings show a stable water level, record the reading. This reading represents the average piezometric level in the rock column along the borehole.

PACKER ASSEMBLY

In assembling the apparatus and performing the tests, all work involving compressed gas should be performed by or under the direction of a driller trained in its safe use. *See section on Compressed Gas Cylinder Safety, in the chapter on Site Safety, for precautions*.

Assemble packers, perforated pipe section, and inflation tubing on the ground. Check that inflation tubes are in good condition. Do not use Teflon tape on compression fittings on tubes. Wind the inflation tube connecting the two packers loosely around the perforated pipe, and secure with electrical tape. Leave enough slack in the tube to accommodate movement of packer heads during inflation, but not so much that the tube can kink or snag under the packers when the assembly is being lowered or raised in the borehole.

Measure and record lengths of packer assembly components as shown in Figure 6-6. The test zone length for a double packer assembly is the distance between the portions of packers that make contact with the borehole wall. For packers with sliding heads, assemble with the fixed caps facing the test zone, or estimate the length that the caps will slide and add to the measured length of the test zone.

Mount the packer assembly on the pipe string, and position in the borehole casing. As the pipe string is being made up, inspect each pipe section to ensure it is clean and open, and joint threads are in good condition. Secure joints wrench-tight. Secure the inflation tube to the pipe string at intervals with electrical tape. Record the size, length, and number of pipe sections installed.

PACKER INFLATION TEST

Perform a packer inflation test to verify proper operation of the packers. For optimum safety and efficiency, perform the test with the packer assembly completely inside either the borehole casing or the corehole. In some cases it may be preferable to position the packer assembly inside a length of casing on the ground surface. *Keep a safe distance from the packers during this test. Improper connections or worn equipment can break resulting in fragmenting of the system. Eye protection is required.*

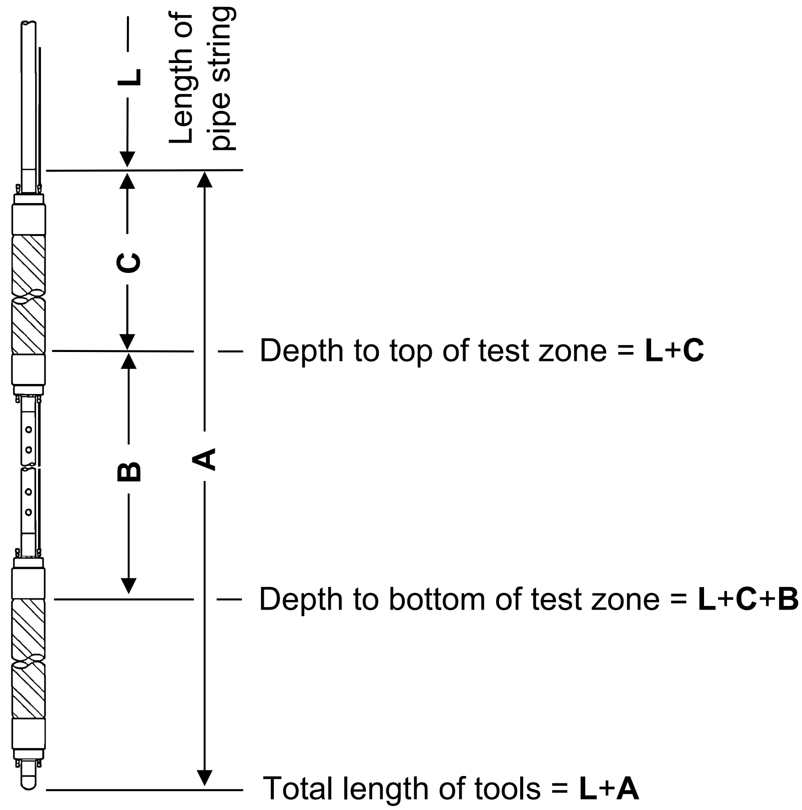


Figure 6-6. Measuring the packer assembly.

After positioning the packers, connect the inflation tube to the regulator on the compressed gas cylinder. Inflate the packers to about 50 percent of the packer manufacturer's maximum allowable inflation pressure, plus the piezometric head at the test location. Wait several minutes for pressures to stabilize, then close the gas cylinder valve. If the pneumatic pressure remains constant, the system is tight. If the pneumatic pressure falls to some lower pressure and then holds steady, insufficient time was provided for the system to equilibrate, and actual packer inflation pressure is that to which the gage fell. If the gage continues falling to a low pressure, the system leaks.

If the system leaks, locate and repair the leak. Begin at the regulator fittings. Grasp the connection in a fist and feel and listen for escaping gas. Listen for bubbling in the pipe string or borehole annulus. Check for buildup of pressure in the test interval by sealing the palm of your hand over the open end of the pipe string.

If the leak cannot be located from the surface, deflate the packers by opening the valve in the inflation tube, or by disconnecting the tubing from the regulator. Deflation can take several minutes. To confirm that deflation is complete, place a finger over the point of gas release. Remove the packers from the borehole. Wet down the entire system, apply low pressure, and look for bubbles that would indicate a leak. Examine the rubber sleeves of the packers, the seal between the rubber sleeves and end caps, the seals between sliding caps and conductor pipe, and the entire length and fittings of the inflation tube.

CONNECTING AND TESTING SURFACE PLUMBING

Assemble surface plumbing. Make pipe and hose connections wrench-tight. Position the bypass valve so it can be operated easily while observing the water pressure gage. The ideal location for the water pressure gage is on the pipe string about 10 pipe diameters below the swivel, where the gage reading accounts for friction losses through all of the surface plumbing. This location is not always practical, however. Ensure that the gage has been recently calibrated. Before attaching surface plumbing to the pipe string, check the accuracy of the water meter by flushing water through it into a container of known volume, and measuring the fill time. Attach a swivel to the top of the pipe string, then attach a hose leading from the instrument string. Make joints and connections tight so no significant water loss occurs between the water meter and the pipe string. Arrange hoses to eliminate kinks and tight bends.

With all components connected, open the line valve and bypass valve to flush water through the system. Check the plumbing for leaks between the water meter and the swivel. Check the operation of the water meter and water pressure gage. If the pressure gage fluctuates excessively and a surge tank is in place, remove and drain the surge tank, and reinstall. A series of surge tanks may be necessary to stabilize the gage, if the pump is worn excessively.

STEP TEST PROCEDURE

A common procedure is to inject water into the test zone under a five-step series of pressures defined by $n \times$ *maximum test pressure*, where for example n = 0.4, 0.7, 1.0, 0.7, and 0.4. Water is injected under each pressure for a sufficient period of time for steady state flow conditions to develop. On the ascending series of pressures, water is injected until at least three readings of water take over 5-minute intervals are essentially equal, or a minimum of 15 minutes. On the descending series of pressures (final two pressures in the example sequence), water is injected until at least one reading of water take over a 5-minute interval is essentially equal to takes at the same pressure in the ascending series, or a minimum of 5 minutes.

"Test pressure" is the water pressure acting at the center of the test section, above the piezometric pressure in the surrounding rock. Test pressure is limited to maintain laminar flow in rock discontinuities, and to prevent hydrofracturing of the rock. A maximum test pressure of 50 psi (115 feet of water head) is typical for design of gravity flow water tunnels. Higher test pressures are used in some applications, such as design of unlined pressure tunnels for hydro-power facilities.

Total Pressure in Test Zone, P_T

$P_T = B + H + G$

P_T is not to exceed (1 psi/ft)(B ft)

Net Test Pressure in Test Zone, P_N

$P_N = P_T - A \quad A = B - C$

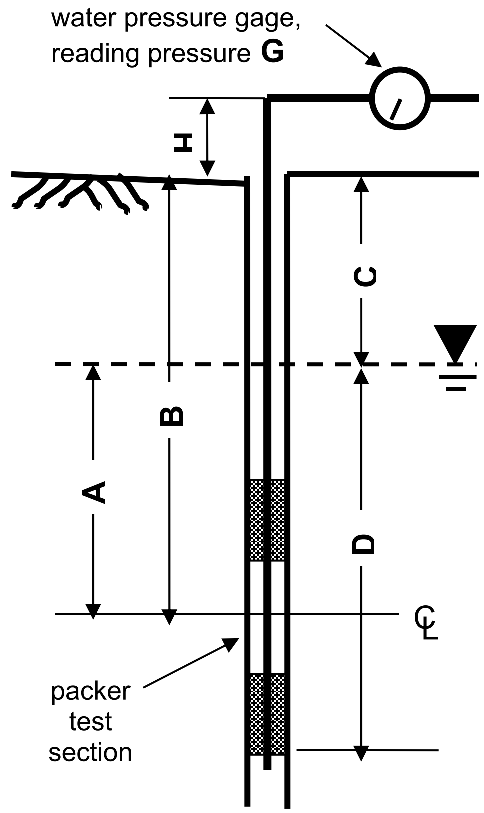
$=(B + H + G) - (B - C)$

$=C + H + G$

P_N is independent of depth to test zone.

P_N is not to exceed 115 ft water head (50 psi) to maintain laminar flow.

Gage pressure, in psi, to produce net test pressure: G (psi)=(P_N - C - H)(0.43)



All pressures in terms of feet of water, unless otherwise noted.

Packer Inflation Pressure, P_I

$P_I = P_T + P_S$ where P_S = seating pressure $\approx$50 psi or higher

Note that P_I changes with depth.

Figure 6-7. Pressure relationships for hydraulic pressure testing.

Pressure relationships are shown in Figure 6-7. In most cases test pressure is not to exceed 1 psi per foot of depth from ground surface. Where piezometric head in the rock is constant with depth, the gage pressure necessary to produce the desired test pressure becomes independent of depth of the test interval. Friction losses are generally neglected in deriving gage pressures for testing, but are accounted for in reducing the data.

Packer inflation pressures are directly proportional to depth, and require adjustment as the depth of the test zone is changed. The pneumatic pressure necessary to inflate the packer during borehole testing is the sum of 1) seating pressure, 2) the piezometric pressure in the rock at the test location, and 3) the test pressure.

PERFORMING THE PRESSURE TEST

POSITIONING THE PACKERS

Prior to testing, examine the core or the core log to identify heavily fractured or severely weathered rock. Plan the test interval sequence to straddle poor rock, so as to prevent packers from being damaged during inflation, to ensure a tight seal against the borehole walls during testing, and to avoid a borehole collapse that could bind the packer assembly.

Testing using double packers normally proceeds from the bottom of the borehole up (upstaging), so that any rock dislodged by the packers falls into the previously tested portion of borehole. A double packer assembly should be lowered no closer than 5 feet above the bottom of the borehole, to avoid debris that may have accumulated there. Hydraulic conductivity along the soil/rock interface is of interest for planning shaft construction, so test the rock as close to this interface as practicable. Never position a packer inside the drill casing to test the rock below, unless the casing has been grouted into the hole.

Position the packer assembly to the appropriate depth and lock the pipe string with a pipe clamp or vise. When lowering packers more than 50 feet below the water table, hydrostatic pressure may flatten the unpressurized rubber sleeve of the packer, causing it to rub on the sides of the borehole. Apply pneumatic pressure to restore the static shape of the sleeve.

With packers positioned in the starting test interval, inflate them to appropriate pneumatic pressure. This may take several minutes. Close the gas cylinder valve, and check the pipe string and borehole annulus for leaks, as for the packer inflation test. Record the packer inflation pressure. Monitor the pneumatic pressure during subsequent testing to confirm the absence of leaks.

Connect the hose from the surface plumbing to the swivel on the pipe string.

CHARGING THE TEST ZONE

To begin the flow of water through the surface plumbing, open the bypass valve completely, close the line valve, and start the pump.

To direct water into the test zone, open the line valve to full open. Then slowly close the bypass valve until the water pressure gage reads the gage pressure necessary to produce desired test pressure in the sequence. Allow the system to run until the water pressure stabilizes, which may take a few minutes. Should the water pressure gage needle behave erratically, it might be stabilized by adjusting the pump speed.

When water pressure has stabilized, begin recording data. Record the time and water meter reading at the start of test. Read the time to the nearest second and the meter to the nearest

0.05 gal. Take readings at prescribed time intervals until successive readings yield essentially equal flow rates. Low take zones generally require more time to stabilize. Observe the water pressure gage during each test, and adjust the bypass valve as necessary to maintain the starting pressure. In testing above the water table, pump water into the test section under the desired pressure for at least 10 to 20 minutes before recording data.

On completing a single step in the pressure sequence, proceed to the next. If the water take at maximum test pressure is zero, terminate the test sequence. Stepping down the pressure sequence may cause the flow indicator to briefly rotate backwards as air in the pipe string expands, so allow the indicator to stabilize. Water takes in a pressure sequence may follow a pattern suggestive of particular ground conditions, as summarized in Figure 6-8.

If the desired pressure cannot be attained with the bypass valve fully closed, record that the pump capacity has been reached and the hydraulic conductivity of the rock is greater than the water take indicates. Perform a falling head test through the pipe string before deflating the packers. If takes are consistently above the capacity of the pump, it may be desirable to shorten the distance between the double packer assembly to continue pressure testing.

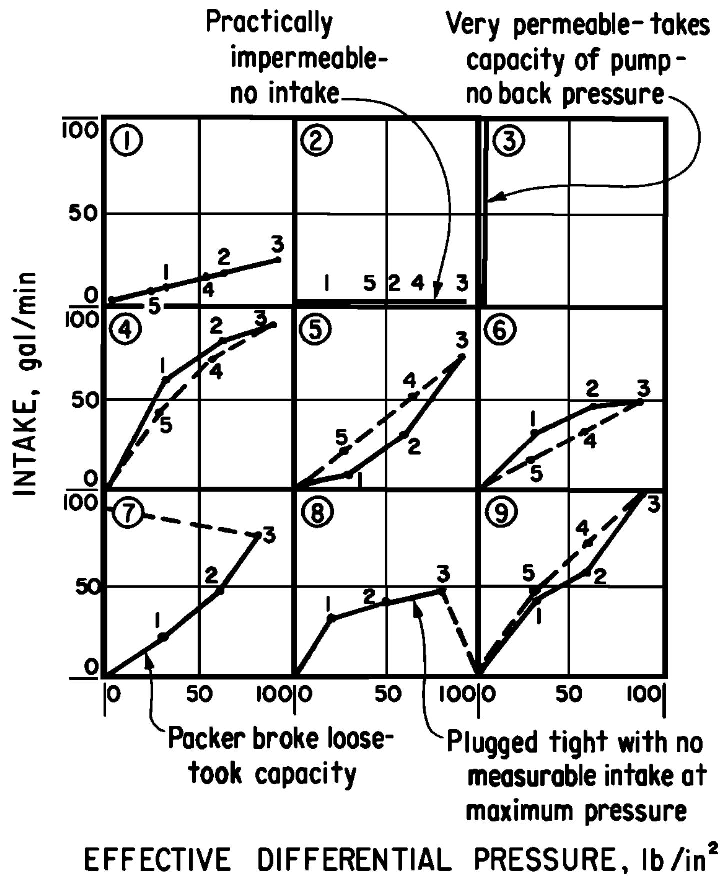
MEASURING THE PIEZOMETRIC LEVEL

Piezometric levels in the rock may vary through the depth of the borehole. This can occur, for example, in areas where bedrock aquifers provide industrial or municipal water supply. If piezometric levels may vary with depth, they should be measured through the pipe string after testing each interval, before deflating the packers.

This measurement is necessary only when the test zone has taken more than 1 gpm. In less permeable zones it may take a long time for the water level to stabilize, and in these cases the piezometric level may be approximated by the static level measured in the open borehole.

REPOSITIONING THE PACKERS

After completing a test sequence, open the bypass valve and stop the pump. Deflate the packers, disconnect the surface plumbing, and move the packers to the next test interval. A double packer assembly would normally be raised the length of the test interval. Keep track of the depth of the packer assembly during a testing sequence by counting the rods into and out of the borehole.



<u>Probable conditions represented by circled numbers:</u>

1. Permeability low, discharge proportional to pressure, flow laminar - narrow, clean fractures.
2. Little or no take regardless of pressure - firm, practically impermeable material, fractures tight.
3. Highly permeable, high rates of water take and no back pressure, gage pressure due to pipe friction only - relatively large open fractures.
4. Highly permeable, flow turbulent - fractures relatively open and permeable; fractures contain fault gouge which tends to expand on wetting, or dislodges and tends to collect in traps that retard flow.
5. Permeability high, increases with time, flow turbulent - fault gouge washes out, fractures probably relatively large.
6. Similar to 4 but fractures tighter and flow is laminar.
7. Highly permeable, test takes capacity of pump with little or no back pressure, flow turbulent - packer failed, or fractures large. Fractures washed clean.
8. Takes full pressure with no water intake near end of test - fractures fairly wide and open but filled with clay gouge which tends to seal when subjected to water under pressure.
9. Open fractures with gouge which tend to first block and then break under increased pressure. Probably permeable, flow turbulent.

Figure 6-8. Interpretation of hydraulic pressure testing results (simulated data). From U.S. Dept. of the Interior, 1977; pp 264-266.

TROUBLESHOOTING

<u>Packers Under-Inflated</u>

A packer moving up the borehole in response to pumping water into the test zone indicates an improper seal around the packer. Confirm that packer inflation pressure has been calculated correctly.

A pulsating water pressure may indicate recurrent surging of water out of the test zone past an under-inflated packer. A sympathetic fluctuation may occur in the pneumatic pressure gage at the regulator.

To correct either condition, slowly increase the packer inflation pressure until the problem ceases, but do not exceed the manufacturer's recommended maximum inflation pressure.

<u>Compressed Gas Leakage</u>

Compressed gas leaking into the test zone during testing may produce the following responses: 1) decreasing rates of take as individual test proceeds, or a need to increase pressure to maintain constant flow rate, 2) periodic backward movement of the water meter dial, or 3) bursts of gas from the bypass valve.

Bubbling in the borehole annular space around the pipe string indicates a leak in the upper gas tube or upper packer.

A drop in pneumatic pressure at the regulator gage indicates a leak somewhere in the gas delivery system or the packers.

A discharge of natural gas from the formation could also cause bursting from the pipe string or bypass valve, or bubbling in the borehole annulus. The majority of gaseous phase discharges from soils and rocks consist of methane. See the chapter on Environmental Sampling and Testing for appropriate precautions.

<u>Water Leakage Past Packer</u>

Water appearing at the top of the drill casing during testing indicates water bypassing the upper packer. The cause may be under-inflated packers, or a rock fracture adjacent the upper packer. Confirm packer inflation pressure, and increase if appropriate. Leakage may not appear at the top of the casing if highly permeable rock lies above the upper packer. A water level indicator can be used to check for a rise in water level in the borehole, but exercise care to avoid entangling the sensor with the pipe string and inflation hose.

Water takes that appear excessive in comparison to the condition of the core may indicate leakage past the bottom packer.

If leakage appears to be through rock fractures past either packer, refer to the core log (or core), and relocate packers up or down to avoid the fracture. If a continuous test record is required it may be necessary to overlap tests to get past the problem zone. If relocating the packers fails, trip the packer string out of the borehole and examine the packers for signs of malfunction.

As alternative solutions: 1) lengthen the perforated conductor to span the problem zone, 2) try a different packer assembly or replace the rubber sleeves, or 3) estimate and record the amount of water being bypassed from the top of the drill casing and subtract from the total flow into the test zone. The appropriate solution depends on project needs and ground conditions. Consider the relationship of the fractured zone to the proposed excavation, and the potential severity of groundwater inflows.

Always compare takes to the condition of rock discontinuities. High take zones or takes that appear excessive should be suspect.

Air Trapped in System

Air trapped in the plumbing system can cause the water meter to appear to run backward when testing a no-take zone. Fluctuations in water pressure cause the volume of trapped air to change. The meter will run forward as the air is compressed, and backward as the air is decompressed. The extent of the fluctuation is generally about 0.1 gal. Record the test as a no-take zone and note the performance of the meter as a remark on the Field Data Sheet.

FRICTION LOSS TEST

In calculating hydraulic conductivity from the field data, friction losses are deducted from pressure and elevation head to determine total head on the test zone. Friction losses are directly proportional to borehole depth (due to length of pipe string) and rock permeability (due to high water velocity in piping), and are inversely proportional to pipe diameter. Friction loss factors for standard pipe are tabulated in Appendix A. In situations where friction losses may be significant, and accurate friction loss data are not available for the piping used (such as drill rods or corroded pipe), a friction loss test should be performed. The test provides data for plotting curves of head loss versus flow rate for standard lengths of pipe.

To set up the test, lay out 100 feet of pipe string on the ground, straight and level. Joints should be wrench tight. If conditions prohibit leveling the string, measure the difference in elevation from end to end. Other lengths of pipe string can be used for convenience, and an adjustment made in the calculations. Attach surface plumbing to the upstream end of the pipe string, in the same manner as for pressure testing. At the downstream end of the pipe string attach a water pressure gage, then a valve (the "string valve"), then another length of pipe.

To establish a flow of water through the test setup, open all three valves, and start the pump. Close the bypass valve until there is a reading on the pressure gage on each end of the pipe string. If pressure readings cannot be achieved with the bypass valve fully closed, slowly close the string valve until there is a reading on both gages. Allow the system to stabilize, this may take several minutes. Adjust the bypass and string valves as necessary to achieve a stable condition.

A minimum of six trials at different pressures and flow rates are recommended. For each trial, measure the flow rate by recording time and water meter readings at regular intervals, as in the water pressure test. Record the pressures at both gages. Increase the pressure in the string by closing either the bypass valve or the string valve further, then repeat the previous step. When sufficient data have been collected, open all valves and stop the pump to terminate the test.

Plot head loss (in feet) versus flow rate (in gpm) on semilog graph paper, with head loss on the log axis. Draw a smooth curve through the plotted points. For lengths of pipe string other than 100 feet, adjust the gage difference as follows:

$$\text{head loss (ft)} = \text{gage difference (psi)} \times \frac{100\text{ ft}}{\text{distance between gages (ft)}} \times 2.31\text{ ft / psi}$$

RECORDING THE FIELD DATA

An example of a completed field data sheet for hydraulic pressure testing is shown in Figure 6-9. Blank field data sheets are included in Appendix C. Fill in entries in the same manner as for boring logs, where applicable. The form includes units of measure commonly used, but if other units are desirable for convenience, line out inapplicable preprinted units and pencil in the correct units, on every sheet on which the change applies. Start a new form for each test zone in the series.

In addition to preparing the preprinted field data sheet, sketch the testing apparatus and packer assembly, including dimensions, as shown in Figures 6-4 and 6-6.

Data reduction is normally performed in the office using a spreadsheet program, though the calculations are simple and can be easily done manually.

Test Zone Measurements: Use the pipe count and packer assembly dimensions to calculate depths to top and bottom of test zone. Depths are measured from ground surface (or water surface if testing offshore), so subtract stickup from the total pipe string length.

Borehole Size/Diameter: Indicate core size (NX for example), and measured outside diameter of core bit.

Pipe String Size/Diameter: For standard water pipe, indicate nominal diameter (1-1/4 for example). For drill rod, indicate rod size (NW for example), and ID measured to nearest 1/16 inch.

MWH MONTGOMERY WATSON HARZA

WATER PRESSURE TEST - FIELD DATA

Project Name Busby Run **Project No.** 319 0201 **BORING NO.** BR-6

Field Engr/Geol L G Anderson **Sheet** 1 **of** 1

Contractor ALD Drilling **Driller** Jim Brooks **Date** 9-8-03

A. Depth to Water: 19.8 ft
Measured in: ☐ Open Borehole ☑ Pipe String

B. Gage Height: 1.8 ft

C. Column Pressure
= A + B
= 21.6 ft x 0.433 psi/ft H_2O = 9.35 psi

Test Zone: Depth to Top 55 ft
Depth to Bottom 66 ft
Length 11 ft

Borehole Size / Dia.: NX / 3 in

Pipe String Size / Dia.: 1.25
☐ New Smooth ☑ Ordinary ☐ Old Rough

Pressure (psi)			Time (hr:min:sec)			Water Meter Reading (gal)		
Test (D)	Gage (D-C)	Packer Inflation	Start	End	Duration	Start	End	Take
20	11	250	9:15:15	9:20:20	5:05	1616.13	1637.48	27.35
				9:25:15	4:55		1665.71	28.23
				9:30:15	5:00		1695.43	29.72
35	26	250	9:40:20	9:45:20	5:00	1749.63	1803.62	53.99
				9:50:20	5:00		1849.48	45.86
				9:55:25	5:05		1902.19	52.71
50	41	250	10:12:00	10:17:00	5:00	1914.08	1962.74	48.66
							2015.41	52.67
							2070.19	54.78

Remarks ____________________

Figure 6-9. Example pressure testing log.

Condition of Pipe String: Water pipe will generally be "new smooth". Drill pipe may be "ordinary" or "old rough". Pipe that is "very rough" should not be used.

Depth to Water: Measure in open borehole, or through pipe string with packers inflated.

Gage Height: The vertical distance from ground surface at the borehole to center of pipe at the water pressure gage position.

Column Pressure: The height of test water in the pipe string above the water table.

Pressures: Test pressure is as defined in the step test procedure. Calculate gage pressure and record to an accuracy of 1 psi. Friction losses are usually ignored in computing the gage pressure necessary to achieve the desired test pressure. However, friction losses should be accounted for if they are significant, say about 20 percent of the test pressure. Use the friction loss tables in Appendix A to estimate friction losses.

If the piezometric head in the rock is so far below ground surface that the column pressure (C) exceeds the intended starting test pressure, increase the test pressures as necessary to obtain a positive starting gage pressure.

Packer inflation pressure is the reading from the pneumatic pressure gage at the compressed gas regulator.

Time: Start and end times may be real time measured using a wristwatch with sweep second hand, or elapsed time measured using a stopwatch, but be consistent. If showing real time, military time is preferred, for example show 2:00 PM as 14:00:00. Show duration in minutes and seconds.

Water Meter Reading: Show the meter reading in the units to which the meter is calibrated. A meter that reads in gallons is preferred, but if the meter reads in another unit such as cubic feet, line out the "gal" unit on the data sheet and show the actual unit. Some meters allow the reading to be zeroed to start each test, which may be convenient.

Remarks: Use this space to describe unusual occurrences, or provide explanatory information. If space will not permit a sufficiently detailed description, use the space to reference another sheet containing the description. For example, write "See sheet __ for supplementary notes on ________", and write the description on a plain sheet numbered sequentially in the series of field data sheets for the borehole.

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Chapter 7 PIEZOMETERS AND OBSERVATION WELLS

INTRODUCTION

Observation wells are used to measure the depth to the groundwater table (or perched water table) in permeable ground. Standpipe piezometers are used to measure pore pressures within confined or semi-confined aquifers. The installations are similar. Vibrating wire piezometers are used to monitor pore pressures in aquifers and aquicludes. Data from wells and piezometers are used to appraise hydraulic relationships between aquifers, such as the direction of groundwater flow, and how withdrawal from one aquifer may affect others in the vicinity.

LOCATING SENSING ZONES

Aquifers are defined as saturated soil or rock through which significant quantities of groundwater move under ordinary hydraulic gradients. An aquifer may be a laterally continuous layer of sand and gravel, such as outwash or alluvium; a finely interbedded sequence of silt and fine sand, such as a lacustrine deposit or an estuarine deposit; or fractured or porous bedrock. Observation wells and standpipe piezometers are appropriate for installation in aquifers, as they require a material volume of water to flow into or out of the standpipe in order to function.

Aquicludes are strata exhibiting low permeability which may bound contiguous aquifers. An aquiclude may be a laterally continuous silty or clayey soil, such as a till or clayey lacustrine deposit; or solid rock. Standpipe wells and piezometers do not function well in aquicludes, because of the long time it takes for groundwater to move into and out of the well.

An example of a well and standpipe piezometer location plan for boreholes drilled across a site is shown in Figure 7-1. By locating the sensing zone near the bottom of the aquifer, the well or piezometer will be useful for a longer period of time should the water level drop due to natural or construction-related activities. Avoid spanning two aquifers with one sensing zone, as the installation will produce a composite water level not representative of either aquifer. A sensing zone about 3 to 5 feet long is adequate for most piezometers. Longer sensing zones may be appropriate for observation wells.

Seals define the sensing zone, and isolate the sensing zone from surrounding influences. It is desirable to place seals in aquicludes to prevent flow of water between aquifers via the borehole. A seal at ground surface prevents infiltration of surface water into the sensing zone.

In general, place only one standpipe installation in a single borehole, because it is difficult to achieve tight seals around more than one riser. If more than one installation is desired at a borehole location, place the deepest piezometer in the sampled borehole, and blind drill an offset hole for each shallower installation. Locate offset holes a minimum of 3 feet apart. When drilling an offset hole to install a piezometer, it may be prudent to sample through the intended sensing zone and seal location, to confirm soil composition.

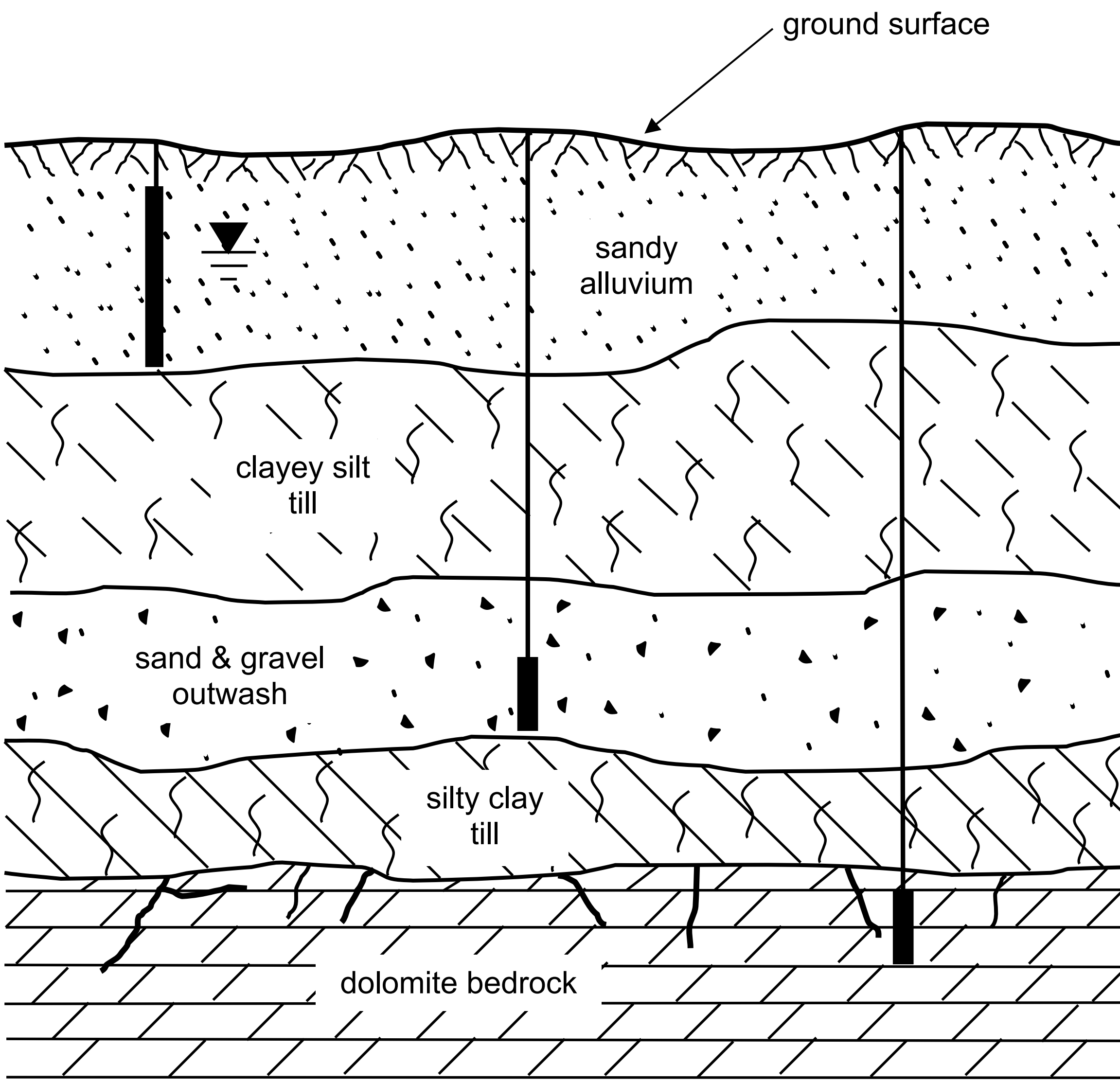

Figure 7-1. Groundwater monitoring scheme.

Identify piezometers with the same numbering code used for the boring. If more than one piezometer is placed in a single boring location, identify the deepest piezometer with the boring code followed by P1, identify the second deepest piezometer or observation well with P2, and so on.

INSTALLING STANDPIPE PIEZOMETERS AND WELLS

Boreholes in which a piezometer is to be installed should be drilled with clean water, and cased as necessary to maintain stability. The use of bentonite as a stabilizing fluid is not recommended, as it can form a clay layer on the borehole walls, sealing the permeable zone. If a drilling fluid additive is necessary to advance the borehole, a biodegradable drilling fluid is preferred, provided that water samples will not be collected for environmental testing. In either case the borehole should be thoroughly flushed with clean water prior to installing the piezometer, to clear soil pores or rock discontinuities in the sensing zone.

Prior to installing a long standpipe piezometer (deeper than about 50 feet), remove turbid water from the borehole. Turbid water will enter the standpipe as it is lowered into the borehole, and suspended silt will eventually settle out and accumulate in the bottom of the standpipe, plugging the screen. A screen plugged in this manner can be difficult to impossible to clear. If turbid water cannot be flushed from the borehole prior to standpipe insertion, flush the standpipe with clear water under low pressure before installing the backfill or seals.

A typical piezometer installation is shown in Figure 7-2. Prepare a sketch during installation to indicate all construction details. A form for well and piezometer installation is included in Appendix C. Record all details accurately. If necessary, modify the form or prepare sketch on a blank sheet of paper. Sound the depth of the filter pack and seals to within 0.5 foot.

The diameter of the riser pipe is inversely related to response time, so the smallest diameter pipe compatible with the monitoring equipment should be used. If only water levels will be monitored, 1-1/4 inch diameter pipe is appropriate. If water samples are to be collected, 2-inch diameter pipe should be used.

A borehole sealant is used to backfill the borehole above the sensing zone. Grout sealants should be separated from the filter pack by a minimum 1-foot thick layer of medium to fine sand (filter pack seal). The depth to filter pack seals need not be measured directly if the required volumes of sand are calculated and measured into the borehole. Bentonite seals should have a minimum length of 3 feet. Seals may consist of bentonite grout, or pellets. Bentonite pellets (3/8 inch dia.) will fall through about 100 feet of water before beginning to dissolve, and will form a seal within 15 to 30 minutes. Clean the pellets of bentonite dust before placing, to reduce their tendency to stick together.

A common source of trouble when installing piezometers is plugging the borehole with backfill materials of pea gravel, sand, or bentonite pellets when filling the annular space around the riser pipe. A plug can develop in seconds if the backfill is placed too quickly, and will be difficult to clear. Place backfill materials slowly, and allow ample time to settle before sounding.

Close the riser pipe with a cap or tape before pulling the casing, to prevent debris from falling down the riser. If for some reason two piezometers are placed in the same borehole, and are of equal pipe diameter, cut the riser of the deeper installation an inch or two shorter than the riser for the shallower installation, to distinguish the two for subsequent monitoring.

The surface protection installation should be free-draining, resistant to vandalism, and easily accessible for periodic readings. Surface protection for piezometers/wells located within a traffic area must be flush with the surface, of sufficient strength to carry wheel loads, and of sound construction so as not to initiate disintegration of surrounding pavement.

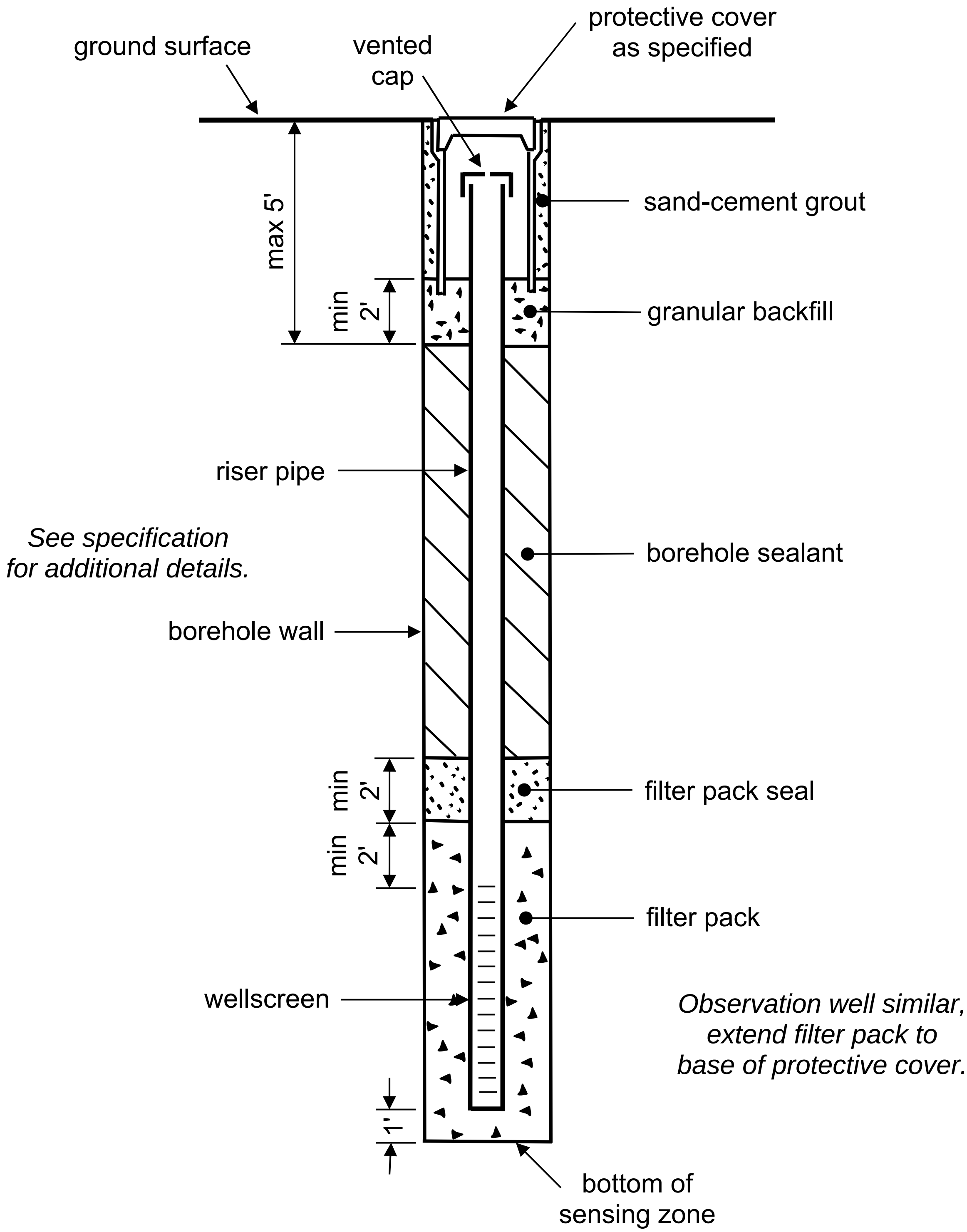

Figure 7-2. Piezometer installation detail.

WELL DEVELOPMENT AND SENSITIVITY TESTS

Develop observation wells and piezometers by clearing fines from the sensing zone, to reduce the response time. Allow bentonite and grout seals to set at least 24 hours before developing. To develop the well, remove water from the riser by airlifting, bailing, or pumping. If the installation is plugged so that the riser does not refill after bailing, fill the riser to the top with water, then slowly plunge a solid rod up and down inside the riser to surge water through the screen. Then repeat the bailing or airlifting. Do not induce severe or abrupt hydraulic gradients that might damage the seals. Avoid drawing the water level down into the screen, or inserting the airlift hose into the screen, as this may aerate the sensing zone.

After developing the well or piezometer, perform a sensitivity test to ensure that it responds properly to changes in groundwater level. Sensitivity tests are analogous to hydraulic conductivity tests in boreholes. Begin by measuring the initial water level in the riser. Then pour water into the riser, filling it to the top, and record the start time. Measure the fall in water level over time, noting either real time or elapsed time from start. Time intervals of 1 to 5 minutes between readings are appropriate for the early portion of the test, but may be extended as the test progresses. Continue readings until the water level approaches its initial value, attempting to take least five readings through the duration of the test. The added water must be clean, and its temperature should be higher than groundwater temperature to prevent air bubbles from forming in the sensing zone.

In a valid test, a plot of depth versus square root of elapsed time should trend in a straight line. Repeat the test as necessary to obtain reliable results. If the water level cannot be filled due to high take, record the approximate rate of flow and the result. Sensitivity test results can be expected to compare in a qualitative way to aquifer permeability estimated from sample descriptions. In an aquifer of very high permeability, permeability of the screen may control response time.

MEASURING WATER LEVELS

Observation wells and standpipe piezometers are generally monitored using an electronic water level indicator. This commonly consists of an electrical probe on a cable, which is lowered down the riser pipe. Contact with the water surface completes an electronic circuit which causes a tone to sound. The cable is marked at regular intervals to show depth. A data sheet for well and piezometer monitoring is included in Appendix C.

The normal depth reference to use when monitoring wells and piezometers is the top of the protective casing. When monitoring piezometers and wells protected with meter boxes mounted flush with the ground surface, use a ruler to span the opening across the meter box to define a consistent reference level. For installations protected by a casing above ground surface, measure water level to the top of the casing. Do not measure to the top of the riser unless specifically instructed to do so. Risers may settle with the backfill, and should not be considered a static reference point. Measure to the nearest 0.1 foot, unless specifically instructed to attempt greater accuracy. Piezometric water levels are affected by changes in barometric pressure, so further refinement is generally unnecessary.

Immediately after taking a reading, compare it for consistency with previous readings, and confirm any significant differences. Contaminants in the well can interfere with closure of the electrical circuit; oil and gasoline are particularly problematic in this regard. False readings can occur when the riser is wet above the water surface, as may be the case when performing a sensitivity test.

Where piezometers are to be monitored over a long term, they should be sounded quarterly or semi-annually to ensure they remain open to the sensing zone. Sound a piezometer with a water level indicator, with the probe turned off. Attempt to lower the probe to the bottom of the riser pipe. To sound deep piezometers it may be necessary to add weight to the probe, so it becomes more apparent when bottom has been reached.

Take appropriate safety precautions when monitoring wells and piezometers in traffic areas, for personal and public protection. Wear a high-visibility safety vest, and ensure suitable means of traffic control. Implement a traffic control plan if necessary.

INSTALLING VIBRATING WIRE OR PNEUMATIC PIEZOMETERS

Vibrating wire piezometers and pneumatic piezometers respond to water pressure applied to a small sensing head mounted on the end of a small-diameter cable. They are simple to install but require specialized equipment for monitoring. The sensing heads do not require a material volume of water to flow into the device, so they are suited for use in low-permeability formations. They offer an advantage over standpipe piezometers where it is desired to monitor pore pressures at multiple depths in a single borehole. Vibrating wire piezometers are gaining popularity over pneumatic piezometers due to their simplicity and longevity.

Characteristics of these devices vary among manufacturers, so install in conformance with the manufacturer's instructions. If the device is to be used to evaluate lateral or vertical groundwater flow gradients across a site, it is necessary to determine precisely the elevation of the sensing head screen, to within about 0.05 foot (1/2 inch). Groundwater flow gradients across a site are indicated by subtle differences in head. Piezometric head at any particular location is the sum of the elevation at that location, and the water pressure. During piezometer installation, measure depth to the sensing screen with reference to a secure stake or other ground surface point on which an accurate elevation surveyed can be performed later. For more detail see Dunnicliff 1988.

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Chapter 8 ENVIRONMENTAL MONITORING AND SAMPLING

MAN-MADE CONTAMINANTS

Drilling or sampling through man-made contaminants of an unknown or potentially hazardous nature is *not* to be performed in the course of a geotechnical investigation, unless an appropriate environmental health and safety plan has been incorporated into the geotechnical program. Any encounter with processed gasoline, fuel oil, lubricating oil, other petroleum products, chemicals, or chemically laden waste is cause to interrupt work to obtain further guidance before continuing. This is necessary to limit the health risk to personnel, to prevent spreading a contaminant into deeper groundwaters, and to prevent accumulation of special waste that would require regulated disposal.

A work interruption due to encountering unknown material may be initiated by the drilling contractor or the field engineer/geologist. The field engineer/geologist is to contact an environmental engineer or scientist with experience in contaminant investigation for direction as to how to proceed. It is advisable to identify an appropriate contact person prior to start of work, to minimize delays should their services be needed.

Retain a sample of the suspect material previously recovered, while avoiding physical contact or inhalation of vapors. Label a resealable freezer bag. Wearing latex or nitrile gloves, place a sample of the suspect material into the bag. Then carefully remove the gloves in a manner to avoid contact with the contaminant, and place the gloves in the bag. Seal the bag, and store in a cool dark place.

The field engineer/geologist is authorized to place the drilling contractor on standby time while the issue is resolved. If it appears a decision as to how to proceed cannot be made in a timely manner (an hour or so), the borehole should be backfilled with grout or cuttings and the drilling operation moved to the next location. All observations, events and times involved should be recorded in the daily activity log.

VOC SCREENING

In locations such as urbanized areas or the vicinity of known dumpsites, it may be appropriate to screen soil samples for volatile organic compounds (VOC's), which would indicate possible contamination by spilled gasoline or other or contaminants. Screening is generally limited to samples above the water table, and to depths within about 20 feet or so of the ground surface, though this may be varied to suit conditions. Samples are screened with a photo-ionization detector (PID), which is capable of detecting VOC's at ppm levels, using a sample headspace screening procedure.

Prepare samples and perform the screening away from vehicle exhaust fumes or other sources of background VOC's that could affect the results. Use latex or nitrile gloves to handle the sample. Prepare a sample by crumpling a portion of the soil sample into an appropriately labeled jar (8 oz or so in size), and promptly cover the jar with aluminum foil.

A resealable polyethylene bag may be used instead of a jar. Shake the sample for about 5 seconds, and allow to warm for about 10 minutes. In cold weather place the sample in a heated area. Measure the approximate VOC concentrations in the headspace air by pushing the PID probe through the aluminum foil or bag. Monitor the PID readout for about 15 seconds, and record the maximum value.

If PID readings of 15 ppm or more are observed, cease drilling and contact the lead geotechnical engineer for instructions on whether or not to continue.

NATURAL PETROLEUM

Crude oil is occasionally encountered in boreholes. It is most likely to be found in rock core, but can occur in soils. Liquid crude may indicate active migration of oil, and suggest active migration of natural gas as well. In rare cases, unweathered crude oil contains light (gasoline-range) hydrocarbons that could generate toxic vapors in an excavation. The extent to which crude oil has been weathered (and its volatiles content) can be determined by laboratory analysis. Samples of soil or rock containing liquid crude oil should be sealed in a close fitting glass or plastic jar as soon as possible after sampling, to prevent loss of volatile constituents. Store the sample on ice, or in a cool place out of the sun. Notify the lead geotechnical engineer as soon as possible, if arrangements have not already been made to analyze the sample. To prevent significant loss of volatiles, testing must be completed within about 48 hours of sampling.

NATURAL GASES

Methane and hydrogen sulfide occur naturally underground, and may discharge from boreholes during drilling operations. Both gases are hazardous, so it is important that the drill crew and field engineer/geologist respond rapidly and correctly to any encounters with gas, to maintain a safe workplace. It is difficult to predict where these gases may occur. Methane, for example, is known to occur in recent organic soils in Milwaukee, in organic inclusions in tills in Chicago and northeastern Illinois, and in bedrock in southeastern Michigan and in Cleveland. Hydrogen sulfide is common in bedrock in Detroit. Thoroughly document any encounter to indicate the type of gas, manner and approximate duration of discharge, and at what point in the drilling process the discharge occurred. Appropriate monitoring equipment should be on hand when drilling in areas suspected of retaining hazardous gas.

It may be desirable to measure flow rates and collect samples of gas discharging from boreholes. However, this work requires equipment and procedures specific to the geologic conditions being investigated, so is beyond the scope of this manual.

METHANE

Methane is an odorless gas, lighter than air, and combustible when mixed with air in concentrations between 5 and 15 percent. It is also a simple asphyxiant, meaning it can displace normal air in a confined space to form a dangerous oxygen-deficient atmosphere. Methane is generated by bacterial decomposition of organic matter in soils, and by thermal decomposition of organic matter in sediments buried thousands of feet deep. Most methane underground occurs in solution in groundwater. Methane also occurs in gaseous phase, and is the prominent constituent of gaseous accumulations in porous soils or fractured rock.

A rapid discharge of a gaseous phase from a borehole is called a “gas kick.” It may be accompanied by ejection of water or drilling fluid, or by gurgling sounds. Gas kicks usually consist of nearly 100 percent methane. Most occur while pulling the drilling string - when pressure on the bottom of the hole is reduced by swabbing of the bit, and by the drop in drilling fluid level.

Gas kicks are very hazardous, as the methane-air mixture can ignite or explode on contact with a spark (friction, static, or electrical), hot surface, or open flame. Suitable precautions should be taken when drilling in formations known to contain gaseous phase accumulations. The drill rig should be equipped with a kill switch in close proximity to the driller’s station to enable quick shut down of the engine. Ignition sources such as heaters and open flames should be kept a safe distance from the borehole, and preferably upwind. In the event of a continuous discharge, maintain a safe distance, take appropriate steps to keep passers-by at a safe distance, and notify the lead geotechnical engineer immediately.

When drilling along a proposed tunnel alignment, any rapid, persistent gaseous phase discharge should be allowed to vent completely before continuing the borehole, even if this may take a day or more. Venting the accumulation will reduce the risk of a gaseous phase discharge into the tunnel during construction. Consult with the lead geotechnical engineer and arrange to compensate the drilling contractor for lost time as a result of encountering a persistent gaseous phase discharge.

Methane discharge from a borehole may also be indicated by bubbles rising from drilling fluids, combustible gas detector response over the borehole or drilling fluid circulation tank, or ignition of gas. Solution phase methane diffusing from groundwater at the top of the borehole, or from drilling fluid in the circulation tank, provides no directly visible indication of gas. Fluid turbulence increases the rate of diffusion.

A portable combustible gas detector can be used to monitor the atmosphere for methane. A common type of detector operates by combusting the methane-air mixture, so responds only to combustible mixtures. *A methane concentration in air near 100 percent will read zero on the meter, due to lack of enough oxygen to support combustion.* Take readings by holding the gas detector over the borehole, or downwind near casing level, within about 6 to 8 inches of the casing. Do not extend the meter into the borehole, as the borehole atmosphere may be oxygen-deficient and incapable of combustion.

Portable combustible gas detectors commonly report methane concentrations in percent of lower explosive limit (LEL), which is 5 percent. A methane concentration of 5 percent in air would be indicated as 100 percent LEL on the meter. Drilling should cease at 20 percent LEL (1 percent methane in air) measured at the drill rig.

Record any indications of methane on the boring log, such as duration of gaseous phase discharge, frequency and magnitude of combustible gas detector readings, size and frequency of bubbles in drilling fluids, and other evidence. Do not risk injury to make observations of methane discharges.

HYDROGEN SULFIDE

Hydrogen sulfide is a highly toxic gas. It can irritate the eyes in concentrations above about 100 ppm, damage the lungs in concentrations above 250, and cause death in concentrations above 500. The allowable exposure limit is 10 ppm. In concentrations between about 0.02 and 100 ppm it smells like rotten eggs. The gas can dull the sense of smell, giving the mistaken impression that exposure was transient. Disappearance of the odor is not an indication of disappearance of the gas. Hydrogen sulfide is generated by bacterial decomposition of organic matter in soils and sedimentary rocks. Bacterial hydrogen sulfide generated below the water table occurs in groundwater only as a solution phase. It does not occur in concentrations high enough to support gaseous phase accumulations or bubbles. It can be a constituent of pore gas above the water table.

Hydrogen sulfide escapes a borehole only by diffusion from groundwater or drilling fluids. The rate of diffusion increases with fluid turbulence. The presence of hydrogen sulfide is likely to be betrayed by its odor. The olfactory senses are an unreliable indicator of potentially toxic concentrations, so if the odor of hydrogen sulfide becomes strong, drilling should cease until appropriate atmospheric monitoring equipment has been acquired.

A portable gas detector can be used to monitor the atmosphere for hydrogen sulfide. Record any indications of hydrogen sulfide on the boring log, such as the intensity of odor, detector reading, or other evidence. Do not risk injury to make observations of hydrogen sulfide discharges.

Chapter 9 SITE SAFETY

INTRODUCTION

The drilling process exposes persons to hazards that can cause physical injury. Some hazards are part of the nature of the work and cannot be eliminated, though they can be mitigated by procedural means. Other hazards occur as a result of unsafe work practices and worksite conditions. The drilling contractor is responsible for conducting his work in a safe manner. You are responsible for recognizing and avoiding hazards on a drilling site - your safety depends it. This chapter has been developed to help you recognize common hazards on drilling sites. The field engineer/geologist has a duty to protect himself and the public from harm. If you think that an unsafe condition has developed at the work site, bring it to the contractor's attention, and notify the lead geotechnical engineer.

In addition to the physical hazards posed by the drilling process, a site can also pose chemical, biological, or radiological hazards. As these hazards are entirely site specific it is important to know something about the site before mobilizing to do work. Some questions to ask are listed below. Affirmative answers require additional preparation prior to mobilization.

- Is the site near an operating or former industrial area where chemical releases to the environment may be of concern (including gas station, dry cleaners)?
- Is the site next to or part of a municipal or industrial landfill? Landfills can be sources of methane, hydrogen sulfide, and bird droppings that can contain infectious yeasts.
- Are there biological hazards associated with the area such as poison ivy, poison oak, or poison sumac? Stinging insects, snakes, wild animals?
- Will the weather pose a hazard to site personnel either due to cold, wet, or hot conditions?

A site with chemical contamination is subject to the OSHA Hazardous Waste Operations and Emergency Response standard (29 CFR 1910.120) and requires a site specific health and safety plan in addition to training and medical monitoring programs.

EMERGENCY PLANNING AND PROCEDURES

Upon assignment to a drill site, the field engineer/geologist should become familiar with the following:

- Drilling contractor's safety procedures.
- Location of first aid equipment.
- Location of fire extinguishers and how to operate them.
- Phone number of the nearest emergency response services.
- Location of nearest phone that could be used in an emergency.
- Address of, or directions to, the site.
- Location of nearest emergency hospital.

- Project health & safety plan.

If you are present at the scene of an emergency, assess the situation. If the area is safe and you are properly trained, render first aid to the victim. Call for assistance and notify emergency services. When the situation is under the control of qualified persons, notify the lead geotechnical engineer or other management representative. Be prepared to identify the facts of the matter, status of emergency services, effect on the public, and any other pertinent information. Do not speak to members of the press or persons not associated with emergency services.

DRILLING

GENERAL OPERATIONS

You are not part of the normal routine of a drilling crew, so can be exposed to hazards by other workers unmindful of your presence. You can avoid these hazards by communicating with those you will be working near, both on your arrival and on departure. When on a drilling site, stay alert. Get into the habit of maintaining an awareness of what is going on all around you.

Drilling rigs and support vehicles can pose a hazard to personnel. Always make the equipment operator aware of your presence when near his machine. Make sure the operator acknowledges your signal. Avoid pinch points where you could be caught between a moving machine and a stationary object. Keep clear of the rig when the mast is being raised. The rig may become unstable, loose items may fall off the mast, or the mast may contact an overhead powerline. Stay clear of suspended loads or winch cables under tension, as cables and connections sometimes fail.

Moving machine parts such as belts, gears, shafts, pulleys, chains, and others can cause injury. These parts are required to be guarded if a user or passer-by can access it, but sometimes the guards are not in place. Observe machinery for exposed moving parts and missing guards, and avoid these areas of the machine. Do not be careless about where you put your hands when near machines. Do not wear loose or bulky clothing near the rig, as it can easily get caught in turning rods or between moving parts.

Hydraulic or pneumatic equipment under load can become a hazard if hoses or seals fail and the load-carrying capacity of the machine is lost. An unsecured end of an air hose can whip violently if the coupling becomes loose under pressure.

Stay clear of the borehole when drilling with a down-hole air hammer rig. Cuttings can plug the exhaust side of the drill string, then suddenly break loose and blast out of the borehole. Stay clear of the airhose if it becomes clogged and is disconnected temporarily.

Stacks of cement and other materials can become unstable and topple, and are especially vulnerable when being loaded or unloaded. Stacks of pipe can become unstable and roll if not adequately secured.

Welding and cutting operations are a hazard to the eyes. Shield your eyes from direct exposure to the ultraviolet rays from welding and cutting and from the sparks that are emitted.

CLEARING UTILITIES

A serious hazard in drilling operations is the possibility of drilling into a buried utility line, particularly a gas line or electrical cable. Clearing utilities is the drilling contractor's responsibility. Before drilling in a particular location, ask the driller if utility clearances have been obtained. Verify that the utility locators have marked buried utilities in the vicinity of the boring. Various colors of paint are used by utilities to distinguish their services. The following color code has been adopted by numerous agencies:

Red:	electrical power lines, conduit, and lighting cables
Yellow:	gas, oil, steam, petroleum, or gaseous materials
Orange:	communications, alarm or signal lines, cable or conduit
Blue:	water
Green:	sewers and drains
Pink:	temporary survey marking
White:	proposed excavation (including boreholes)

"One call" utility clearing services generally limit their mapping to utilities within the public right-of-way. They do not have maps of utilities on most private, commercial, or government properties, though they may mark the point at which a utility enters such a property. "As-built" drawings from private property owners cannot be assumed to be complete or up to date. Not all utility owners subscribe to one-call utility clearing services, and those who do not must be contacted directly. Non-subscribers may include public sewer authorities, the military, and owners of cross-country oil or gas lines.

Do not take chances with drilling into a utility. If the driller encounters a shallow obstruction that may be a utility, stop. Ask the driller to verify that all utilities have been accounted for. Note that locators occasionally mark utilities incorrectly, so the marks are not totally reliable. Marks in street intersections and on curves are particularly prone to error. Compare the depth of any obstruction to that of known buried features that maybe present at a site (utilities, tunnels, underground vaults, etc.). If the driller remains uncertain about the utilities, relocate the boring or obtain direction from the lead geotechnical engineer on how to proceed.

Overhead powerlines are also a hazard. A safe distance must be maintained between the powerline and the mast of the rig. For construction work around lines rated 50 kV or below, at least 10 feet of clearance must be maintained between the lines and any part of the rig. For lines above 50 kV, ANSI recommends an additional 5 feet of clearance for every additional 150 kV of line energy up to 750 kV, and an additional 10 feet of clearance for voltages between 750 to 1000 kV. Line voltages cannot be determined visually. If in doubt about an appropriate safe distance, encourage the driller to call the utility and ask for their direction. The distances cited may be too short for safe operation when the drilling process involves standing rods above the mast, as a tall stack of rods may lean or slip from vertical alignment.

PERSONAL PROTECTIVE APPAREL AND EQUIPMENT

Personal protective apparel can provide a last defense against injury where other hazard control measures have failed. You are responsible for using the necessary apparel and equipment, for inspecting it, and maintaining it in functional condition. OSHA standards require employers to furnish, and employees to use, suitable protective equipment where there is a "reasonable probability" that injury can be prevented by such equipment. When in doubt, use the protective equipment available.

HEAD PROTECTION

Hard hats are required head protection for all employees on drilling sites. Hard hats protect against falling objects, projectiles, and bumps. They may help guard against electrical shock. In hot weather, the shell of the hat protects the head from direct rays of the sun, while the liner provides an airspace to help cool the head.

Examine your hardhat occasionally for cracks, gouges or chips, and replace if it exhibits damage or sustains a severe blow. Inspect the suspension system and replace it at the first indication of deterioration. Do not store materials between the suspension and the shell. Do not drill holes in your hat, paint it or otherwise modify it. Do not store it where it may be damaged by heat or sunlight. Hardhats must be ANSI Z89.1 approved.

EYE PROTECTION

Eye protection must be worn whenever personnel may be exposed to airborne particles, dusts, or chemical splash. Safety glasses are the most common eye protection and look very much like normal glasses. Goggles provide a secure shield around the entire eye to protect against hazards coming from many directions. Goggles should be worn when hammering rock core. Safety glasses and goggles must be ANSI Z87.1 approved.

FOOT PROTECTION

Boots are required for field engineer/geologist staff on drill sites. Proper boots provide protection from falling objects, sharp objects, molten metal or wax, hot surfaces, and slippery surfaces. Soles should be designed for outdoor use. Steel toed boots are recommended, and should be ANSI Z41 approved.

TRAFFIC

VEHICULAR TRAFFIC

Drilling sites are commonly located in city streets, where appropriate traffic control is required to maintain a smooth, safe flow of vehicles. It is the contractor's responsibility to arrange the worksite to minimize interference with the normal flow of traffic, and to guide motorists in a clear and positive manner through the area. Drilling vehicles should not be parked so as to obstruct traffic signs of a regulatory or warning type.

A typical traffic control zone for a work area in a street is shown in Figure 9-1. Most traffic control zones can be divided into five areas, with the appropriate length of each depending on local traffic conditions. The transition area and buffer area behind the barricades are intended as an emergency stopping space for traffic that may breach the barricades. This space should not be used for parking and general congregating.

Any traffic control zone is an obstruction to the normal flow of traffic and should be considered a hazardous area. Do not rely on barricades to protect you from oncoming traffic.

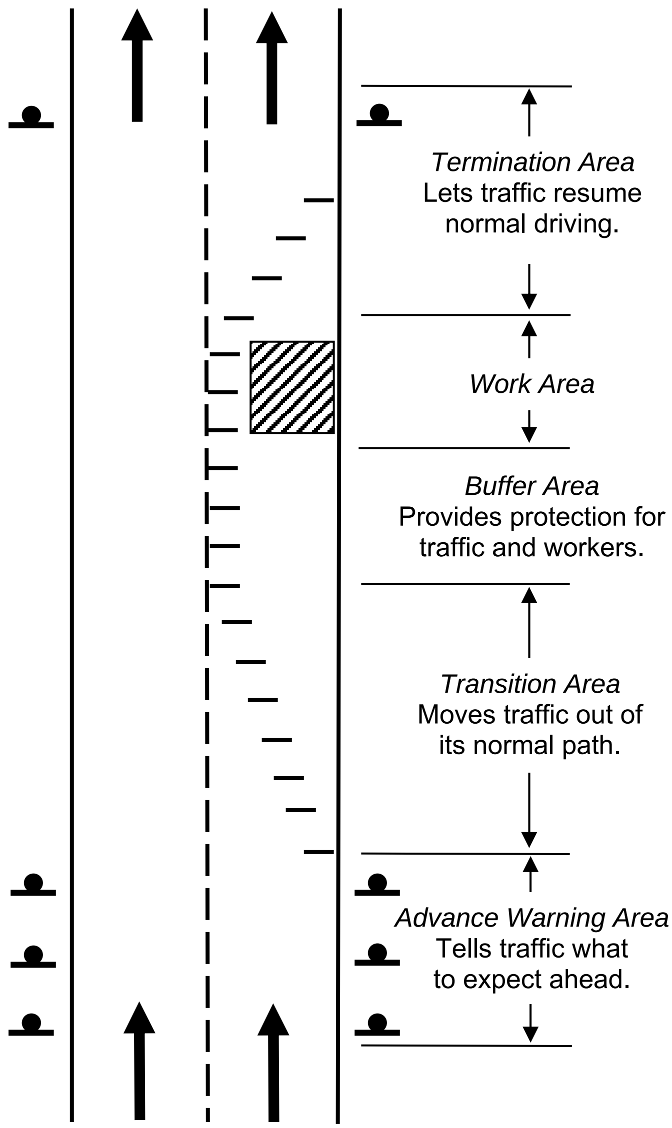


Figure 9-1. Areas in a traffic control zone.

Occupy a safe location in the work area. Use extra care when crossing the street in the vicinity of a traffic control zone. When working in areas of heavy or high speed traffic, wear a high-visibility safety vest. If working at night, stay alert for drunken drivers that may be guided into your area by lights associated with the work.

Remember that the function of the traffic control zone is to protect the workmen *and* the public.

PEDESTRIAN TRAFFIC

The driller should practice good housekeeping in the work area to minimize tripping and slipping hazards to workers and to the public. Sidewalks and other pedestrian pathways in the vicinity of the work are to be kept clear of equipment, cuttings, and drilling fluids. During cold weather, walkways should be kept free of ice. Walkways that cannot be kept clear should be barricaded during active work periods, and opened at other times. Unattended boreholes are to be covered or barricaded.

USE OF COMPRESSED GAS CYLINDERS

Compressed gas is used to inflate pneumatic packers in hydraulic pressure testing. Inflation and deflation of packers should be performed by a driller trained in safe use and transport of compressed gas. The following is a basic guideline to safe handling of a gas cylinder during pressure testing, for the field engineer/geologist's information.
The safest gas for inflating pneumatic packers is nitrogen. It is not flammable, toxic, or chemically reactive. Nitrogen is an asphyxiant, meaning it can displace air and deprive the victim of oxygen, so precautions should be taken if using nitrogen in an enclosed space.

Oxygen can increase the fire hazard around combustible materials such as grease and oil, and should not be used. Compressed air is also a fire hazard and should not be used.

Know the contents of a cylinder, and the properties and health hazards of that gas. Cylinders that do not bear a legibly written, stamped, or stenciled identification of contents should not be used, and should be returned to the vendor. Do not depend on color coding for identification. Always assume that a compressed gas cylinder is full and handle accordingly.

The cylinder should have a valve protection cap in place at all times when not in use. The cap should be screwed all the way down and should fit securely. Do not attempt to remove a stuck cap by using a lever in the cap ports.

Transport a cylinder only on a wheeled cart specifically designed for gas cylinders. When a cylinder is to be moved, disconnect the regulator and secure the valve cap in place before releasing from the securing device. Do not drag, roll, or slide a cylinder. Do not carry a cylinder by the valve cap.

Secure the cylinder with chain or strap to a stable stationary object, to prevent it from falling over and shearing off its valve. Uncontrolled discharge of compressed gas could result in an explosion or rapid projection of the cylinder. Secure the gas cylinder away from the pipe handling area. Do not expose the cylinder to temperatures higher than 50º C (122º F). Never leave an open cylinder unattended, or unsecured.

Use the proper regulator for the gas in the cylinder. If the connections do not fit together readily, the wrong regulator is being used. Clean the threads and mating surfaces of the regulator and tube connections before attaching the regulator, as particulate can cause the regulator to malfunction. Attach the regulator with the flow control valve on the regulator outlet closed, and preferably with the regulator flow backed off (counterclockwise). Use a cylinder wrench or other tightly fitting wrench to tighten the regulator nut and tube connections. Keep connections to piping, regulators, and other appliances tight. Do not use Teflon tape on cylinder connections.

In using the compressed gas system, open the main cylinder valve slowly until it stops, pointing the valve opening away from yourself and other persons. Stand away from the face and back of the gage. If using a special wrench to open the main valve, leave the wrench in place so the gas supply can be shut off quickly in case of an emergency. If the valve is frozen and cannot be opened, return the cylinder to the vendor.

When finished using the compressed gas system, turn off the main cylinder valve, bleed the regulator and lines, and close the regulator. Do not leave pressure on the regulator by closing down flow from the regulator without shutting off the main cylinder valve. Handle empty cylinders with same care as a full cylinder.

Chapter 10 RECORD KEEPING

GENERAL

Field records provide physical evidence of satisfactory work performance. They form the basis for subsequent design, and may be used to defend design decisions should a contractual or legal dispute arise. The results of all investigations and testing should be well documented. Field records should be neat, clean, accurate, complete, consistent, and concise.

Perform record-keeping on site at the time the work is being performed, and on designated forms. In no case are field logs to be prepared from cursory notes, or to be copied over. Protect logs from weather, soil, and splash from drilling activities. Write with a pencil or indelible ink. When time permits, but at least once each day, review field logs and correct deficiencies. Do not record data or write notes on the back of forms, as this information may be missed in subsequent photocopying. Make every effort to complete each record on the same day the work is performed, but if for some reason this is not possible, do not back-date the form. Field forms are an expedient for routine work. If the forms provided are unsuitable, carefully record field data on blank note or calculation paper, with complete heading information.

Prepare a separate file folder for project records and each type of record kept. These may include instructions, boring locations, access permits, specifications, communications, daily activity logs, boring logs, well/piezometer logs, sample delivery logs, testing records, etc. Each field record must contain the following minimum information:

Project name and number
Name of person preparing the record
Date
Page numbers
Field activity

Send copies of field records to the lead geotechnical engineer on at least a weekly basis. The field engineer/geologist should maintain a copy of all records in the field. These can provide adequate documentation should the original records be lost or destroyed. The lead geotechnical engineer should review field records in a routine and timely manner.

A complete set of blank field logs is included in Appendix C. They are intended to be used as originals for generating additional logs on a photocopier, as needed. Use minimum 24 pound stock paper for generating field logs, or waterproof paper if wet conditions are expected. Standard office copy paper is too light to hold up well to field work.

MISCELLANEOUS RECORDS

Field Daily Activity Log: Use this log to document the day's activities, including major decisions made, and changes in the drilling program. Check the appropriate entries in the

Contents Checklist, and describe or explain each checked entry. Reference entries to time, as much as practicable. Where describing delays in the work, clearly identify any time lost due to difficult ground conditions. If additional space is required, continue on activity log forms, or on blank sheets appropriately labeled and numbered in sequence.

Field Quantities Log: Use this log to document units of work completed each day. For each day, or each shift if working multiple shifts, identify each work unit performed and the quantity completed. Follow the format of the unit price schedule in the drilling contract. Use the Remarks entry for explanatory notes, such as how Standby Time was used. Ask the driller to review the completed form, and sign if acceptable to him. It is important to have the form completed and signed the day the work is performed, as it forms the basis of payment to the contractor.

Sample Delivery Log: This form is to be filled out by the field engineer/geologist, and checked and signed by the person delivering the samples to the receiving facility (normally the driller). A representative of the receiving facility (normally a laboratory manager or representative) is to compare this record against samples received, and sign the form if in order. Any damage to samples in shipment is to be described. The original should be retained in the lab. A copy of the signed form should be returned to the field engineer/geologist.

Boring Location Diagram: A sketch should be prepared to show the specific location of each boring as drilled, usually one boring per 8-1/2" x 11" sketch, in sufficient detail so that the correct boring location could be determined within 1 foot. Indicate general location using street names at intersections, building addresses, etc. Show specific location with accurate measurements with reference to curb lines, utility poles identified by number, fire hydrants, and other permanent, visible features. The sketch need not be to scale.

Boring location diagrams are commonly prepared prior to drilling, and used in clearing utilities. If a boring location is adjusted during the drilling program, mark any adjustments on the appropriate diagram.

Photo Log: Log all project-related photographs taken on site on a lined sheet of paper. Include the following column headings: Date, Time (if relevant), Photo Number, Subject (brief description).

VARIANCES

We cannot prepare specifications and procedures that will accommodate all subsurface conditions or equipment limitations that arise during a subsurface investigation. On occasion it will be necessary to deviate from planned procedures or to develop additional procedures, to address changes. Variances from contract specifications and planned procedures are to be documented on the daily activity log, testing procedure record, or on a separate variance report. All variances require final approval of the lead geotechnical engineer. The field engineer/geologist is to exercise judgment in deciding whether or not to allow the drilling contractor to proceed with a variance on a short term basis, prior to obtaining the lead geotechnical engineer's approval. It will be the lead geotechnical engineer’s responsibility to document any variances initiated by him.

SITE RESTORATION

The drilling contractor is normally required to restore each drilling site as near as practicable to its original condition. On streets this would require pavement repair. On lawns it may require minor grading, spreading of topsoil, seeding, and mulching. The field engineer/geologist is responsible for verifying that site restoration at every drill site has been satisfactorily completed. Restoration should be completed promptly, preferably within one week of drilling. Records of each site inspection should be kept, either on the field daily activity log or on a separate site restoration record. In some cases it may be appropriate to photograph each site prior to start of work and again on completion of restoration.

During drilling, encourage the driller to keep the area clear of trash that might be blown onto adjacent private or public property, or into waterways.

APPENDIX A - GENERAL REFERENCE

Soil Logging Reference Sheet
Rock Logging Reference Sheet
Field Engineer/Geologist's Equipment List
Friction Loss Tables
Pressure Conversion Tables

SOIL LOGGING REFERENCE SHEET

Sample ID Codes:

S-	Standard split-spoon sample (2" od)
SL-	3" OD split-spoon sample
T-	Thin walled tube sample

Relative Density Of Granular Soils

Relative Density	No. Blows Per Foot, N
Very Loose	0-4
Loose	4-10
Medium	10-30
Dense	30-50
Dense	>50
Very Dense	

Ref. Terzaghi, Peck, and Mesri 1996, p. 60.

Consistency Of Cohesive Soils

Consistency	q_u (tsf)	N	Characteristics
Very Soft	< 0.25	<2	Sample will sag or slump under own weight.
Soft	0.25 to 0.5	2 to 4	Sample can be pinched in two between fingers.
Medium Stiff	0.5 to 1.0	4 to 8	Sample can be easily imprinted with fingers.
Stiff	1.0 to 2.0	8 to 15	Sample can be imprinted with considerable effort.
Very Stiff	2.0 to 4.0	15 to 30	Readily indented by thumbnail.
Hard	> 4.0	> 30	Indented with difficulty by thumbnail.

Ref. Terzaghi, Peck, and Mesri 1996, p. 63.

Naming Granular Soils

Identifying Term	Content by Weight Percent
Trace	>0 to 10
Little	10 to 20
Some	20 to 30
And	30 to 50

Naming Silt-Clay Combinations

Identifying Term	Plasticity Index	Degree of Plasticity	USCS
Clayey Silt	>0 to 7	low	ML, or CL-ML for PI=4 to 7
Silty Clay	7 to 40	medium to high	CL, CH
Clay	> 40	high	CH

Naming Organic Soils

Identifying Term	Plasticity Index	Degree of Plasticity	USCS Symbols
Silt with organics Organic Silt Organic Clay	1 to 7 7 to 40 > 40	low medium to high high	**ML** or **OL** **OL**, ML, **OH**, MH, CL, CH **OH**, CH

Degrees of Decomposition of Wood

Term	Definition
Fresh	Little to un-decomposed, retains properties of sound wood.
Fibrous	Somewhat decomposed, visual appearance of wood, but fibers soft, pull apart easily by hand.
Particulate	Well to severely decomposed, little or no fibrous characteristics remaining.

Bedding Spacing and Fabric in Soil

Term	Sedimentary Structure	Characteristic Soil Unit
massive	Without internal structure; obscurely layered.	lodgment till
bedded	Sequential layers.	reworked till, outwash, lacustrine deposit
layer	Distinctly defined tabular body of sediment.	reworked till, outwash, lacustrine deposit
interbedded	Alternating layers of differing composition	outwash, lacustrine deposit, alluvial deposit
well bedded	Beds are numerous and clearly defined.	outwash, lacustrine deposit, alluvial deposit
laminated	Small scale sequence of layers.	lacustrine deposit
varved	Regularly alternating thin beds of silt and clay, of seasonal sedimentary origin.	lacustrine silt and clay deposit
mottled	Spotted or variations in color.	Soils near or above the water table.
few	One or less occurrences per foot.	
occasional	One to twelve occurrences per foot.	
frequent	More than 12 per occurrences foot.	

Degree Of Wetness

Term	Definition
Dry	Soil contains no free water.
Moist	Soil feels damp, but does not wet palm.
Wet	Soil readily wets palm of hand.

ROCK LOGGING REFERENCE SHEET

Field Estimation of Rock Compressive Strength

Strength description	Approximate Compressive Strength (ksi)	Properties of hand specimen
Very weak	1.5 to 3.5	Brittle or tough, may be broken in hand with difficulty.
Weak	3.5 to 15	Crumbles under firm blows of sharp end of hammer.
Moderately weak	15 to 35	
Moderately strong	35 to 140	5 mm indentations with sharp end of hammer.
Strong	140 to 290	Hand-held specimen can be broken with single blow of hammer.
Very strong	>290	More than one hammer blow required to break specimen.

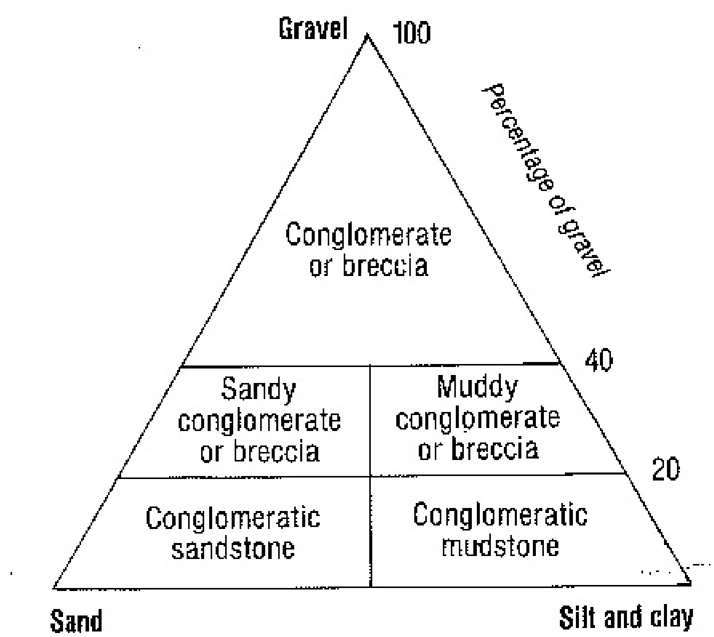
Source: Geological Society Engineering Group Working Party, 1977; Tbl. 4.

Mudrock Nomenclature

Silt & Clay Content	*Massive Mudrock*	*Fissile Mudrock*
>2/3 silt, <1/3 clay	siltstone	silt shale
1/3 to 2/3 silt	mudstone	mud shale
<1/3 silt, >2/3 clay	claystone	clay shale

Source: Blatt 1992; Tbl. 6-1.

Conglomerate and Breccia Nomenclature:



Coal Nomenclature:

Humic (banded) coal:

- bright
- bright with dull bands
- bright and dull
- mainly dull with numerous bright bands
- dull with minor bright bands
- dull

Sapropelic (non-banded) coal:

- dull with conchoidal fracture surfaces
- shaley (silt and clay is disseminated throughout)

Sedimentary Structure Descriptors:

- laminations - layering on a scale of 1 to 2 mm (±)
- beds - layering on a scale of 1 to 5 cm (±)
- other thicknesses - include thickness dimension
- massive - absence of sedimentary structure
- flat-bedded - horizontal layering
- cross-bedded - inclined layering; common dip angles are 20° to 25°
- laminated - horizontal layering
- cross-laminated - inclined layering

Terms to Describe Degree of Weathering/Alteration

Term	*Description*
Fresh	Unchanged from original state.
Slightly weathered	Slight discoloration, slight weakening.
Moderately weathered	Considerably weakened, penetrative discoloration. Large pieces cannot be broken by hand.
Highly weathered	Large pieces can be broken by hand. Does not readily disaggregate (slake) when dry sample immersed in water.
Completely weathered	Considerably weakened. Slakes in water. Original texture apparent.
Residual soil	Soil derived by *in situ* weathering but having lost original texture and fabric.

Source: Geol. Soc. Eng. Group Working Party, 1995; Tbl. 2.

Terms to Describe Condition of Discontinuities:

Type:
B bedding
J joint
S shear
F fault

Aperture:
Record the separation in mm. N for none.

Roughness:
VR very rough (near-vertical steps and ridges)
R rough (ridges, side-steps, and asperities evident, abrasive to touch)
SR slightly rough (asperities can be felt)
SM smooth (smooth to touch)
SL slickensided (smooth glassy finish with visible striations)

Infilling:
Record material type and thickness in mm. Leave blank for none.

Use the following abbreviations for common infill (define any other abbreviations used):
CL clay
SI silt
SA sand
PY pyrite
QZ quartz
GR graphite

Weathering:
Describe using standard abbreviations for weathering.

FIELD ENGINEER/GEOLOGIST'S EQUIPMENT LIST

Quantity	Item	Notes
General		
1	cell phone and battery charger	
1	first aid kit	
1	portable, plastic file box	
10	file folders	
40	daily activity logs	
20	laboratory log sheets	
1	note or calc pad, 8-1/2"x11"	
2	plastic cover sheets	to protect field log
4	mechanical pencils with 0.5 mm HB lead	
1	6-inch 45º triangle	
1	12-inch ruler	
1	6-foot folding rule	
2	erasers	
1	clipboard	
1	hardhat	
1	eye protection	
1 pair	steel toe boots	
1	watch with sweep second hand	
1	pocket knife	
1	street map	
1	camera (optional)	
1	resealable freezer bag	for environmental sample
1 pr	latex gloves	for environmental sample
Soil Drilling and Sampling		
30	soil boring logs - field	
20	piezometer installation forms	
20	piezometer sensitivity test sheets	
1	stiff knife-bladed spatula	splitting soil samples
1	hand penetrometer	
6	permanent black fine tip felt markers	marking jar labels and lids
2	permanent black wide chisel tip felt markers	marking sample boxes, tubes
	electrical tape	
1 roll	small resealable freezer bags	sealing tubes
1 box	water level indicator	bagging miscellaneous samples
1	hand towel	(may be provided by driller)
1	hand cleaner	
1		
Rock Coring		
50	rock coring logs - field	
4	permanent black wide chisel tip felt markers	marking core boxes
	permanent blue wide tip felt markers	
4	permanent red wide tip felt markers	marking core
4	permanent black fine tip felt marker	marking core
1	lumber crayon	marking core
1	rock hammer	marking core
1	bottle of 10% HCl solution, with eyedropper	
1	protractor	optional
1	heavy duty plastic wrap and tape	
1 roll		

Pressure Testing		
1	hand calculator	
1	25-foot steel tape measure	
1	stopwatch	

GROUT MIXES

Mixes for Hard to Medium Soils

Material	Weight	Ratio by Weight
Portland cement	94 lbs (1 bag)	1
Water	30 gallons	2.5
Bentonite	25 lbs (as required)	0.3

Mixes for Hard to Soft Soils

Material	Weight	Ratio by Weight
Portland cement	94 lbs (1 bag)	1
Water	75 gallons	6.6
Bentonite	39 lbs (as required)	0.4

Mix cement with water first, then mix bentonite. Adjust the amount of bentonite to produce a grout with a uniformly thick consistency. Bentonite quantities are a starting point only, and will vary with the type used, method of mixing, and pH of the water.

SCHEDULE 40 STEEL PIPE—FRICTION LOSS FOR WATER IN FEET PER 100 FEET

U. S. Gallons per Minute	¼ In.		⅜ In.		½ In.		¾ In.	
	V Ft/Sec	h_f Frict.	V Ft/Sec	h_f Frict.	V Ft/Sec	h_f Frict.	V Ft/Sec	h_f Frict.
0.8	2.47	12.7						
1.0	3.08	19.1						
1.2	3.70	26.7						
1.4	4.32	35.3	2.35	7.85				
1.6	4.93	45.2	2.68	10.1				
1.8	5.55	56.4	3.02	12.4				
2.0	6.17	69.0	3.36	15.0	2.11	4.78		
2.5	7.71	105.0	4.20	22.6	2.64	7.16		
3.0	9.25	148.0	5.04	31.8	3.17	10.0		
3.5	10.79	200.0	5.88	42.6	3.70	13.3		
4.0	12.33	259.0	6.72	54.9	4.22	17.1	2.41	4.21
5	15.42	398	8.40	83.5	5.28	25.8	3.01	6.32
6			10.08	118	6.34	36.5	3.61	8.87
7			11.8	158	7.39	48.7	4.21	11.8
8			13.4	205	8.45	62.7	4.81	15.0
9			15.1	258	9.50	78.3	5.42	18.8
10			16.8	316	10.56	95.9	6.02	23.0
12					12.7	136	7.22	32.6
14					14.8	183	8.42	43.5
16					16.9	235	9.63	56.3
18							10.8	70.3
20							12.0	86.1
22							13.2	104
24							14.4	122
26							15.6	143
28							16.8	164

U. S. Gallons per Minute	1 In.		1¼ In.		1½ In.	
	V Ft/Sec	h_f Frict.	V Ft/Sec	h_f Frict.	V Ft/Sec	h_f Frict.
6	2.23	2.68				
8	2.97	4.54				
10	3.71	6.86				
12	4.45	9.62	2.57	2.48		
14	5.20	12.8	3.00	3.28		
16	5.94	16.5	3.43	4.20	2.52	1.96
18	6.68	20.6	3.86	5.22	2.84	2.42
20	7.42	25.1	4.29	6.34	3.15	2.94
22	8.17	30.2	4.72	7.58	3.47	3.52
24	8.91	35.6	5.15	8.92	3.78	4.14
26	9.65	41.6	5.58	10.37	4.10	4.81
28	10.39	47.9	6.01	11.9	4.41	5.51
30	11.1	54.6	6.44	13.6	4.73	6.26
35	13.0	73.3	7.51	18.2	5.51	8.37
40	14.8	95.0	8.58	23.5	6.30	10.79
45	16.7	119.0	9.65	29.4	7.04	13.45
50	18.6	146	10.7	36.0	7.88	16.4
55			11.8	43.2	8.67	19.7
60			12.9	51.0	9.46	23.2
65			13.9	59.6	10.24	27.1
70			15.0	68.8	11.03	31.3
75			16.1	78.7	11.8	35.8
80					12.6	40.5
85					13.4	45.6
90					14.2	51.0
95					15.0	56.5
100					15.8	62.2

U. S. Gallons per Minute	2 In.		2½ In.		3 In.		4 In.	
	V Ft/Sec	h_f Frict.	V Ft/Sec	h_f Frict.	V Ft/Sec	h_f Frict.	V Ft/Sec	h_f Frict.
25	2.39	1.29						
30	2.87	1.82						
35	3.35	2.42	2.35	1.00				
40	3.82	3.10	2.68	1.28				
45	4.30	3.85	3.02	1.60				
50	4.78	4.67	3.35	1.94	2.17	0.662		
60	5.74	6.59	4.02	2.72	2.60	0.924		
70	6.69	8.86	4.69	3.63	3.04	1.22		
80	7.65	11.4	5.36	4.66	3.47	1.57		
90	8.60	14.2	6.03	5.82	3.91	1.96		
100	9.56	17.4	6.70	7.11	4.34	2.39	2.52	0.624
120	11.5	24.7	8.04	10.0	5.21	3.37	3.02	0.877
140	13.4	33.2	9.38	13.5	6.08	4.51	3.53	1.17
160	15.3	43.0	10.7	17.4	6.94	5.81	4.03	1.49
180			12.1	21.9	7.81	7.28	4.54	1.86
200			13.4	26.7	8.68	8.90	5.04	2.27
220			14.7	32.2	9.55	10.7	5.54	2.72
240			16.1	38.1	10.4	12.6	6.05	3.21
260					11.3	14.7	6.55	3.74
280					12.2	16.9	7.06	4.30
300					13.0	19.2	7.56	4.89
350					15.2	26.1	8.82	6.55
400							10.10	8.47
450							11.4	10.65
500							12.6	13.0
550							13.9	15.7
600							15.1	18.6

U. S. Gallons per Minute	5 In.		6 In.		8 In.	
	V Ft/Sec	h_f Frict.	V Ft/Sec	h_f Frict.	V Ft/Sec	h_f Frict.
160	2.57	0.487				
180	2.89	0.606				
200	3.21	0.736				
220	3.53	0.879	2.44	0.357		
240	3.85	1.035	2.66	0.419		
260	4.17	1.20	2.89	0.487		
300	4.81	1.58	3.33	0.637		
350	5.61	2.11	3.89	0.851		
400	6.41	2.72	4.44	1.09	2.57	0.279
450	7.22	3.41	5.00	1.36	2.89	0.348
500	8.02	4.16	5.55	1.66	3.21	0.424
600	9.62	5.88	6.66	2.34	3.85	0.597
700	11.2	7.93	7.77	3.13	4.49	0.797
800	12.8	10.22	8.88	4.03	5.13	1.02
900	14.4	12.9	9.99	5.05	5.77	1.27
1000	16.0	15.8	11.1	6.17	6.41	1.56
1100			12.2	7.41	7.05	1.87
1200			13.3	8.76	7.70	2.20
1300			14.4	10.2	8.34	2.56
1400			15.5	11.8	8.98	2.95
1500					9.62	3.37
1600					10.3	3.82
1700					10.9	4.29
1800					11.5	4.79
1900					12.2	5.31
2000					12.8	5.86
2100					13.5	6.43
2200					14.1	7.02

NOTE: The above table shows average values of pipe friction for new pipe. For commercial installations it is recommended that 15% be added to the above values. No allowance for aging of pipe is included.

FORMULAE

$$V = CR^{0.63}\left(\frac{H}{L}\right)^{0.54} \times 1.32$$

where V = Velocity in Feet per Sec.

R = Hydraulic Radius = $\frac{\text{dia. pipe in Ft.}}{4}$

H = Friction Head.

L = Length of Piping in Feet.

C = Constant depending upon Roughness of Pipe, also upon R.

or

$$H = \left(\frac{147.85\ Q}{CD^{2.63}}\right)^{1.852}$$

where $\frac{H}{10}$ = Friction Head for L = 100 ft.

Q = G. P. M.

D = Dia. of Pipe in Inches. (Actual)

C = 100—For other Value of "C" the figures in the table should be multiplied by $K = \left(\frac{100}{C}\right)^{1.852}$

TABLE GIVING COEFFICIENT "C" AND FACTOR "K" FOR DIFFERENT KINDS AND SIZES OF PIPES

Coefficient C	Factor K	VARIOUS KINDS PIPE — Size of Pipe in Inches ⅛" to 3" — CONDITION OF PIPE	Coefficient C	Factor K	4	5	6	8	10	12	16	20	24	30	36	42	48	54	60
					Corresponding years of service of cast iron pipe in soft, clear, unfiltered river water. — Years of Service														
140	.54	Very Smooth & Straight W. I., Brass, Tin, Copper & Lead Pipe	140	.54	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
130	.62	Ordinary Straight Brass, Tin, Copper & Lead Pipe	130	.62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	.71	Smooth New W. I. Pipe	120	.71	4	4	4	5	5	5	5	5	5	6	6	6	6	6	6
110	.84	Fairly Smooth New W. I. Pipe	110	.84				10	10	10	11	11	11	12	12	12	12	12	12
100	1.00	Ordinary W. I. Pipe	100	1.00	13	14	15	16	17	17	18	19	19	19	20	20	20	20	20
90	1.22	Medium Old W. I. Pipe	90	1.22						26	27	28	29	30	30	30	30	31	31
80	1.52	Old W. I. Pipe	80	1.52	26	28	30	33	35	37	39	41	42	43	44	45	45	46	47
60	2.58	Very Rough Pipe	60	2.58	45	50	55	62	68										
40	5.46	Badly Tuberculated Pipe	40	5.46	75	87	95												

00 Indicates the very best new cast iron pipe, laid perfectly straight.
0 Indicates good new cast iron pipe.

The foregoing values can also be used for welded steel pipe.
For riveted steel pipe the average value of "C" is lower than for cast iron pipe. The data on hand indicates a value of C equals 110 for new riveted pipe, decreasing in the course of about 10 years to 100. For older pipes riveted steel pipe of a given age will carry the same quantity of water as cast iron pipe of the same size and 10 years older.

For gasoline C = 130 Factor K x Sp. Gr.

FRICTION LOSSES THROUGH SCREW PIPE FITTINGS IN TERMS OF EQUIVALENT LENGTHS OF STANDARD PIPE

Nominal Pipe Size Inches	Actual Inside Diameter Inches	Gate Valve	Long-Sweep Elbow or on Run of Standard Tee	Medium—Sweep Elbow or on Run of Tee Reduced in Size ¼	Standard Elbow or on Run of Tee Reduced in Size ½	Angle Valve	Close Return Bend	Tee Through Side Outlet	Globe Valve
Factor of Resistance		0.25	0.33	0.42	0.67	0.90	1.00	1.33	2.00
½	0.662	0.335	0.442	0.56	0.89	1.20	1.34	1.79	2.68
¾	0.824	0.475	0.627	0.79	1.27	1.71	1.90	2.52	3.80
1	1.049	0.640	0.844	1.07	1.72	2.30	2.56	3.40	5.12
1¼	1.38	0.902	1.19	1.51	2.42	3.24	3.61	4.80	7.22
1½	1.61	1.09	1.43	1.83	2.92	3.92	4.36	5.79	8.72
2	2.06	1.49	1.96	2.50	3.99	5.36	5.96	7.92	11.92
2½	2.46	1.86	2.46	3.13	5.00	6.72	7.47	9.93	14.94
3	3.06	2.46	3.25	4.11	6.66	8.87	9.86	13.11	19.72
4	4.026	3.44	4.53	5.77	9.22	12.37	13.70	18.28	27.50
5	5.047	4.57	6.00	7.68	12.20	16.47	18.30	24.33	36.60
6	6.065	5.72	7.55	9.61	15.30	20.61	22.90	30.45	45.00
7	7.024	6.90	9.10	11.60	18.50	24.84	27.60	36.70	55.20
8	7.981	8.10	10.70	13.60	21.71	29.16	32.40	43.09	64.80
10	10.020	10.70	14.10	17.97	28.70	38.52	42.80	56.92	85.60
12	12.090	12.50	17.80	22.68	36.28	48.60	54.00	71.82	108.00

This Table Based on Fosters formula:—$L = 53.75\ rd^{1.25}$
In which—L = equivalent length of straight pipe in feet.
r = resistance factor.
d = diameter of fitting in feet.
Foot valve loss = zero provided foot valve has area of 150% of suction pipe.
(A. S. M. E. Trans. Vol. 42, pg. 648, 1920)

FRICTION LOSSES IN PIPE FITTINGS IN TERMS OF EQUIVALENT LENGTHS OF STRAIGHT PIPE

Nominal Pipe Size Inches	Standard Gate Valve or Exp'n Joint	Long Rad. 90° Elbow or Run of Standard Tee	Med. Sweep 90° Elbow or Run of Tee Reduced ¼	Standard 90° Elbow or Run of Tee Reduced ½	Square 90° Elbow Welded Construction	Standard 45° Elbow	Standard Tee Thru Side Outlet	Standard Tee Side Inlet Divided Outlet	Ordinary Entrance Loss
14	18.5	24.5	31	49	58	14.5	98	70	22.5
16	21.5	28.5	36	58	66	16.5	115	80	26.0
18	25.0	33	42	67	75	18.5	132	91	29.5
20	28.5	38	48	78	83	20.5	150	102	32
24	36	47	60	98	101	25	185	121	40
30	47	61	80	126	127	32	242	151	50
36	59	79	100	156	150	38	305	179	60
42	71	95	120	189	175	44	370	210	70
48	83	110	139	219	200	50	435	242	80

WATER FRICTION IN 100 FEET OF SMOOTH BORE HOSE

For Various Flows and Hose Sizes, Table Gives Velocity of Water and Feet of Head Lost in Friction in 100 Feet of Smooth Bore Hose.

Sizes of Hose Shown are Actual Inside Diameters.

Flow in U. S. Gals. Per Min.	Velocity in Feet Per Sec.	Friction Head in Feet	Velocity in Feet Per Sec.	Friction Head in Feet	Velocity in Feet Per Sec.	Friction Head in Feet	Velocity in Feet Per Sec.	Friction Head in Feet	Velocity in Feet Per Sec.	Friction Head in Feet	Velocity in Feet Per Sec.	Friction Head in Feet
	⅝″		¾″		1″		1¼″		1½″		2″	
1.5	1.6	2.3	1.1	.97								
2.5	2.6	6.0	1.8	2.5								
5	5.2	21.4	3.6	8.9	2.0	2.2	1.3	.74	.9	.3		
10	10.5	76.8	7.3	31.8	4.1	7.8	2.6	2.64	1.8	1.0	1.0	.2
15	2½″		10.9	68.5	6.1	16.8	3.9	5.7	2.7	2.3	1.5	.5
20	1.3	.32			8.2	28.7	5.2	9.6	3.6	3.9	2.0	.9
25	1.6	.51	3″		10.2	43.2	6.5	14.7	4.5	6.0	2.5	1.4
30	2.0	.70	1.4	.3	12.2	61.2	7.8	20.7	5.4	8.5	3.1	2.0
35	2.3	.93	1.6	.4	14.3	80.5	9.1	27.6	6.4	11.2	3.6	2.7
40	2.6	1.2	1.8	.5			10.4	35.0	7.3	14.3	4.1	3.5
45	2.9	1.5	2.0	.6			11.7	43.0	8.2	17.7	4.6	4.3
50	3.3	1.8	2.3	.7			13.1	52.7	9.1	21.8	5.1	5.2
60	3.9	2.5	2.7	1.0			15.7	73.5	10.9	30.2	6.1	7.3
70	4.6	3.3	3.2	1.3					12.7	40.4	7.1	9.8
80	5.2	4.3	3.6	1.7	4″				14.5	52.0	8.2	12.6
90	5.9	5.3	4.1	2.1	2.3	.5			16.3	64.2	9.2	15.7
100	6.5	6.5	4.5	2.6	2.5	.6			18.1	77.4	10.2	18.9
125	8.2	9.8	5.7	4.0	3.2	.9					12.8	28.6
150	9.8	13.8	6.8	5.6	3.8	1.3					15.3	40.7
175	11.4	18.1	7.9	7.4	4.5	1.8	5″		6″		17.9	53.4
200	13.1	23.4	9.1	9.6	5.1	2.3	3.3	.8	2.3	.32	20.4	68.5
225	14.7	29.0	10.2	11.9	5.7	2.9	3.7	1.0	2.6	.40		
250	16.3	35.0	11.3	14.8	6.4	3.5	4.1	1.2	2.8	.49		
275	18.0	42.0	12.5	17.2	7.0	4.2	4.5	1.4	3.1	.58		
300	19.6	49.0	13.6	20.3	7.7	4.9	4.9	1.7	3.3	.69		
325			14.7	23.5	8.3	5.7	5.3	2.0	3.7	.80		
350			15.9	27.0	8.9	6.6	5.7	2.3	4.0	.90		
375			17.0	30.7	9.6	7.4	6.1	2.6	4.3	1.0	8″	
400					10.2	8.4	6.5	2.9	4.5	1.1	2.6	.28
450					11.5	10.5	7.4	3.6	5.1	1.4	2.9	.35
500					12.8	12.7	8.2	4.3	5.7	1.7	3.2	.43
600					15.3	17.8	9.8	6.1	6.8	2.4	3.8	.60
700					17.9	23.7	11.4	8.1	7.9	3.3	4.5	.80
800							13.1	10.3	9.1	4.2	5.1	1.1
900							14.7	12.8	10.2	5.2	5.8	1.3
1000							16.3	15.6	11.4	6.4	6.4	1.6
1100							17.9	18.5	12.5	7.6	7.0	1.9
1200									13.6	9.2	7.7	2.3
1300									14.7	10.0	8.3	2.6
1400									15.9	11.9	8.9	3.0
1500									17.0	13.6	9.6	3.3
1600											10.2	3.7
1800											11.5	4.7
2000											12.8	5.7
2500											16.0	8.6
3000											19.1	12.2

PRESSURE AND EQUIVALENT FEET HEAD OF WATER

Lbs. Per Sq. In.	Feet Head	Lbs. Per Sq. In.	Feet Head	Lbs. Per Sq. In.	Feet Head	Lbs. Per Sq. In.	Feet Head
1	2.31	20	46.18	120	277.07	225	519.51
2	4.62	25	57.72	125	288.62	250	577.24
3	6.93	30	69.27	130	300.16	275	643.03
4	9.24	40	92.36	140	323.25	300	692.69
5	11.54	50	115.45	150	346.34	325	750.41
6	13.85	60	138.54	160	369.43	350	808.13
7	16.16	70	161.63	170	392.52	375	865.89
8	18.47	80	184.72	180	415.61	400	922.58
9	20.78	90	207.81	190	438.90	500	1154.48
10	23.09	100	230.90	200	461.78	1000	2309.00
15	34.63	110	253.98	......	....	....	....

FEET HEAD OF WATER AND EQUIVALENT PRESSURES

Feet Head	Lbs. Per Sq. In.	Feet Head	Lbs. Per Sq. In.	Feet Head	Lbs. Per Sq. In.	Feet Head	Lbs. Per Sq. In.
1	.43	30	12.99	140	60.63	300	129.93
2	.87	40	17.32	150	64.96	325	140.75
3	1.30	50	21.65	160	69.29	350	151.58
4	1.73	60	25.99	170	73.63	400	173.24
5	2.17	70	30.32	180	77.96	500	216.55
6	2.60	80	34.65	190	82.29	600	259.85
7	3.03	90	38.98	200	86.62	700	303.16
8	3.46	100	43.31	225	97.45	800	346.47
9	3.90	110	47.65	250	108.27	900	389.78
10	4.33	120	51.97	275	119.10	1000	433.09
20	8 66	130	56.30	......	....	......	....

EQUIVALENT VALUES OF PRESSURE
Inches of Mercury—Feet of Water—Pounds per Sq. In.

Inches of Mercury	Feet of Water	Pounds per Sq. In.	Inches of Mercury	Feet of Water	Pounds per Sq. In.	Inches of Mercury	Feet of Water	Pounds per Sq. In.
1	1.13	0.49	11	12.45	5.39	21	23.78	10.3
2	2.26	0.98	12	13.57	5.87	22	24.88	10.8
3	3.39	1.47	13	14.70	6.37	23	26.00	11.28
4	4.52	1.95	14	15.82	6.86	24	27.15	11.75
5	5.65	2.44	15	16.96	7.35	25	28.26	12.25
6	6.78	2.93	16	18.09	7.84	26	29.40	12.73
7	7.91	3.42	17	19.22	8.33	27	30.52	13.23
8	9.04	3.91	18	20.35	8.82	28	31.65	13.73
9	10.17	4.40	19	21.75	9.31	29	32.80	14.22
10	11.30	4.89	20	22.60	9.80	29.929	33.947	14.6969

PRACTICAL SUCTION LIFTS AT VARIOUS ELEVATIONS ABOVE SEA LEVEL

ELEVATION	Barometer Reading Lbs. Per Sq. In.	Theoretical Suction Lift Feet	Practical Suction Lift Feet	Vacuum Gauge* Inches
At Sea Level	14.7	34.0	22	19.5
¼ mile—1,320 feet—above sea level	14.0	32.4	21	18.6
½ mile—2,640 feet—above sea level	13.3	30.8	20	17.7
¾ mile—3,960 feet—above sea level	12.7	29.2	18	15.9
1 mile—5,280 feet—above sea level	12.0	27.8	17	15.0
1¼ mile—6,600 feet—above sea level	11.4	26.4	16	14.2
1¼ mile—7,920 feet—above sea level	10.9	25.1	15	13.3
2 miles—10,560 feet—above sea level	9.9	22.8	14	12.4

NOTE: Multiply barometer in inches by .491 to obtain lbs. per sq. in. *Vacuum gauge readings in inches correspond to practical suction lift in feet only when pump is stopped. Pipe friction increases vacuum gauge readings when pump is running. For quiet operation, vacuum gauge should never register more than 20 inches when pump is running.

WATER

Altitude	Temperatures in Degrees Fahrenheit									
	120	130	140	150	160	170	180	190	200	210
Sea Level	−10	−7	−5	−2	0	+3	+5	+7	+10	+12
2000	−7	−5	−2	+1	+3	+5	+7	+10	+12	+15
4000	−5	−2	+1	+3	+5	+7	+10	+12	+14	
6000	0	+1	+3	+5	+7	+10	+12	+14	+16	
8000	0	+3	+5	+7	+9	+12	+14	+16		
10000	+2	+4	+7	+9	+11	+14	+16	+18		

This table gives the maximum permissible suction lift or the minimum head permitted on the suction side of a pump at various altitudes and liquid temperatures. A minus sign before a number indicates maximum suction lift. A plus sign before a number indicates minimum head. These figures are to be used as a guide and are not guaranteed.

When pumping volatile liquids such as gasoline and naphtha, special consideration must be given to the amount of suction lift and the size of the suction pipe used. On such liquids the suction lift, whether it is actual vertical lift or is caused by pipe line friction, must be kept as low as possible, and should never exceed 12 feet.

For liquids such as lube oil, molasses, etc., a suction lift up to 24 feet, at sea level, is usually satisfactory.

APPENDIX B - ASTM STANDARDS LIST

SOIL

ASTM D 1586 Penetration Test and Split-Barrel Sampling of Soils
ASTM D 1587 Thin-Walled Tube Geotechnical Sampling of Soils
ASTM D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D 2488 Description and Identification of Soils (Visual-Manual Procedure)
ASTM D 2573 Field Vane Shear Tests in Cohesive Soil
ASTM D 4220 Preserving and Transporting Soil Samples
ASTM D 5783 Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
ASTM D 6151 Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling
ASTM D 6519 Sampling of Soil Using the Hydraulically Operated Stationary Piston Sampler

ROCK

ASTM D 2113 Rock Core Drilling and Sampling of Rock for Site Investigation
ASTM D 5079 Preserving and Transporting Rock Core Samples
ASTM D 6032 Determining Rock Quality Designation (RQD) of Rock Core

APPENDIX C - FIELD LOGS

Soil Boring Log
Rock Coring Log
Field Daily Activity Log
Field Quantities Log
Sample Delivery Log
Water Pressure Test Field Data
Well / Piezometer Installation Sketch
Well / Piezometer Sensitivity Test
Well / Piezometer Water Level Record

Appendix B
Notice of Entry
Sample Letter

The Narragansett Bay Commission
One Service Road
Providence, RI 02905
401 • 461•8848
401 • 461•6540 Fax
TTY (RI RELAY OPERATORY711)

http://www.narrabay.com

Vincent J. Mesolella
Chairman

Raymond J. Marshall, P.E.
Executive Director

September 29, 2017

Certified Mail - Return Receipt Requested

Riverfront Lofts
160 Exchange Street
Pawtucket, Rhode Island 02860

Subject: Narragansett Bay Commission CSO Control Facilities Phase III
Notice of Entry: Plat 22, Lot 330

Dear Property Owner:

The Narragansett Bay Commission is currently designing facilities for the Phase III Combined Sewer Overflow (CSO) Program to enable the design of an underground storage tunnel. The NBC is conducting a geophysical survey to determine the depth and configuration of the bedrock along the proposed Pawtucket tunnel alignment. The attached figure depicts the proposed limits of the geophysical survey at the above referenced parcel.

Please be advised that in accordance with R.I.G.L. § 46-25-24.1 and the NBC's Rules For Acquisition of Property and Rights, the NBC is hereby notifying you that it intends to enter upon the above-referenced property to conduct a geophysical survey. The geophysical survey is a non-invasive survey technique requiring no disturbance to the site. The activity would take approximately 2 to 4 hours. Staff will coordinate field activities to minimize any disruption to the site.

We expect to commence the geophysical survey on or after 16 August 2017. In accordance with NBC Rules and Regulations, the NBC will compensate you at a rate of $50 for the entry. Said compensation will be paid within a reasonable time after entry.

If you have any questions, please do not hesitate to contact me at 461-8848, extension 362. Our design engineer (Chris Feeney, Stantec) will be on-site during the survey. Should you have any specific questions on the timing and/or coordination of the field work, please feel to contact him at christopher.feeney@stantec.com or 401-214-1738.

Very truly yours,

Thomas Brueckner, P.E.
Engineering Manager

Enclosures

cc: Ms. Kathryn Kelly, P.E. – Narragansett Bay Commission

Appendix C
Example
Dig Safe Form

digsafe.com

Dig Safe Ticket # ______________________ **Date** ____/____/____ **Time** ______________________

Contr I.D. ___________ **Caller's Name** __________________________ **Title** ____________________

Phone # ____________________ **Fax #** ___________________ **Alt #** ___________________________

Email address _______________________________ **Business Hours** ________ **to** ____________

Company ____

Address ____

City ____ **State** __________ **Zip** ___________

State _______________ **Municipality** ____

(optional) **Latitude** ____________________ **Longitude** _____________________

Address/Intersection ____

Buffer Distance (Please circle): 500' 600' 700' 800' 900' 1000' 1100' 1200' 1320'

Nearest Cross St 1 ____

Nearest Cross St 2 ____

Additional Information ____

Type of Work ____

Area of Work ____

Area Premarked? Y _________ N __________

Start Date _____/______ **Time** ______ : ______

Excavator Doing Work ____

Member Companies Notified:

- **There may be non-member utilities in the area that you need to notify.**
- **Electric and other companies may not mark lines they don't own or maintain.**
- **The excavator is responsible to maintain marking placed by member utilities.**
- **Tickets expire exactly 30 days from today in NH and VT; 60 days in ME (excavation must start within 30 days).**

Appendix D

Field Exploration Forms

Pare Corporation
10 Lincoln Road, Suite 210
Foxboro, MA 02035
508-543-1755
508-543-1881

BORING NUMBER B17-XXX

TEST BORING REPORT

PROJECT NAME ____________________

CLIENT ____________________

CONTRACTOR ____________________

PROJECT NO.
START
FINISH
DRILLER
LOGGED BY
CHECKED BY

ELEVATION
DATUM

LOCATION

	CASING	SAMPLER	BARREL	DRILLING EQUIPMENT & PROCEDURES
Type Inside Diameter (in.) Hammer Weight (lb.) Hammer Fall (in.)				Rig Make & Model: Bit Type: Drill Mud: Casing: Hoist/Hammer:

DEPTH (ft)	SPT	SAMPLE NO.	RECOVERY (in)	SAMPLE DEPTH (ft)	USCS SYMBOL	GRAPHIC LOG	VISUAL-MANUAL IDENTIFICATION & DESCRIPTION (Density/consistency, color, max. particle size, structure, odor, moisture, optional descriptions, geologic interpretation)	DRILLING NOTES
0								
5								
10								
15								
20								
25								
30								

WATER LEVEL DATA

DATE/TIME	ELAPSED TIME (hr.)	DEPTH (ft.) TO: BOTTOM OF CASING	BOTTOM OF HOLE	WATER

SAMPLE IDENTIFICATION

O Open End Rod
T Thin Wall Tube
U Undisturbed Sample
S Split Spoon
G Geoprobe

REMARKS:

Pare Corporation
10 Lincoln Road, Suite 210
Foxboro, MA 02035
508-543-1755
508-543-1881

BORING NUMBER B17-1

CORE BORING REPORT

PROJECT NO.

DEPTH (ft)	DRILL RATE (min/ft)	RUN NO.	ELEV/ DEPTH (ft)	REC (in/%)	RQD (in/%)	DISCON (#/ft)	GRAPHIC LOG	VISUAL DESCRIPTION AND REMARKS	DISCONTINUITIES Type	Apt	Dip Angle	Rgh	Wea	Infill
0														
5														
10														
15														
20														
25														
30														

GROUND SURFACE EL. __________

Note: Refer to the Field Manual for Subsurface Exploration attached to the work plan for description of rock classification system codes.

SOIL SAMPLE JAR CAP LABELLING

JAR LID

PARE JOB #

BORING #

SAMPLE #

Depth A---------------------------------Z Depth

BLOW COUNTS

#-#-#-#

ENGINEER INITIALS
PROJECT MANAGER INITIALS

RECOVERY/PENETRATION

JAR #/#

DATE

JAR SIDE LABEL

PROJECT NAME	PROJECT NUMBER
BORING NUMBER	
SAMPLE NUMBER	DEPTH
RECOVERY/PENETRATION	
DATE	

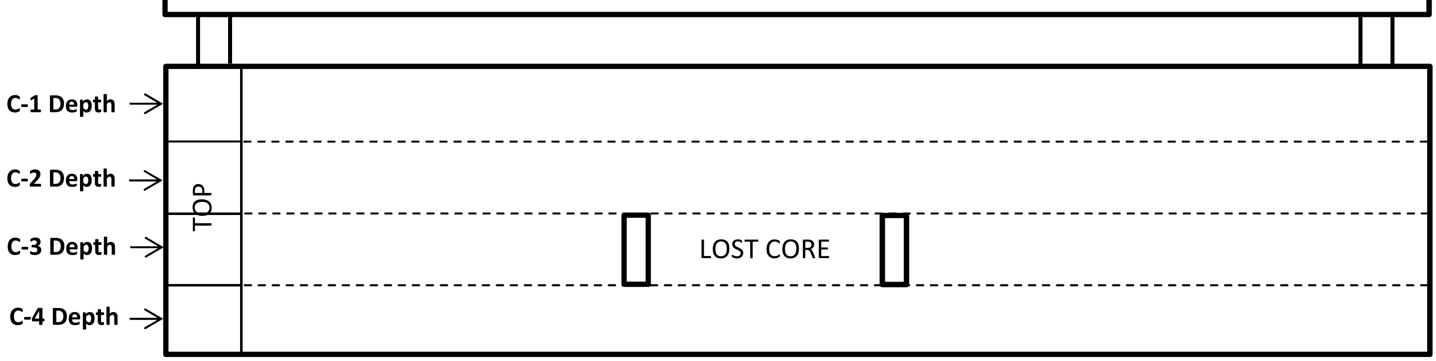
ROCK CORE SAMPLE BOX LABELLING

TOP OF BOX AND SIDES OF BOX

PROJECT NAME
PROJECT NUMBER
BORING NUMBER
BOX ___ OF ___
DEPTH: _____ TO _____
DATE:

INSIDE BOX

PROJECT NAME	RUN NO.	DEPTH, FT.	RECOV, IN (%)	RQD, %
PROJECT NUMBER				
BORING NUMBER				
BOX ___ OF ___				



FIELD DAILY ACTIVITY LOG

Project Name ______________________________ **Sheet** ________ **of** ________

Project Number ______________________________ **Date** ________________

Contents Checklist

- ☐ day's activities & events
- ☐ weather conditions
- ☐ communications / phone calls
- ☐ visitors on site
- ☐ important decisions
- ☐ changes from plans & specs
- ☐ attachments (sketches, etc.)
- ☐ site safety issues
- ☐ other

Field Engineer ______________________________ **Date** ________________

The Narragansett Bay Commission

Stantec

PARE CORPORATION

FIELD QUANTITIES LOG

Project Name ____________________ **Sheet** ______ **of** ______

Project Number ____________________ **Date** ____________

Boring No.	Description of Work Unit	Quantity

Remarks: (Explain standby time, identify any deviations from price schedule, etc.)

Field Engineer ____________________ **Date** ____________

Driller ____________________ **Date** ____________

SAMPLE DELIVERY LOG

Project Name ______________________________ **Sheet** ______ **of** ______

Project Number ______________________________ **Date** ______________

Field Engineer ______________________________

Boring No.	Soil Sample Box No.	Jar Sample Nos.	Tube Sample Nos.	Other Samples	Core Box No.

Receiving Facility: ______________________________

Delivered By: ______________________________ **Date:** ______________

Received By: ______________________________ **Date:** ______________

Condition Received: ☐ **Undamaged** ☐ **Damaged (describe below)**

Remarks: ______________________________

WATER PRESSURE TEST - FIELD DATA

Project Name ________________ **Project No.** ________________ **BORING NO.** __________

Field Engineer ____ **Sheet** _____ **of** ______

Contractor __________________ **Driller** ______________________ **Date** _______________

A. Depth to Water: ____________________ ft

Measured in: ☐ Open Borehole ☐ Pipe String

B. Gage Height: ______________________ ft

C. Column Pressure

= A + B

= _______ft x 0.433 $\frac{psi}{ft\ H_2O}$ = _________psi

Test Zone: Depth to Top ____________ ft

Depth to Bottom __________ ft

Length _________________ ft

Borehole Size / Dia.: ___________________

Pipe String Size / Dia.:__________________

☐ New Smooth ☐ Ordinary ☐ Old Rough

Pressure (psi)			**Time (hr:min:sec)**			**Water Meter Reading (gal)**		
Test (D)	**Gage (D-C)**	**Packer Inflation**	**Start**	**End**	**Duration**	**Start**	**End**	**Take**

Remarks ____

____

Stantec

PARE CORPORATION

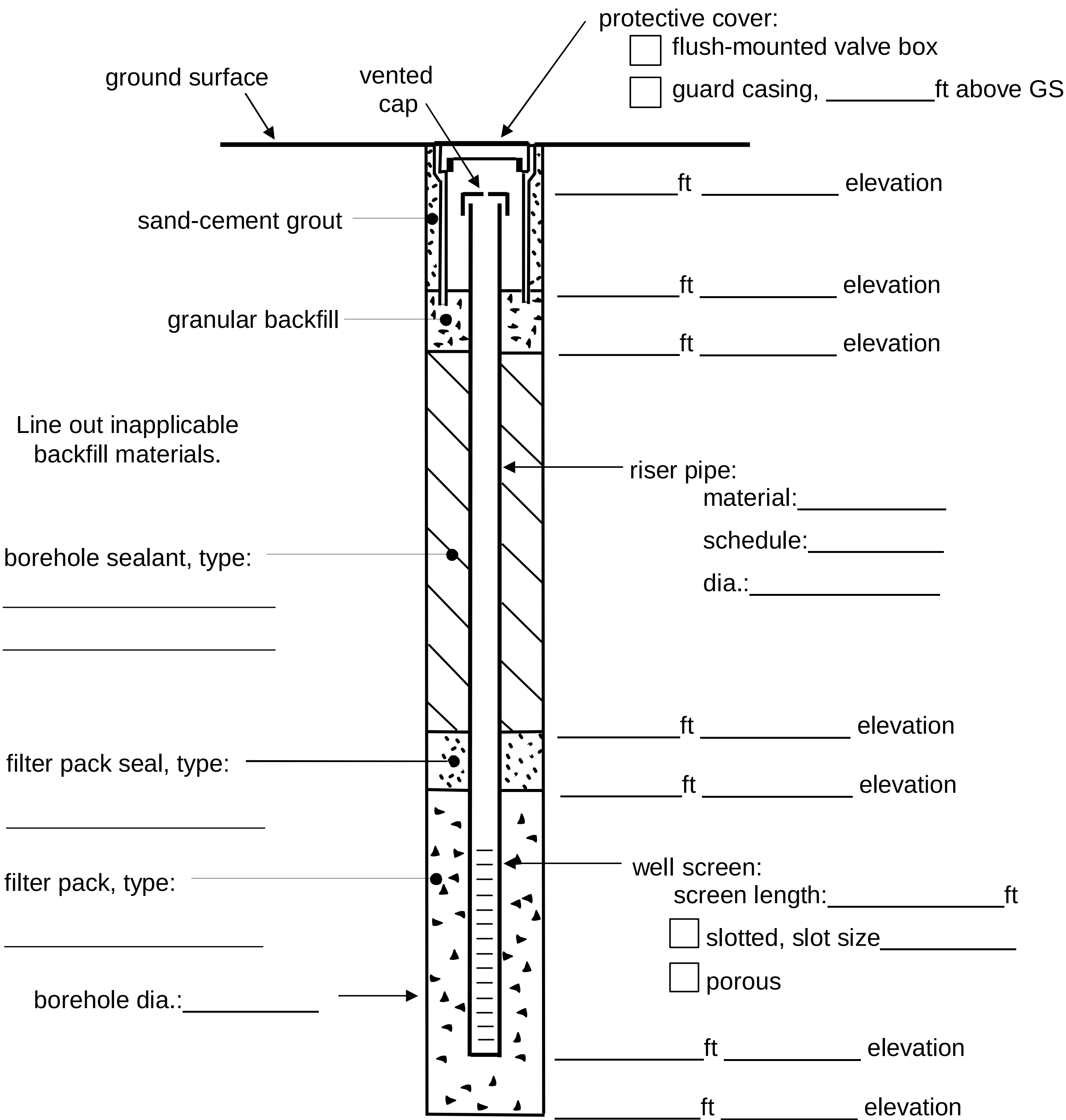
The Narragansett Bay Commission

WELL/PIEZOMETER INSTALLATION SKETCH

Project Name ______________________________ **WELL/PIEZO. NO.** ____________

Project Number ______________________________ **Sheet** ________ **of** __________

Field Engineer ______________________________ **Date** ______________________



WELL/PIEZOMETER SENSITIVITY TEST

Project Name ______________________________ **WELL/PIEZO. NO.** ____________

Project Number ______________________________ **Sheet** ________ **of** ___________

Field Engineer ______________________________ **Date** ______________________

Well/piezometer was developed in the following manner:

☐ bailing ☐ airlifting ☐ pumping out ☐ filling with water and surging

Remarks: ____

____

Depth to water prior to testing:____________ Time: ____________

Fill the well/piezometer with water, and measure the fall in water level with time.

Trial ________________		**Trial** __________________		**Trial** __________________	
Time (real or elapsed)	**Depth to Water (ft)**	**Time (real or elapsed)**	**Depth to Water (ft)**	**Time (real or elapsed)**	**Depth to Water (ft)**

WELL/PIEZOMETER WATER LEVEL RECORD

Project Name ______________________________ **WELL/PIEZO. NO.** ____________

Project Number ______________________________ **Sheet** ________ **of** ________

Reference [(1)] ______________________________ **Ref. Elev.** ____________

Formation Sensed ______________________________

Location Description [(2)] ______________________________

Date	Time	Read By	Depth to Water (ft)	Elevation of Water	Remarks

(1) Normally, the top of protective casing.

(2) Street intersection, address, etc.

DRILL RIG INSPECTION CHECKLIST

SECTION 1: General Information		
Date:	Project no.:	Location:
Time	Inspected by:	

SECTION 2: Personal Protective Equipment						
All using appropriate PPE and in good condition?			Compliance			Comments
			N/A	Yes	No	
1. Ear Protection						
2. Gloves						
3. Hard hat						
4. Safety Boots						
5. Safety Glasses						
6. Dust Mask						

SECTION 3: DRILL RIG	Compliance			Comments
Description of condition	N/A	Yes	No	
1. Toolbox complete?				
2. Equipment in good condition?				
3. All hazardous machine parts guarded?				
4. Whip checks on all air hoses secure?				
5. Valve connection				
6. Fire extinguisher				
6. Emergency Button Location				
7. Last Rig Inspection 's Report				
8. Fluids and Filters				
9. Casing, pipes and split spoon				
10. Any Leaks? (Air, fluid)				
11. Hand Tools				
12. Wires, holes, cables' inspection				
13. Hammers' Condition				
14. Final walk around rig				

PACKER TEST CHECKLIST

Project Name:		**Project No.:**	
Subcontractor:			
Inspector:			
Location:		**Date:**	
Boring No.:			
Water Level (Before):	**Time:**	**Water at:**	
Water Level (After):	**Time:**	**Water at:**	

Test Equipment:	Checked By	Comments
1. For Single Packer and Double Packers		
• Inflation hoses		
• Injection hoses		
• Stuffing box		
• Pump		
• Couplings		
• O-rings		
• An upper fixed end. - Both of the rubber element ends fixed to the pipe mandrel. - Equipped with 1 or 2 inflation inlets with adapters.		
• An inflatable elements - with steel fittings on both sides. - For 4 inch diameter borehole, recommended nominal diameter in inch = 2.2, 2.9, and 3.5. - The contact length with the rock shall be at least 5 times the diameter of the borehole.		
• Make sure there is no leak path present at the mechanical seals of the sliding end.		
2. Extra equipment for Single Packer		
• The diffuser - made of stainless steel.		
3. Extra Equipment for Double Packers		
• The total area of the perforation is at least twice the cross sectional area of the pipe.		
• An extension kit (if needed) for longer injection zone		
• Packer end cap for blocking flow through bottom of packers		
• Inflation line in the test zone		
Equipment Testing		
• All inflation equipment must be pressured test to 2000 psi (for pneumatic systems) or 500 psi (for hydraulic system).		
• All packers must be tested to maximum design pressure		
• Ability to calibrate friction losses in pumping system and packer system prior to testing.		
• By pass valve installed before and after the pressure/flow and to protect flow meter from back pressure.		
• The testing packers must be inflated to the working pressure to ensure a proper seal (approximately 250 psi).		
• Pressure gauge calibration		
Packer Test Preparation		
• The testing packers must be inflated to the working pressure to ensure a proper seal (approximately 250 psi).		
• Check packer assembly for any leakage. Inflate to maximum gland working pressure in appropriate length and diameter of drill casing or drill rods.		
• Check wire line connector on packer assembly and stuffing box components.		
• Prepare and check water feeding system: tank, pump, connection hoses, pressure gauges, valves and flow-meter.		
• Design test parameter: depth and length of tested zone, drilling bit depth, position of packers, inflation pressure and water pressure for three stages.		
• Drill hole preparation: Flush the drill hole with clean water in order to remove the drilling mud and cuttings.		
• Pull rod up to locate drill bit at selected depth.		
• Prepare winch		
• Install stuffing box on drill rods.		
• Measure groundwater level prior to installing packer system several times to assess static groundwater level.		

• Lift the packer assembly using the wireline and lower to landing ring at drill bit - check if seats on landing ring by "listening" to rods using wrench, etc. If possible, check depth marking on wireline if there has been marked for the expected depth.		
• Inflate packer slowly (by 50 psi step) until working pressure has been reached.		
• After inflation is completed, monitor packer inflation line pressure for 2 minutes minimum to see if system is leaking. If no leak apparent then, move to next step.		
• Seal stuffing box cap and watch water feed system.		
• Check inflation lines and inflation pressure to ensure no leaks occur, check water feeding system, prepare stop-watch and field test form.		
• Packer is now ready for testing		

Appendix C – Stage Gate Criteria Inputs

NBC Program Stage Gate Criteria and Inputs
(Design-Bid-Build Delivery Model)

Key:

- DC = Design Consultant
- IGA = intergovernmental agreement
- MOU = memorandum of understanding
- O&M = Operation and Maintenance
- OPCC = Opinion of Probable Construction Cost
- OPCS = Opinion of Probable Construction Schedule
- PM/CM = Program Manager/Construction Manager
- PXP = Project Execution Plan
- QMP = Quality Management Plan
- RIDEM = Rhode Island Department of Environmental Management
- RIDOT = Rhode Island Department of Transportation

Stage Gate 1: Authorization to Procure

Purpose: To verify 1) adequate due diligence and compliance with all conceptual requirements and 2) readiness to procure a design consultant.

Preceding Stage: Conceptual Design **Review Panel:** Stage Gate Committee

	Criteria	Inputs
Need and Scope	• Project need and design scope • Changes from validation tracked and documented	• Statement of Work for design • Scope and WBS consistent with PDS • Up-to-date Change Log
Delivery Strategy and Resources	• Delivery strategy is selected and confirmed • PM/CM resources committed and external needs identified to confirm resources for the next Phase • PM/CM project manager responsible for project identified • Design Consultants have been pre-qualified through if separate RFQ evaluation process is being performed.	• Confirm funding source • Finalized list of qualified Design Consultants • Identify PM/CM project manager
Schedule and Budget	• Verify cash flow projection aligns with constraints • Realistic schedule that meets critical-need dates • OPCC is acceptable and within budget • Project baseline aligns with latest forecast • Schedule/cost variances tracked against baseline • Schedule milestones, constraints, and interdependencies on related projects and goals and objectives of Phase III identified • Milestones comply with Consent Agreement	• Project Execution Plan • Project budget (Class 4 OPCC) • Cash flow projection • Up-to-date Primavera P6 schedule • Up-to-date Change Log
Engineering and Design	• Conceptual Design meets the performance standards define in Re-Evaluation Plan • Conceptual Design complies with Program Design Guide • Conceptual Design meets RIDEM standards defined in Consent Agreement	• Alternatives Analysis Summary (where applicable) • Design Criteria Report and Drawings • Value Analysis Report (where applicable) • Up-to-date Project issues log
Environmental, Cultural, and Land Use	• Phase IIIA Conceptual Design Resource agency permit requirements identified • Identify conditions and constraints of anticipated permits • Coordinate with RI Historic Heritage Preservation Commission	• Identify list of required environmental and cultural resources permits in Phase IIIA Conceptual Design Work Plan • Design conforms and/or addresses identified environmental and utility permits • Relevant documentation applicable from regulatory agencies • Document meetings and points of contact at State and local jurisdictions • Identify list of construction permits
Real Estate and Easements	• Identify permanent, underground, and construction easements for the project • Identify required land acquisitions for above ground structures identification process • NBC and PM/CM coordination on defined real estate easements	• Summary of required real estate acquisitions • Summary of required right-of-way-entry acquisitions • Confirm that Real Estate and Easement Plan is being executed
Operations and Maintenance	• Operations and maintenance personnel have reviewed and commented on the Conceptual Design	• Draft approach to incorporate operations and maintenance specifications
Public Outreach and Stakeholder Engagement	• Public outreach efforts on track and the relevant resources have been notified on the project	• Inventory of potential stakeholders • Confirm that Public Outreach and Stakeholder Communication Plan is appropriate and required activities are being performed
Interfaces	• Interfaces with state/local agencies have been identified and have been informed on project activities (e.g. RIDEM, RIDOT, local municipalities) • IGAs/MOUs reviewed and any requirements completed (as required) • Design conforms to all existing and pending IGAs/MOUs • Inventory of all required IGAs/MOUs is up to date	• Up-to-date inventory of all IGAs/MOUs • Design conforms to all existing and pending IGAs/MOUs • Coordination with state/local agencies
Value and Risk Management	• Confirm first Risk Management Workshop was held • Risks and mitigation measures identified • New risks added and resolved risks retired • Confirm value analysis was conducted and best alternative selected	• Up-to-date risk register • Up-to-date issues log

Construction and Health and Safety	• Safety by design elements have been identified in conceptual design • Construction and health and safety personnel have reviewed and commented on the Conceptual Design	• Draft approach to incorporate safety design specifications
Quality Control	• Required documents were reviewed and accepted by appropriate technical staff • Required documentation to support internal/external quality audit	• Prior design review comments an signed off by Planning and Design Manager and/or PM • Compliance with Program Design Guide and Quality Management Plan

Stage Gate 2: Authorization to Notify to Award

Purpose: To verify 1) the preferred Design Consultant is the appropriate firm to complete the design of the project.

Preceding Stage: Conceptual Design **Review Panel:** Stage Gate Committee

	Criteria	Inputs
Need and Scope	• Preferred Design Consultant has been identified through evaluation process • Confirm preferred Design Consultant's Scope of Work complies with Project Requirements	• Design Contract Request for Proposals (RFP) • Design Consultant Proposals • Recommendation of Award Memorandum
Delivery Strategy and Resources	• PM/CM resources committed and external needs identified to confirm resources for the next Phase	• [None]
Schedule and Budget	• Confirm preferred Design Consultant's design schedule complies with Program schedule • Confirm preferred Design Consultant's Price Proposal complies with Program opinions of probable construction cost and cash flow estimates	• Design Consultant Proposals • Project budget (Class 4 OPCC) • Cash flow projection • Up-to-date Primavera P6 schedule • Up-to-date Change Log
Engineering and Design	• Confirm preferred Design Consultant's technical proposal complies with Statement of Work and Project Requirements	• Design Consultant Proposals • Statement of Work and Request for Proposals
Environmental, Cultural, and Land Use	• No discrete activity at this stage	• [None]
Real Estate and Easements	• No discrete activity at this stage	• [None]
Operations and Maintenance	• No discrete activity at this stage	• [None]
Public Outreach and Stakeholder Engagement	• Make available results of Design Consultant Proposal Review and Selection Process	• Design Consultant Proposals • Recommendation of Award Memorandum
Interfaces	• No discrete activity at this stage	• [None]
Value and Risk Management	• [None]	• [None]
Construction and Health and Safety	• No discrete activity at this stage	• [None]
Quality Control	• Confirm Design Consultant proposals are complete and non-compliant proposals rejected • Confirm Design Consultant's QA/QC procedures conform to Program requirements • Prepare Recommendation of Award Memorandum	• Design Consultant Proposals and QA/QC Procedures • Recommendation of Award Memorandum

Stage Gate 3: Authorization to Issue Notice to Proceed

Purpose: To verify 1) the amendment to the PM/CM contract is authorized / executed, and 2) the PM/CM can issue the NTP to the Design Consultant

Preceding Stage: Conceptual Design **Review Panel:** Stage Gate Committee

	Criteria	Inputs
Need and Scope	• Project need and scope defined • Changes from validation tracked and documented	• Professional Services Agreement between PM/CM and Design Consultant
Delivery Strategy and Resources	• PM/CM resources committed and external needs identified to confirm resources for the next Phase • Negotiated scope and fee finalized	• Amendment to PM/CM Professional Services Contract to Procure Design Consultant
Schedule and Budget	• Confirm preferred Design Consultant's design schedule complies with Program schedule • Confirm preferred Design Consultant's Price Proposal complies with Program budget and cash flow estimates	• Up-to-date Project Execution Plan • Design Consultant Proposals • Project budget (Class 4 OPCC) • Cash flow projection • Up-to-date Primavera P6 schedule • Up-to-date change log
Engineering and Design	• Confirm preferred Design Consultant's technical proposal complies with State of Work and project requirements	• Statement of Work and Request for Proposals • Design Consultant Proposals
Environmental, Cultural, and Land Use	• No discrete activity at this stage	• [None]
Real Estate and Easements	• No discrete activity at this stage	• [None]
Operations and Maintenance	• No discrete activity at this stage	• [None]
Public Outreach and Stakeholder Engagement	• Make available results of Design Consultant Proposal Review and Selection Process	• Design Consultant Proposals • Recommendation of Award Memorandum
Interfaces	• No discrete activity at this stage	• [None]
Value and Risk Management	• No discrete activity at this stage	• [None]
Construction and Health and Safety	• No discrete activity at this stage	• [None]
Quality Control	• [None]	• [None]

Stage Gate 4: Authorization to Bid

Purpose: To verify 1) detailed design documents are appropriately complete and have been adequately reviewed, 2) project risks are properly addressed, and 3) readiness to procure a construction contractor.

Preceding Stage: Final Design **Review Panel:** Stage Gate Committee

	Criteria	Inputs
Need and Scope	• Final design documents meets original project need • Final design documents provides best value considering full life-cycle cost • Changes to scope were appropriately justified through the Change Management Process	• Final design submittal (drawings and specifications) • Final Bid Documents • Up-to-date Change Log
Delivery Strategy and Resources	• Final delivery strategy and bid documents aligned • PM/CM resources committed and external needs identified to confirm resources for the next Phase • Engineering Services During Construction and Construction Management resources secured	• Contract Documents and Bid Package • Up to date Project Execution Plan
Schedule and Budget	• Verify cash flow projection aligns with budget constraints • Schedule is realistic and meets critical need dates • OPCC (AACE Class 2) is acceptable and meets PM/CM and NBC methodology standards • Schedule/cost variances tracked against previous stage gate • Schedule milestones, constraints, and interdependencies identified	• Up-to-date Project Execution Plan • Project budget (Class 2 OPCC) • Cash flow projection • Up-to-date Primavera P6 schedule • Up-to-date change log
Design	• Final design meets the requirements in the Design Guide and Design Consultant's contract. • Final design phase review comments have been addressed • Any comments received from agency design reviews incorporated into the bid documents • Certificate of Authorization from RIDEM is obtained	• Final design submittal (drawings and specifications) • Consultant's final Opinion of Probable Construction Cost (Class 2) • RIDEM Certificate of Authorization
Environmental, Cultural, and Land Use	• Construction Contractor permits are identified and Owner construction permits are obtained • Environmental, cultural resources and construction permits obtained; or a risk analysis has been completed for the acquisition of outstanding permits and any potential impacts to construction • Conditions of existing permits identified and the PM/CM team is informed	• Design phase permits required for design completion and acceptance • State/local permits required for construction • RIDEM Order of Approval • RIDEM Certificate of Authorization • Identification of permitting conditions for construction phase of project • Design conforms to all permit conditions • Relevant information from regulatory agencies has been received
Real Estate and Easements	• Verify completion of required real estate, easement, and right-of-way acquisition	• Completed real estate acquisitions • Confirm that Real Estate and Easement Plan is being executed
Operations and Maintenance	• Operations and maintenance personnel reviewed and commented on final design • Operations and maintenance constraints on construction sequencing incorporated in the specifications	• Final design incorporates operations and maintenance specifications
Public Outreach and Stakeholder Engagement	• Public outreach efforts on track	• Inventory of potential stakeholders has been identified • Substantive public/stakeholder comments incorporated into design documents • Communication plan with impacted residential and business
Interfaces	• Interfaces with agencies impacted by construction are identified • Obtained required IGAs and MOUs (as required) • IGAs/MOUs reviewed and any requirements completed or incorporated into design documents •	• Required IGAs and MOUs • Design conforms to all existing and pending IGAs and MOUs
Value and Risk Management	• Risks and appropriate mitigation measures identified • New risks added and resolved risks retired • Confirm value engineering was performed and appropriate solutions were incorporated	• Up-to-date risk register (including outcomes of Risk Management Workshop) • Value Engineering Reports
Construction and Health and Safety	• Construction and health and safety personnel have reviewed and commented on the final design • Constructability review comments have been addressed	• [None]

Quality Control	• Required documents reviewed and accepted by appropriate technical staff	• Review comments signed off by Planning and Design Manager and/or PM • Compliance with Program Design Guide and QMP • Confirm DC's quality control review of design submittal

Stage Gate 5: Authorization to Award

Purpose: To verify the integrity of the procurement process and confirm final, contracted project construction cost.
Preceding Stage: Final Design **Review Panel:** Stage Gate Committee

	Criteria	Inputs
Need and Scope	• Lowest responsive/responsible bidder identified • Bonding company accepts project bid	• Contract Documents and Invitation to Bid • Contractor bids
Delivery Strategy and Resources	• PM/CM resources committed and external needs identified to confirm resources for the next Phase • Bid results/tabulations reviewed for outliers, bid errors, or red flags • Bonding company accepts bid and state acceptance to insure	• Bid results/tabulations • PM/CM letter identifying lowest responsive/responsible bidder • Up-to-date Project Execution Plan
Schedule and Budget	• Verify cash flow projection aligns with budget constraints • Schedule is realistic and meets critical need dates • Budget based on construction contractor bid is acceptable • Schedule/cost variances tracked against previous stage gate • Consent Decree Milestones are confirmed	• Up-to-date Project Execution Plan • Project budget (Bid Prices) • Cash flow projection • Up-to-date Primavera P6 schedule • Up-to-date change log
Design	• [None]	• [None]
Environmental, Cultural and Land Use	• Required permits are in place and included in bid package • Conditions of existing permits identified and included in the bid documents	• Required permits incorporated in Construction Documents • Project notification forms to regulatory agencies completed
Real Estate and Easements	• Real estate, easement, and right-of-way agreements in place • Provisions for delineation of easement boundaries included in the bid documents • Property owners/tenants notified of pending construction	• Completed real estate acquisitions • Confirm that Real Estate and Easement Plan is being executed
Operations and Maintenance	• Operations and maintenance staff aware of any coordination items required for construction • NBC IM and operations staff made aware of any operational impacts associated with construction	• Operations and maintenance specifications • Operations impacts identified • By-pass pumping requirements
Public Outreach, Stakeholder Engagement & Public Affairs	• Construction coordination with local agency points of contact is underway • Construction schedule and traffic impacts identified • Final strategy for public outreach of state/local agencies, local businesses is complete and coordinated with NBC Public Affairs Manager	• Stakeholder and property owner outreach strategy complete
Interfaces	• IGAs/MOUs reviewed and any requirements completed	• Terms and conditions of IGAs/MOUs identified
Value and Risk Management	• Risks and appropriate mitigation measures identified • New risks added and resolved risks retired	• Up-to-date risk register
Construction and Health and Safety	• Contract Summary and Award Recommendation • Review Bidders OSHA record • Check references on health and safety compliance	• Summary of lowest responsive, responsible bidder's health and safety performance • Identify reference input on health and safety
Quality Control	• Required QA/QC documents reviewed and accepted by appropriate technical staff	• Required QA/QC documents have been prepared

Stage Gate 6: Substantial Completion

Purpose: To verify 1) construction and associated permits/environmental compliance activities have been completed and 2) contract terms have all been satisfied. To confirm the asset performs as designed. To initiate warranty period. To confirm the work has been completed per the specifications.

Preceding Stage: Startup and Commissioning **Review Panel:** Stage Gate Committee

	Criteria	Inputs
Need and Scope	• Project meets performance requirements per contract requirements • Installed components are functional • Individual project components meet design and operational criteria	• Contract Documents • Letter from the Construction Contractor asking for substantial completion • Certification of Substantial Completion • Punch list • Start-up and Commissioning Checklist • Status update on warranty period
Delivery Strategy and Resources	• Delivery strategy resulted in satisfactory implementation • PM/CM resources committed and external needs identified to confirm resources for the next phase	• Up-to-date Project Execution Plan
Schedule and Budget	• Verify cash flow projection aligns with budget constraints. • Warranty period schedule established and is tracked through the program controls	• Up-to-date Primavera P6 schedule • Project budget • Up-to-date change log
Design	• As-constructed improvements are in general conformance with the design documents and provide the intended functions	• Final design documents • Testing documentation • Red-line markups
Environmental, Cultural, and Land Use	• Environmental permit condition compliance is monitored • Required environmental documentation is in place and provisions for long-term monitoring implemented	• Compliance with environmental permits • Plan for completion final site restoration • Monitoring requirements identified and appropriately transferred to the contractor if required • Compliance with land use approval requirements
Real Estate and Easements	• Real Estate easement status monitored • Restoration conditions for temporary easements identified	• Notifications to property owners/tenants of the impending completion of construction • Secure written acceptance of post-construction site conditions from property owners (and tenants, if applicable) • Secure written acceptance of post-construction site conditions from property owners (and tenants, if applicable)
Operations and Maintenance	• Verify NBC IM and operations have reviewed the as-constructed improvements and concur with substantial completion	• Operations and Maintenance Manuals from Contractor • Training and on-site manufacturer support scheduled
Public Outreach and Stakeholder Engagement	• Coordination with key stakeholders is continuing during construction	• Stakeholder and property owner outreach activities are continuing
Interfaces	• IGAs/MOUs reviewed and any requirements completed	• Construction conforms to all existing and pending IGAs/MOUs
Value and Risk Management	• Risks and appropriate mitigation measures identified • New risks added and resolved risks retired	• Up-to-date risk register
Construction and Health and Safety	• Construction personnel confirm acceptance of project • Verify health and safety personnel have reviewed the as-constructed improvements and concur with substantial completion	• Contractors and third-party testing records • Operator Training Summary Report • Construction Contractor's Certificate of Substantial Completion • Insurance, warranties, and guarantees • Certificates of proper installation
Quality Control	• Required documents reviewed and accepted by appropriate technical staff	• Required documents reviewed and accepted by appropriate technical staff • Contractors and third-party testing records

Stage Gate 7: Final Acceptance

Purpose: To verify 1) the punch list is complete and 2) authorization for lien releases by subcontractors and suppliers; and 3) regulatory compliance closeout documents are drafted and submitted to NBC. To initiate program-level closeout process.
Preceding Stage: Construction Close-out **Review Panel:** Stage Gate Committee

	Criteria	Inputs
Need and Scope	• Project construction completed per contract requirements • Project documentation complete and files organized per PM/CM, NBC and Consent Decree requirements • Project 'post-mortem' documentation including process improvement opportunities complete and reviewed • Project documentation is organized and prepared for close-out • Site restoration is completed in accordance with project requirements	• Contract Documents • Record drawings and close-out documents • Project warranties • Process improvements and knowledge transfer
Delivery Strategy and Resources	• Delivery strategy resulted in satisfactory implementation	• NBC Feedback on Project Delivery
Schedule and Budget	• Validate final project budget and cost values • Update and finalize the project schedule • Final pay application has been reviewed and accepted	• Project budget summary • Target cash flow projection • Up-to-date Primavera P6 schedule • Up-to-date change log
Design	• Verify DC deliverables are received and distributed to the agreed upon parties for final record	• As-Built Record Drawings • QA/QC testing documentation • Close-out documentation
Environmental, Cultural, and Land Use	• Permit requirements fulfilled and documentation provided to regulatory agencies, as required	• Regulatory compliance • Final permit sign-off, as required (e.g. Building Permit) • Compliance with land use approval requirements for close out
Real Estate and Easements	• Final documentation for easements obtained • Easements filed with local land evidence record	• Final easement record documents • Secure written acceptance of post-construction site conditions from property owners
Operations and Maintenance	• Operations and maintenance personnel confirm acceptance of project • Operations and maintenance personnel received required training and documentation from the contractor • Operations and maintenance manuals reviewed and accepted	• Record Drawings • Operation and Maintenance Manuals • Training Manuals • Warranties • NBC training documentation
Public Outreach and Stakeholder Engagement	• Inform stakeholders that construction is complete • Coordinate public outreach requirements with local agencies	• Stakeholder and property owner outreach activities
Interfaces	• IGAs/MOUs reviewed and any requirements completed • Interfaces with other projects established, tested, and deemed functional	• Construction conforms to all existing and pending IGAs/MOUs
Value and Risk Management	• Risks and appropriate mitigation measures identified • New risks added and resolved risks retired	• Up-to-date risk register
Construction and Health and Safety	• Construction personnel confirm acceptance of project •	• Acceptance of Contractor and third-party testing records • Lien Releases • Acceptance of operations and maintenance manuals • Acceptance of Record Drawings • Completed punch list • Completed Start-Up and Commissioning Checklist
Quality Control	• Required documents stated reviewed and accepted by appropriate technical staff	• Required documents reviewed and accepted by appropriate technical staff • Contractors and third-party testing records

Appendix D – Design Checklists and Project Summary Form

30% Design Project Checklist

Project Name:

Project Manager (DC):

Project Manager (PM/CM): **Date Completed:**

Planning/Design Manager Approval (PM/CM): **Date Approved:**

Chief Engineer/Program PTL Approval (PM/CM): **Date Approved:**

30% Submittal Date: **30% Milestone Date:**

Purpose: The 30% design should generally consist of completion of a basis of design, preliminary drawings, OPCC, and geotechnical investigation summary. The basis of design should include an overview of the project design, all design criteria and findings identifying potential conflicts or concerns to be addressed moving forward to the 60% design. Preliminary drawings should include the completed survey of the existing conditions and utility information including services, initial alignments of proposed pipelines, locations of critical structures/features, identification of potential utility conflicts, and preliminary pipe depths or profiles of proposed and existing conditions at critical locations. OPCC should be consistent with OPCC standards. Environmental and geotechnical subsurface investigations (as appropriate) should be completed and recommendations included for any additional subsurface investigations needed, including justification.

This ***30% Design Project Checklist*** is provided to Project Managers and Design Consultants responsible for project design. Items presented in this checklist are a compilation of industry-standard design criteria, specific design criteria and general lessons learned from previously constructed projects. This list is not intended to be all inclusive. Project Managers shall review each item listed in this checklist and indicate whether or not the item has been addressed in the 30% submittal, or if it is not applicable. For every item not addressed, a comment shall be provided. All items not addressed shall be addressed in the 60% Design Project Checklist.

A completed ***30% Design Project Checklist*** shall be required prior to scheduling a Technical Review Meeting.

Yes	No	N/A	General and Project Management	Comments
☐	☐	☐	1. Kick-off meeting with PM/CM conducted?	
☐	☐	☐	2. Initial site visit/walk conducted with PM/CM and DC?	
☐	☐	☐	3. Have site photos of the project corridor been included?	
☐	☐	☐	4. Has the DC utilized approved materials?	
☐	☐	☐	5. Design coordination initiated with City/Agency/Utility?	
☐	☐	☐	6. Have potential new easements been identified?	
☐	☐	☐	7. Has the preliminary design (30% design), OPCC, and Basis of Design been prepared?	
☐	☐	☐	8. Has a 30% QA/QC statement been provided by the DC?	
☐	☐	☐	9. Have major stakeholders such as schools/hospitals been identified?	
☐	☐	☐	10. Is the design coordinated with local planned water, sewer, gas, streetscape improvements, etc.?	
☐	☐	☐	11. Has an outline of specification sections been submitted?	
☐	☐	☐	12. Does the drawing set include a Phase III program standard cover sheet; index sheet; general notes, abbreviations, and legend sheet as appropriate? Does it comply Program CAD Standards?	
☐	☐	☐	13. Does the basis of design report and supporting documentation include the results of all field investigation data (i.e. geotechnical, survey, inspections, field walk, etc.)?	
☐	☐	☐	14. Does the design documentation include a project specific checklist developed by the DC?	

Yes	No	N/A	Drawing Layout/Data Collection/Survey Coordination	Comments
☐	☐	☐	1. North arrow shown on all plans (Ideally up or to the right)?	
☐	☐	☐	2. Field survey completed to contractual obligations?	
☐	☐	☐	3. Has all data been presented in approved datum? NAD83 (H) and NGVD29(V) and shown on plans.	
☐	☐	☐	4. Horizontal and/or vertical scales (written and scale) shown on each sheet, where applicable?	
☐	☐	☐	5. Accuracy of topographic mapping checked via site walks?	
☐	☐	☐	6. Benchmark(s) identified on the site plan and located at a minimum every 500 feet along the route?	
☐	☐	☐	7. All rights-of-way, property lines, and easements shown (source of data noted?	
☐	☐	☐	8. All flood plains, edge of wetlands, buffer zones and setbacks shown?	
☐	☐	☐	9. Have highway and railroad right-of-ways been identified?	
☐	☐	☐	10. If applicable, has a note been added stating that Contractor is required to coordinate with railroad prior to start of work?	
☐	☐	☐	11. Lawn or kept areas, trees and shrubs are shown (size and type)?	
☐	☐	☐	12. All underground utilities and structures, ducts, overhead wires, and service connections shown?	

☐	☐	☐	13. Location of existing houses (plat/lot, ownership name), buildings, fences, walls, signs, poles, mailboxes, and structures shown?	
☐	☐	☐	14. Has the DC team completed a field walk through along the alignment and documented field notes and photos?	

Yes	No	N/A	Utility Coordination	Comments
☐	☐	☐	1. Have all existing NBC record drawings and service connections been collected and reviewed?	
☐	☐	☐	2. Has a meeting with NBC IM and Operations been conducted?	
☐	☐	☐	3. Have all utility contacts (National Grid gas and electric, Verizon, Cox, PWSB, RIDOT, 3rd party fiber) been made and existing drawings obtained and incorporated into plans?	
☐	☐	☐	4. Existing Town/City utility drawings obtained?	
☐	☐	☐	5. Do all proposed water, sewer, and drain lines connect to existing lines?	

Yes	No	N/A	Soils/Groundwater/Erosion Control	Comments
☐	☐	☐	1. Soil borings/monitoring wells/test pits field surveyed and completed, if seasonally acceptable?	
☐	☐	☐	2. Have geotechnical investigation guidelines and work plan standards been followed? Are the results of the Geotechnical Investigation Summary provided?	
☐	☐	☐	3. Was the borings/monitoring wells plan reviewed by the PM for incorporating alternate spacing and numbering prior to implementation?	
☐	☐	☐	4. Was soil/groundwater sampling conducted at proposed pipe depth along the alignment?	
☐	☐	☐	5. Was soil/groundwater sampling conducted along the anticipated areas of excavation to identify possible contamination? Was depth sufficient to design SOE?	
☐	☐	☐	6. Have all borings/monitoring wells been shown on the plans?	
☐	☐	☐	7. Has DC provided recommendations for additional borings or monitoring wells with justification?	
☐	☐	☐	8. Road, railroad, or other special locations requiring boring, jacking, or directional drilling identified?	

Yes	No	N/A	Permitting	Comments
☐	☐	☐	1. Local and State permits/approvals identified and schedule for approval estimated.	
☐	☐	☐	2. Did the 30% plans include the necessary field investigation to identify natural resources and regulatory buffers, setbacks, and jurisdictions?	
☐	☐	☐	3. Do design drawings adequately display anticipated erosion and sediment controls?	
☐	☐	☐	4. Does the basis of design define strategies to mitigate impacts to resource areas that may lead to prolong regulatory review?	
☐	☐	☐	5. Are there any deviations to design that would impact compliance with RIDEM requirements (consent agreement and approved CSO plan)?	

Yes	No	N/A	Roadway and Traffic Management	Comments
☐	☐	☐	1. Has a preliminary concept for maintaining traffic been prepared? Have major traffic concerns been identified?	
☐	☐	☐	2. Has adjacent project work been considered and coordinated?	
☐	☐	☐	3. Have state highways been identified?	
☐	☐	☐	4. Has anticipated paving schedules been coordinated with City/Town?	
☐	☐	☐	5. Road names, state route numbers, and right-of-way widths shown?	

Yes	No	N/A	Water Main Design	Comments
☐	☐	☐	1. Do 30% design drawings identify need for water main relocation to accommodate proposed design elements?	
☐	☐	☐	2. Does the plan identify existing valves and proposed valves and number of services impacted by shutdown?	
☐	☐	☐	3. Did design identify need for water by-pass plan?	
☐	☐	☐	4. Are noted water main relocation and/or placement in conformance with PWSB standards?	
☐	☐	☐	5. Does the design report include PWSB design checklist as an attachment?	
☐	☐	☐	6. Are pipe material and valve type identified and consistent with PWSB?	

Yes	No	N/A	CSO Consolidation Design	Comments
☐	☐	☐	1. Does the hydraulic capacity meet the defined hydraulic criteria based on model results (i.e. peak flow, maximum velocity)?	
☐	☐	☐	2. Does the HGL meet the defined level of service?	
☐	☐	☐	3. Minimum depth of cover over sewers is 5' whenever possible.	
☐	☐	☐	4. Manholes are spaced a maximum of 500 feet apart?	
☐	☐	☐	5. Drops of at least 0.1' included in all manholes to comply with RIDEM criteria?	
☐	☐	☐	6. Computations provided that indicate slopes on the gravity sewers produce a minimum velocity of 2 fps based on and appropriate Manning's coefficient.	
☐	☐	☐	7. Verify Minimum slopes meet TR-16 criteria.	
☐	☐	☐	8. Verify velocities are less than 10 fps, unless special provisions have been made for erosion.	
☐	☐	☐	9. Force mains should enter the gravity sewer no more than 2' above the flow line of the receiving manhole.	
☐	☐	☐	10. If pipe drop exceeds 2.5' in a manhole, use an external drop manhole. Pipe drops must have a cleanout.	

Yes	No	N/A	GSI Design	Comments
☐	☐	☐	1. Does the design comply with RIDEM SW Design Manual?	
☐	☐	☐	2. Does maximum capture volume and promote infiltration?	
☐	☐	☐	3. Drainage maps completed with pre- and post-development sub-areas delineated?	
☐	☐	☐	4. Details meet RIDEM standards?	
☐	☐	☐	5. Basis of design identifies capture volume and reduction of volume for 3-month storm.	
☐	☐	☐	6. Design incorporates features to minimize maintenance and use native plantings.	
☐	☐	☐	7. Minimum velocity in a drain is 2 fps.	

Yes	No	N/A	Sewer Design	Comments
☐	☐	☐	1. Existing manhole numbers are indicated as reported on the record drawings?	
☐	☐	☐	2. Does design comply with RIDEM criteria for sanitary and water separation?	
☐	☐	☐	3. Does basis of design and drawings consider proposed construction method and temporary SOE?	

Yes	No	N/A	Storm Drain Design	Comments
☐	☐	☐	1. Peak runoff rates computed/modeled with Program approved method?	
☐	☐	☐	2. New drains and outfalls designed for a 10-year, 24-hour storm? DC to document required design criteria based on road rating and applicable state/local requirements.	
☐	☐	☐	3. Drainage maps completed with pre- and post-development sub-areas delineated?	
☐	☐	☐	4. Clearance with other utilities shall be a minimum of 18” vertically. Manholes located at all pipe size changes, vertical grade breaks, horizontal angle deflections great than five degrees, mainline pipe intersections, and at a minimum of 300’ intervals	
☐	☐	☐	5. When mainline pipe size changes at a manhole, the pipe crowns are matched.	
☐	☐	☐	6. Minimum depth of cover over drains is 42”. Exceptions may be required.	
☐	☐	☐	7. Minimum velocity in a drain is 2 fps.	

Yes	No	N/A	Other Specific Issues or Concerns of the PM	Comments
☐	☐	☐	1. Project Manager (PM/CM) recommends proceeding to Technical Review Meeting?	
☐	☐	☐	2. Did the DC submit the necessary inputs to facilitate technical review meeting?	
☐	☐	☐	3. Other	
☐	☐	☐	4.	
☐	☐	☐	5.	

Yes	No		Date
☐	☐	**1. Design Consultant Authorized to Advance to Next Stage of Design?** **(If DC is Conditionally Authorized to Advance the Design, Attach a Summary of these Conditions to this Checklist)**	

60% Design Project Checklist

Project Name:

Project Manager (DC):

Project Manager (PM/CM): **Date Completed:**

Planning/Design Manager Approval (PM/CM): **Date Approved:**

Chief Engineer/Program PTL Approval (PM/CM): **Date Approved:**

60% Submittal Date: **60% Milestone Date:**

Purpose: The 60% design should generally consist of the proposed alignment and profile, location of all structures, resolution of utility conflicts, property lines, proposed utility relocations, and easements. The intent is for the design to show an essentially complete project to allow a complete PM/CM, NBC, utility, municipal, and permitting review to including contract drawings, project manual, cost estimate, and subsurface investigations. The 60% submittal should include all Division 0 and Division 1 specifications essentially complete with draft versions of all remaining specification sections. The 60% design documents should identify anticipated type and limits of temporary SOE, construction dewatering, present findings of field investigations during previous phase, and prepare documentation to support permit level plans for regulatory submission. OPCC should be consistent with OPCC standards.

This **60% Design Project Checklist** is provided to Project Managers and Design Consultants responsible for project design. Items presented in this checklist are a compilation of industry-standard design criteria, program specific design criteria and general lessons learned from previously constructed projects. This list is not intended to be all inclusive. Project Managers shall review each item listed in this checklist and indicate whether or not the item has been addressed in the 60% submittal or if it is not applicable. For every item not addressed a comment shall be provided. All items not addressed shall be addressed in the 90% Design Checklist.

A completed ***60% Design Project Checklist*** shall be required prior to scheduling a Technical Review Meeting.

Yes	No	N/A	General and Project Management	Comments
☐	☐	☐	1. Have all unresolved items in the 30% checklist been resolved?	
☐	☐	☐	2. Design coordination meetings conducted with City, RIDEM, RIDOT, or other agency?	
☐	☐	☐	3. Have updates to design criteria, 30% design, OPCC update, and revision/updates Basis of Design (if applicable) been prepared?	
☐	☐	☐	4. Were Program, PWSB, and RIDOT standard details used?	
☐	☐	☐	5. List of project stakeholders for future outreach and traffic management been prepared. Contact information included?	
☐	☐	☐	6. Has the project area been re-walked with the 60% plans to look for accuracy and any changes?	
☐	☐	☐	7. Have easement plans been prepared? Legal descriptions and easement filings to be prepared by others.	
☐	☐	☐	8. If appropriate, have the plans been distributed for peer review and/or value engineering?	
☐	☐	☐	9. If structure inspections are included, are they complete and has a draft summary report been submitted?	
☐	☐	☐	10. Does the drawing set include a Phase III program standard cover sheet; index sheet; general notes, abbreviations, and legend sheet as appropriate? Does it comply Program CAD Standards?	
☐	☐	☐	11. Does the design documentation include a project specific checklist developed by the DC? Does the design include cross-discipline review?	
☐	☐	☐	12. Has private property restoration been identified and clearly defined including driveway repaving?	
☐	☐	☐	13. Does the submission include Program Standard specification (DIV 0 and 1) and applicable technical specifications? It is noted that some technical specifications may not be fully developed.	
☐	☐	☐	14. Has a 60% QA/QC statement been provided by the DC?	

Yes	No	N/A	Drawing Layouts/ Data Collection/Survey Coordination	Comments
☐	☐	☐	1. Has required clearing and grubbing been shown and limits defined?	
☐	☐	☐	2. Proposed and existing ground elevations shown on plans/profiles?	
☐	☐	☐	3. All new sanitary sewers, drains and major water mains are profiled?	
☐	☐	☐	4. Are large diameter pipes, manholes, catch basins, vaults, electrical ducts, etc. shown to scale, including outside dimensions?	
☐	☐	☐	5. Are final site restoration of all disturbed areas delineated on drawings?	
☐	☐	☐	6. Are paving limits delineated on drawings?	

☐	☐	☐	7. Does drawing set delineate required erosion and sediment control details and notes?	
☐	☐	☐	8. Accuracy of surface features/structures checked via site walks?	
☐	☐	☐	9. Benchmark(s) identified on the site plan and located at a minimum every 500 feet along the route?	
☐	☐	☐	10. All rights-of-way, property lines, and easements shown (source of data noted?	
☐	☐	☐	11. All flood plains, edge of wetlands, buffer zones and setbacks shown?	
☐	☐	☐	12. Have highway and railroad right-of-ways been identified?	
☐	☐	☐	13. If applicable, has a note been added stating that Contractor is required to coordinate with railroad prior to start of work?	
☐	☐	☐	14. Lawn or kept areas, trees and shrubs are shown (size and type)?	
☐	☐	☐	15. All underground utilities and structures, ducts, overhead wires, and service connections shown?	
☐	☐	☐	16. Location of existing houses (plat/lot, ownership name), buildings, fences, walls, signs, poles, mailboxes, and structures shown?	
☐	☐	☐	17. Has the DC team completed a field walk through along the alignment and documented field notes and photos?	

Yes	No	N/A	Utility Coordination	Comments
☐	☐	☐	1. Have duct bank dimensions been verified through test pits and/or confirmation by utilities? Often times they are stacked.	
☐	☐	☐	2. All existing fire hydrants and valve locations shown and verified?	
☐	☐	☐	3. Water mains of any size crossing other utilities are profiled, conflicts resolved?	
☐	☐	☐	4. Have any SUE investigation been conducted? Are the results shown on the drawings?	
☐	☐	☐	5. Have City/Town records been checked to locate the presence of underdrains?	
☐	☐	☐	6. Have all overhead conflicts been identified during site walks?	
☐	☐	☐	7. Have all the dimensions and shape (egg, oval, cradle, etc.) of all large diameter and crossing sewers and drains been verified?	
☐	☐	☐	8. Design coordination meetings conducted with Utilities when needed. Have 60% plans been submitted to utilities (list at bottom of checklist)?	

Yes	No	N/A	Soils/Groundwater/ Erosion Control	Comments
☐	☐	☐	1. Supplemental soil borings and monitoring wells complete?	
☐	☐	☐	2. Where refusal is encountered above final excavation depth, have rock cores been taken and has rock been profiled and characterized? Has geotechnical engineer confirmed adequacy of spacing?	
☐	☐	☐	3. Has a draft soils management plan been incorporated into the design drawings and specifications? Have regulated/impacted soils been identified during the environmental investigation?	
☐	☐	☐	4. Does the design include temporary SOE, construction dewatering, construction sequence, and geotechnical instrumentation?	
☐	☐	☐	5. Do drawings conform to RIDEM erosion control and sedimentation regulations?	
☐	☐	☐	6. Erosion and sediment control devices shown and details included?	
☐	☐	☐	7. Have groundwater levels been determined and shown on boring logs?	
☐	☐	☐	8. Have water levels been monitored in monitoring wells?	
☐	☐	☐	9. Has a draft geotechnical/environmental summary memo been prepared? Did EH&S consultant review?	
☐	☐	☐	10. Has the soil disposal method been defined? Soil pre-characterization may require additional delineation over stockpiling or centralized soil disposal.	
☐	☐	☐	11. Have the borings and monitoring wells been shown on the plans and profiles, including supplemental borings and monitoring wells.	

Yes	No	N/A	Permitting	Comments
☐	☐	☐	1. Local and State permit/approval applications prepared (as needed). Submit following the 60% review.	
☐	☐	☐	a. CRMC	
☐	☐	☐	b. RIDOT Physical Alternation	
☐	☐	☐	c. RIDEM Order of Approval	
☐	☐	☐	d. RIPDES permit for stormwater	
☐	☐	☐	e. National Grid Gas – encroachment review	

Yes	No	N/A	Roadway and Traffic Management	Comments
☐	☐	☐	1. Have pavement and sub-base thicknesses been clearly identified in the borings including asphalt and concrete?	
☐	☐	☐	2. Has a preliminary concept for maintaining traffic been prepared?	
☐	☐	☐	3. Has anticipated paving schedules been coordinated with City/Town?	
☐	☐	☐	4. Have state highways been identified?	
☐	☐	☐	5. Has a note been added stating that Contractor is required to obtain permits from RIDOT prior to start of work?	

Yes	No	N/A	Water Main Design	Comments
☐	☐	☐	1. Did 30% design drawings identify need for water main relocation to accommodate proposed design elements?	
☐	☐	☐	2. Does the plan identify existing valves and proposed values and number of services impacted by shutdown?	
☐	☐	☐	3. Did design identify need for water by-pass plan?	
☐	☐	☐	4. Are noted water main relocation and/or placement in conformance with PWSB standards?	
☐	☐	☐	5. Does the design report include PWSB design checklist as an attachment?	
☐	☐	☐	6. Are pipe material and valve type identified and consistent with PWSB?	

Yes	No	N/A	Sewer	Comments
☐	☐	☐	1. The manhole diameter is adequate for the number, diameter, and angle of pipes entering and leaving?	
☐	☐	☐	2. A minimum of 10' horizontal separation is maintained between sewer lines; between sewer lines and water lines; and between sewer lines and storm drainage structures, where possible.	
☐	☐	☐	3. If water and sewer lines cross perpendicular, is joint spacing maximized from the crossing location?	
☐	☐	☐	4. All sewers are labeled with size, grade, length, direction of flow, and type and class of pipes?	
☐	☐	☐	5. All manholes are labeled with rim and invert elevations; coordinates; and/or locations, size and inverts of drop pipes?	
☐	☐	☐	6. Drops of at least 0.1' included in all manholes to comply with RIDEM criteria?	
☐	☐	☐	7. Verify Minimum slopes meet TR-16 criteria.	
☐	☐	☐	8. Avoid siphons where possible. If required, are pig launching and flushing connections provided in access manholes?	
☐	☐	☐	9. Velocities greater than 10 fps should be avoided, unless special provisions have been made for erosion.	

Yes	No	N/A	Storm Drain Design	Comments
☐	☐	☐	1. Catch basin connector laterals are profiled, where necessary?	
☐	☐	☐	2. The pipe material, size, and slope shown?	
☐	☐	☐	3. Are grates or trash racks at inlets and access barriers (outlet end) shown on exposed ends of all drains 18” or greater?	
☐	☐	☐	4. Have utility conflicts been resolved on catch basin laterals?	
☐	☐	☐	5. Manholes have been designed such that changes in pipe size match crown elevations?	
☐	☐	☐	6. Specific requirements such as hoods, deep sumps, etc. are incorporated.	
☐	☐	☐	7. If building disconnections are included, are they sufficiently detailed?	

Yes	No	N/A	CSO Consolidation Design	Comments
☐	☐	☐	1. Does the hydraulic capacity meet the defined hydraulic criteria based on model results (i.e. peak flow, maximum velocity)?	
☐	☐	☐	2. Does the HGL meet the defined level of service?	
☐	☐	☐	3. All crossings with other utilities are shown and conflicts resolved?	
☐	☐	☐	4. Existing sewer connections to the property shown on drawings.	

Yes	No	N/A	GSI Design	Comments
☐	☐	☐	1. Does the design comply with RIDEM SW Design Manual?	
☐	☐	☐	2. Does maximum capture volume and promote infiltration?	
☐	☐	☐	3. Drainage maps completed with pre- and post-development sub-areas delineated?	
☐	☐	☐	4. Details meet RIDEM standards?	
☐	☐	☐	5. Basis of design identifies capture volume and reduction of volume for 3-month storm.	
☐	☐	☐	6. Design incorporates features to minimize maintenance and use native plantings.	
☐	☐	☐	7. Minimum velocity in a drain is 2 fps.	

Other Specific Issues or Concerns of the PM:

Yes	No	N/A		Comments
☐	☐	☐	1. Direct Manager (PM/CM) recommends proceeding to technical review meeting.	
☐	☐	☐	2. Did the DC submit the necessary inputs to facilitate technical review meeting?	
☐	☐	☐		
☐	☐	☐		
☐	☐	☐		
☐	☐	☐		

Yes	No		Date
☐	☐	**1. Design Consultant Authorized to Advance to Next Stage of Design?** **(If DC is Conditionally Authorized to Advance the Design, Attach a Summary of these Conditions to this Checklist)**	

90% Design Project Checklist

Project Name:

Construction Package:

Project Manager (PM/CM): **Date Completed:**

Planning/Design Manager Approval (PM/CM): **Date Approved:**

Chief Engineer/Program PTL Approval (PM/CM): **Date Approved:**

90% Submittal Date: **90% Milestone Date:**

Purpose: 90% design should consist of a substantially complete design of all project elements that meets all required project criteria. The deliverable should communicate a complete project to allow a complete PM/CM, NBC, utility, municipal, and permitting review. The 90% design documents shall be suitable for final permitting and to identify final revisions required prior to initiating construction. It should also be used to confirm that the anticipated project cost meets the budgeted amount.

The 90% design shall include:

- alignment and profile,
- location of all structures,
- resolution of utility conflicts,
- final temporary/permanent easements and property acquisitions,
- proposed utility relocations,
- temporary SOE design,
- construction dewatering,
- construction methodology, and
- construction sequence.

The 90% design deliverable shall include:

- 90% Design Drawings and Specifications,
- Final Basis of Design Report,
- OPCC, consistent with Program standards,
- Project schedule (final design and construction)
- Requirements for temporary SOE design,
- Requirements for construction dewatering, pretreatment, and discharge system design

Items presented in this checklist are a compilation of industry-standard design criteria, specific design criteria and general lessons learned from previously constructed projects. This list is not intended to be all inclusive. Project Manager and Technical Lead shall review each item listed in this checklist and indicate whether or not the item has been addressed in the 90% submittal, or if it is not applicable. For every item not addressed, a comment shall be provided. All items not addressed shall be addressed in the Final Design Documents.

A completed ***90% Design Project Checklist*** shall be required prior to scheduling a Technical Review Meeting.

Yes	No	N/A	General and Project Management	Comments
☐	☐	☐	1. Have updates to design criteria, 90% design, OPCC, and schedule been prepared based on current project stage?	
☐	☐	☐	2. Have design coordination meetings conducted with RIDEM, RIDOT, municipalities, and other agencies as required?	
☐	☐	☐	3. Were standard details used where applicable?	
☐	☐	☐	4. Has a list of project stakeholders for future outreach and traffic management been prepared, and contact information included?	
☐	☐	☐	5. Has Design-Build team performed a site walk to confirm accuracy and confirm changes from 30% Design, RFP, and accepted Proposal?	
☐	☐	☐	6. Have temporary/permanent easement plans been prepared?	
☐	☐	☐	7. If appropriate, have the plans have been distributed for peer review and/or value engineering?	
☐	☐	☐	8. If structure inspections are included, are they complete and has a draft summary report been submitted?	
☐	☐	☐	9. Does the drawing set include a Phase III program standard cover sheet; index sheet; general notes, abbreviations, and legend sheet as appropriate? Does it comply Program CAD Standards?	
☐	☐	☐	10. Does the design documentation include a project specific checklist developed by the Design-Build team? Does the design include cross-discipline review?	
☐	☐	☐	11. Has private property restoration been identified and clearly defined including driveway repaving?	
☐	☐	☐	12. Does the submission include applicable technical specifications?	
☐	☐	☐	13. Have project specific milestones been developed?	
☐	☐	☐	14. Has 90% QA/QC statement been provided by Design-Build team?	
☐	☐	☐	15. Has Pawtucket Tunnel design been coordinated with design of Pump Station Fit-Out and applicable near surface facilities?	
☐	☐	☐	16. Has a Construction Packaging Plan been prepared?	
☐	☐	☐	17. Has design incorporated risk mitigation strategies and VE proposals?	

Yes	No	N/A	Drawing Layouts/ Data Collection/Survey Coordination	Comments
☐	☐	☐	1. Has required clearing and grubbing been shown and limits defined?	
☐	☐	☐	2. Proposed and existing ground elevations shown on plans/profiles?	
☐	☐	☐	3. Is site restoration of all disturbed areas delineated on drawings?	
☐	☐	☐	4. Are paving limits, where applicable, delineated on drawings?	
☐	☐	☐	5. Does drawing set delineate required erosion and sediment control details and notes?	
☐	☐	☐	6. Accuracy of surface features/structures checked via site walks?	
☐	☐	☐	7. Benchmark(s) identified on the site plan and located at each work shaft and drop shaft site.	
☐	☐	☐	8. All rights-of-way, property lines, and easements shown (source of data noted?	
☐	☐	☐	9. All flood plains, edge of wetlands, buffer zones and setbacks shown?	
☐	☐	☐	10. Have highway and railroad rights-of-way been identified? Requirements for coordination in advance of construction to be identified.	
☐	☐	☐	11. Lawn or kept areas, trees and shrubs are shown (size and type)?	
☐	☐	☐	12. All underground utilities and structures, ducts, overhead wires, and service connections shown?	
☐	☐	☐	13. Location of existing houses (plat/lot, ownership name), buildings, fences, walls, signs, poles, mailboxes, and structures shown?	
☐	☐	☐	14. Has the Design-Build team completed a field walk through along the alignment and documented field notes and photos?	
☐	☐	☐	15. Are construction staging and stockpile areas shown on drawings?	
☐	☐	☐	16. Have required temporary construction facilities been identified and are they shown on design drawings?	

Yes	No	N/A	Basis of Design	Comments
☐	☐	☐	1. Does the hydraulic capacity meet the defined hydraulic criteria based on model results (i.e. peak flow, maximum velocity)?	
☐	☐	☐	2. Does the HGL meet the defined level of service?	
☐	☐	☐	3. Have construction methodology considerations (e.g., impacts to existing structures and mitigation, loading conditions, initial excavation support, groundwater control) been identified and incorporated into 90% design?	
☐	☐	☐	4. Has tunnel boring machine availability been confirmed?	
☐	☐	☐	5. Has tunnel segmental lining design been incorporated into 90% design?	
☐	☐	☐	6. Has a permanent drainage system and waterproofing requirements for pump station shaft been designed?	
☐	☐	☐	7. Have adits, vent shafts, de-aeration chambers been designed?	
☐	☐	☐	8. Have initial and permanent structural support systems been identified for drop shafts, work shafts, and pump station shaft?	
☐	☐	☐	9. Has the potential need for pre-excavation grouting been identified and incorporated into 90% design?	
☐	☐	☐	10. Are groundwater dewatering discharge requirements (e.g., pretreatment requirements, disposal outlet, etc.) established and required permits identified?	
☐	☐	☐	11. Have the results of CFD modeling and physical modeling of OF-218 facilities been incorporated into 30% design?	

Yes	No	N/A	Utility Coordination	Comments
☐	☐	☐	1. Have all known utility conflicts been identified and are utility relocations proposed?	
☐	☐	☐	2. Have duct bank dimensions been verified through test pits and/or confirmation by utilities?	
☐	☐	☐	3. All existing fire hydrants and valve locations shown and verified?	
☐	☐	☐	4. Water mains of any size crossing other utilities are profiled, conflicts resolved?	
☐	☐	☐	5. Have any SUE investigation been conducted? Are the results shown on the drawings?	
☐	☐	☐	6. Have City/Town records been checked to locate the presence of underdrains?	
☐	☐	☐	7. Have all overhead conflicts been identified during site walks?	
☐	☐	☐	8. Have all the dimensions and shape (egg, oval, cradle, etc.) of all large diameter and crossing sewers and drains been verified?	
☐	☐	☐	9. Design coordination meetings conducted with Utilities when needed. Have progress plans been submitted to utilities (list at bottom of checklist)?	

Yes	No	N/A	Soils/Groundwater/ Erosion Control	Comments
☐	☐	☐	1. Supplemental soil borings and monitoring wells complete?	
☐	☐	☐	2. Where refusal is encountered above final excavation depth, have rock cores been taken and has rock been profiled and characterized? Has geotechnical engineer confirmed adequacy of spacing?	
☐	☐	☐	3. Has a draft soils management plan been incorporated into the design drawings and specifications? Have regulated/impacted soils been identified during the environmental investigation?	
☐	☐	☐	4. Does the design include temporary SOE, construction dewatering, construction sequence, and geotechnical instrumentation?	
☐	☐	☐	5. Do drawings conform to RIDEM erosion control and sedimentation regulations?	
☐	☐	☐	6. Erosion and sediment control devices shown and details included?	
☐	☐	☐	7. Have groundwater levels been determined and accounted for in design and construction impacts?	
☐	☐	☐	8. Have water levels been monitored in monitoring wells?	
☐	☐	☐	9. Has the soil and rock disposal methods and receiving facilities been defined?	
☐	☐	☐	10. Have the borings and monitoring wells been shown on the plans and profiles, including supplemental borings and monitoring wells?	

Yes	No	N/A	Permitting	Comments
☐	☐	☐	1. Local and State permit/approval applications prepared (as needed).	
☐	☐	☐	a. CRMC	
☐	☐	☐	b. State Fire Marshal – Blasting	
☐	☐	☐	c. RIDEM Order of Approval	
☐	☐	☐	d. RIPDES permit for stormwater management	
			e. RIPDES for construction dewatering (if required)	
☐	☐	☐	f. National Grid	

Yes	No	N/A	Roadway and Traffic Management	Comments
☐	☐	☐	1. Have required pavement and sub-base thicknesses been identified based on existing conditions?	
☐	☐	☐	2. Are haul routes and traffic management requirements incorporated into drawings? Have major traffic concerns been identified?	
☐	☐	☐	3. Have anticipated paving schedules been coordinated with City/Town?	
☐	☐	☐	4. Have state highways been identified?	
☐	☐	☐	5. Has a note been added stating that Contractor is required to obtain permits from RIDOT prior to start of work?	

Yes	No	N/A	Water Main Design	Comments
☐	☐	☐	1. Did 90% design drawings identify need for water main relocation to accommodate proposed design elements?	
☐	☐	☐	2. Does the plan identify existing valves and proposed values and number of services impacted by shutdown?	
☐	☐	☐	3. Did design identify need for water by-pass plan?	
☐	☐	☐	4. Are noted water main relocation and/or placement in conformance with PWSB standards?	
☐	☐	☐	5. Does the design report include PWSB design checklist as an attachment?	
☐	☐	☐	6. Are pipe material and valve type identified and consistent with PWSB?	

Other Specific Issues or Concerns of the PM:

Yes	No	N/A		Comments
☐	☐	☐	1. Direct Manager (PM/CM) recommends proceeding to technical review meeting.	
☐	☐	☐	2. Did the Design-Build team submit the necessary inputs to facilitate technical review meeting?	
☐	☐	☐	3. Is the design ready to proceed to final design?	
☐	☐	☐	4. Has the Design-Build team provided QMP documentation?	
☐	☐	☐	5. Are there any outstanding design issues that need to be resolved prior to proceeding to final design and start of construction?	
☐	☐	☐		

Yes	No		Date
☐	☐	**1. Design Consultant Authorized to Advance to Next Stage of Design?** **(If DC is Conditionally Authorized to Advance the Design, Attach a Summary of these Conditions to this Checklist)**	

Phase III CSO Program

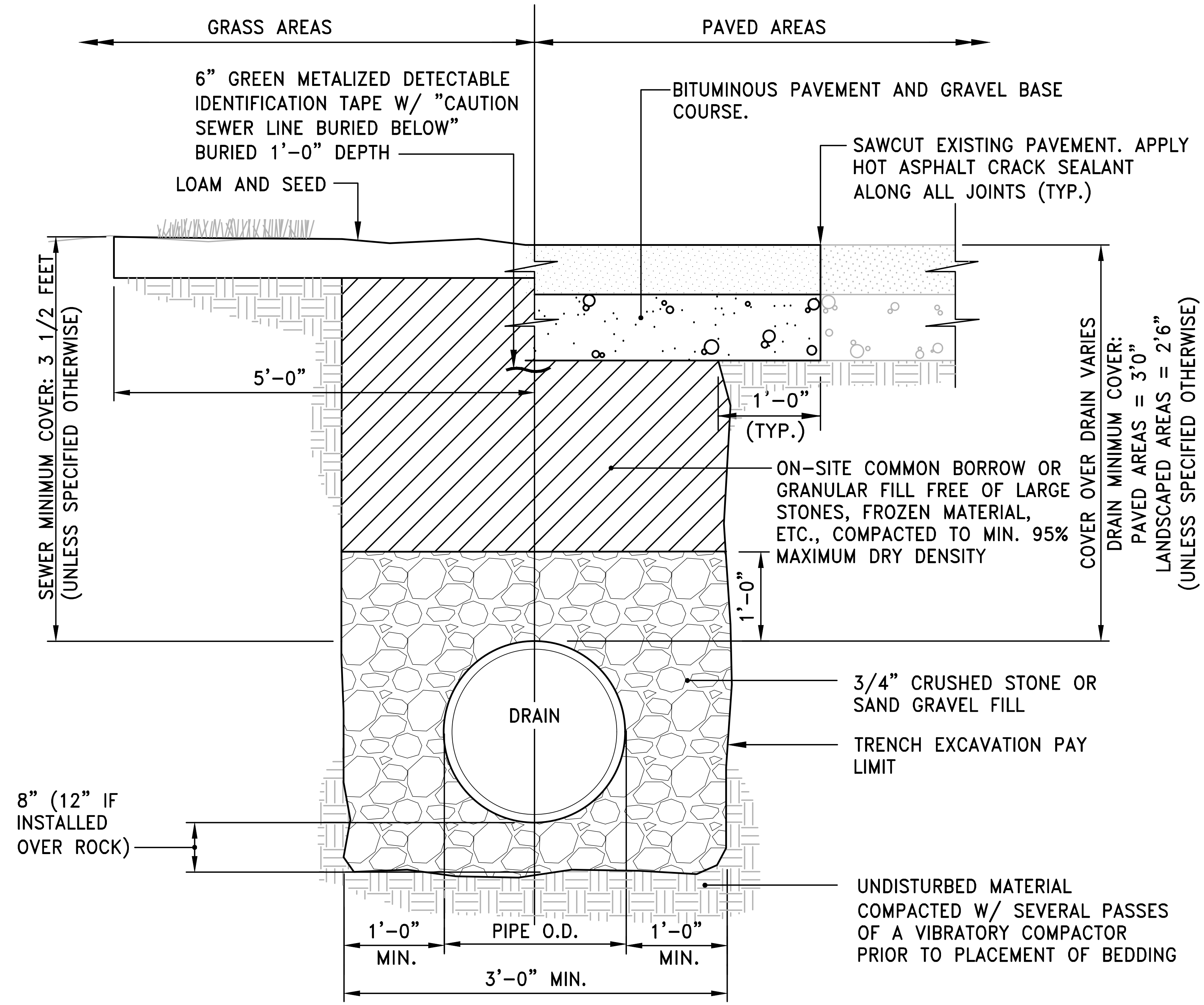
PROJECT SUMMARY FORM

Project Name & Number:
Outfalls Addressed:
Design Consultant:
Date of Submission:
Design Stage:

Project Summary
(Enter description here)
Changes since Project Conception/Phase III CSO Program Reevaluation
•   •   •
Has Design Changed to Require a New Environmental Assessment?
Yes ☐ **No** ☐   **If yes, please provide comment below.**
Is Work Proposed within RIDEM or CRMC Regulated Wetlands or Coastal Zones?
Yes ☐ **No** ☐   **If yes, please provide comment below.**

Is Work Proposed within FEMA-mapped Floodplains?
Yes ☐ No ☐ **If yes, please provide comment below.**
Does Design Comply with State Requirements for Resiliency (RIDEM, CRMC)?
Yes ☐ No ☐ **If yes, please provide comment below.**
Does Design Comply with TR-16?
Yes ☐ No ☐ **If yes, please provide comment below.**
Anticipated Design/Construction Schedule?
Final Design Completion Date: **Construction Start Date:** **Construction Completion Date:**

Appendix E – Standard Program Details



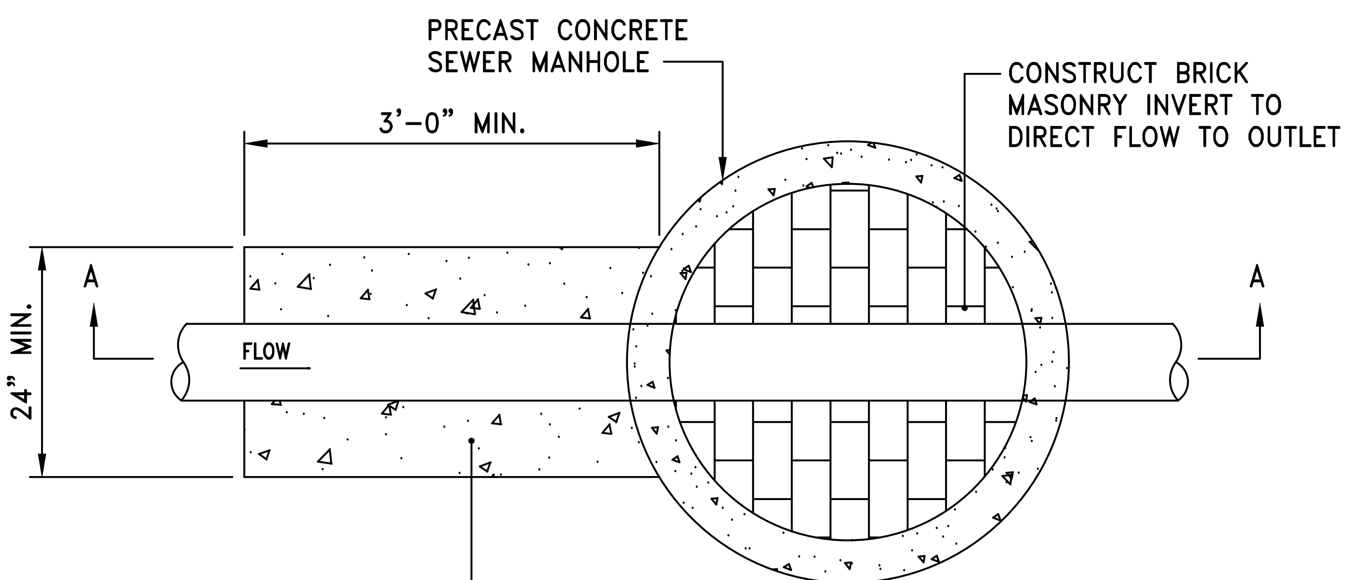
NOTES:

1. WHERE THE DISTANCE BETWEEN THE SAWCUT AND EDGE OF PAVEMENT IS 3' OR LESS, THE CONTRACTOR SHALL REPLACE THE PAVEMENT FROM THE TRENCH EDGE TO THE EXISTING EDGE OF PAVEMENT.

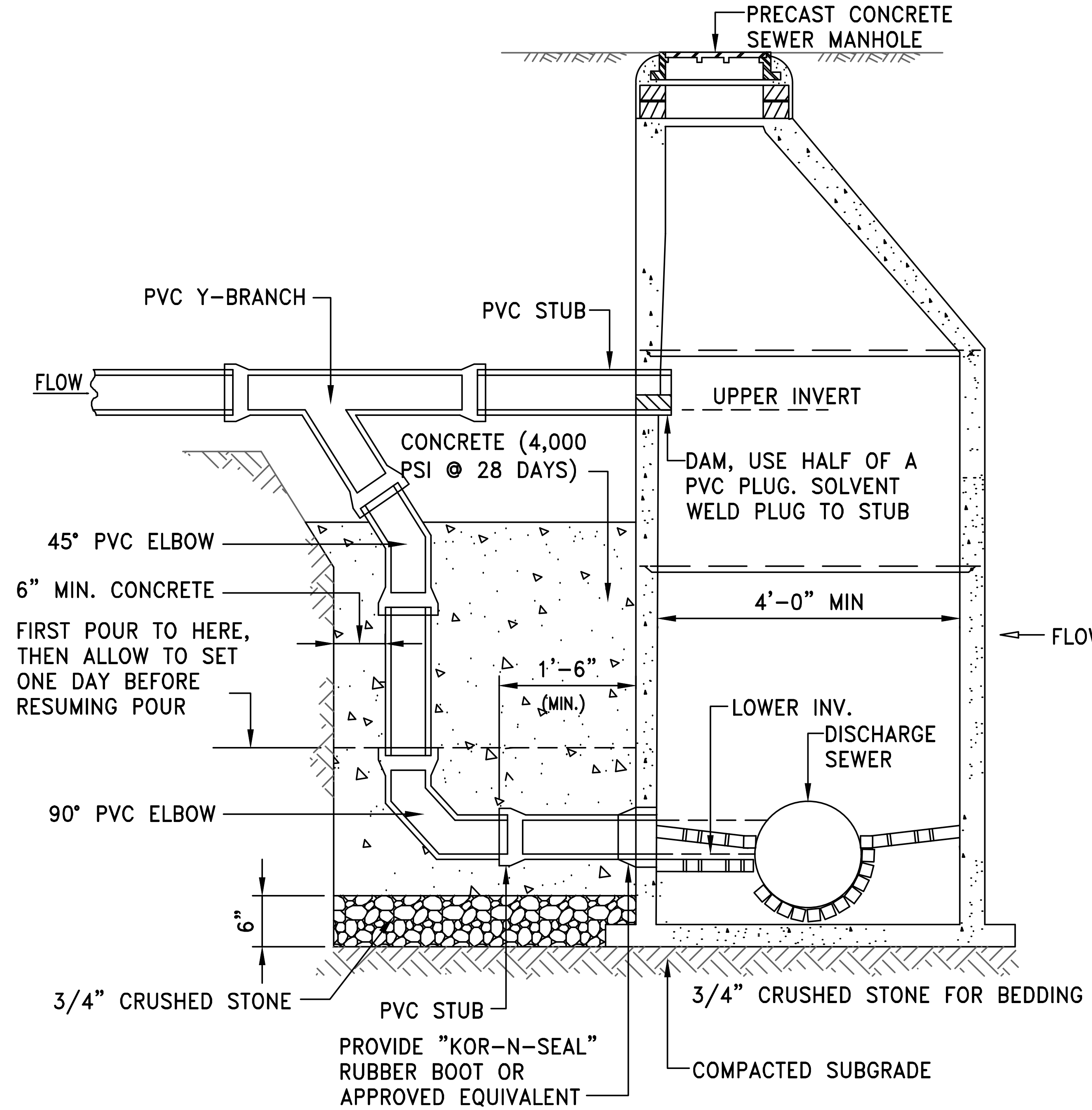
2. 3/4" DIA. CRUSHED STONE SHALL BE USED AS BEDDING WHERE TRENCH IS BELOW THE GROUND WATER TABLE.

DRAIN/SEWER TRENCH DETAIL

NOT TO SCALE



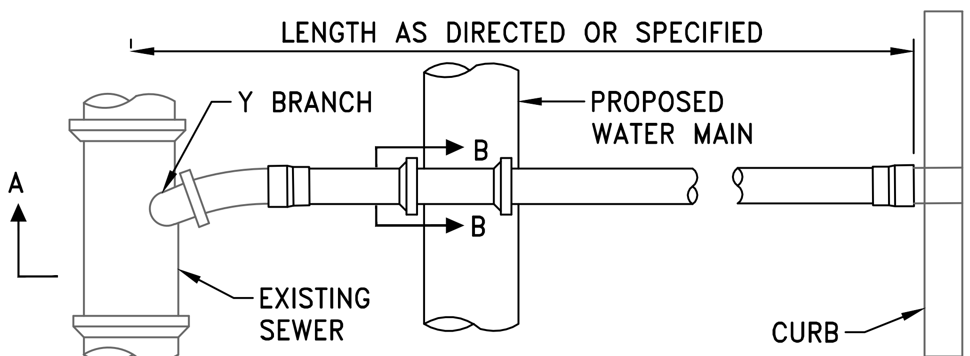
PLAN



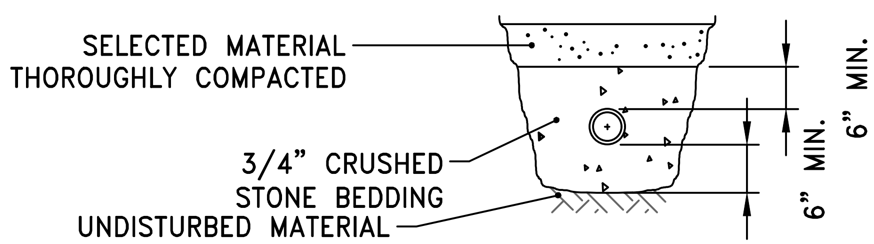
SECTION A-A

PROPOSED EXTERIOR DROP MANHOLE DETAIL

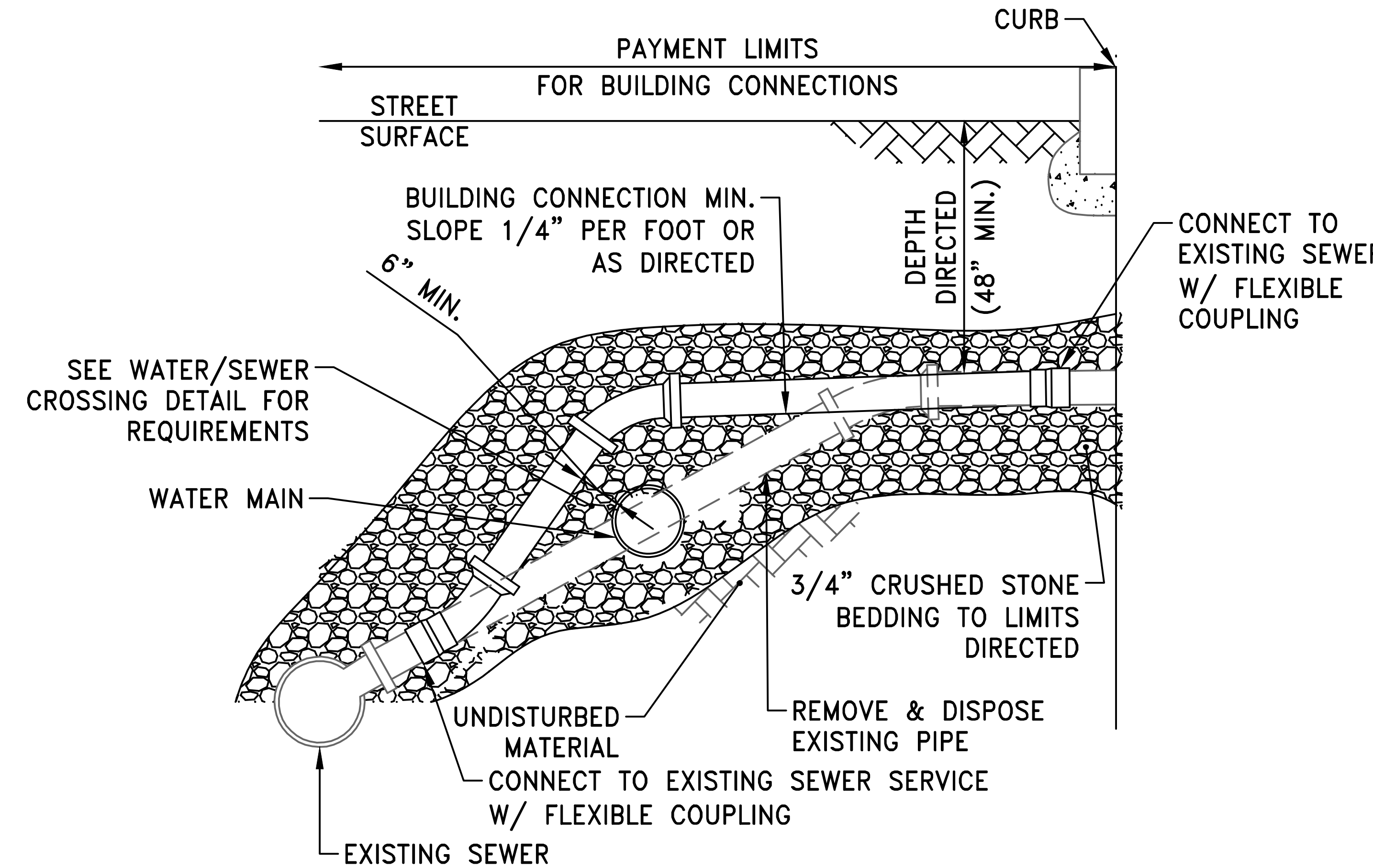
NOT TO SCALE



PLAN



SECTION B-B



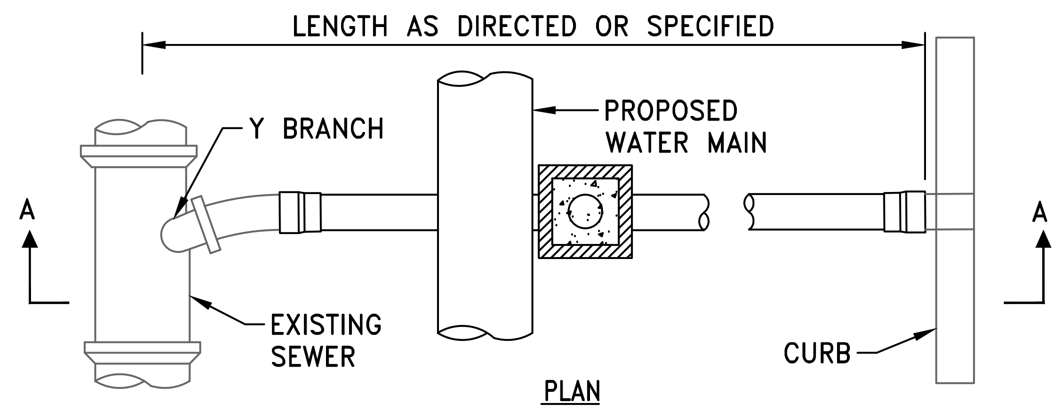
SECTION A-A

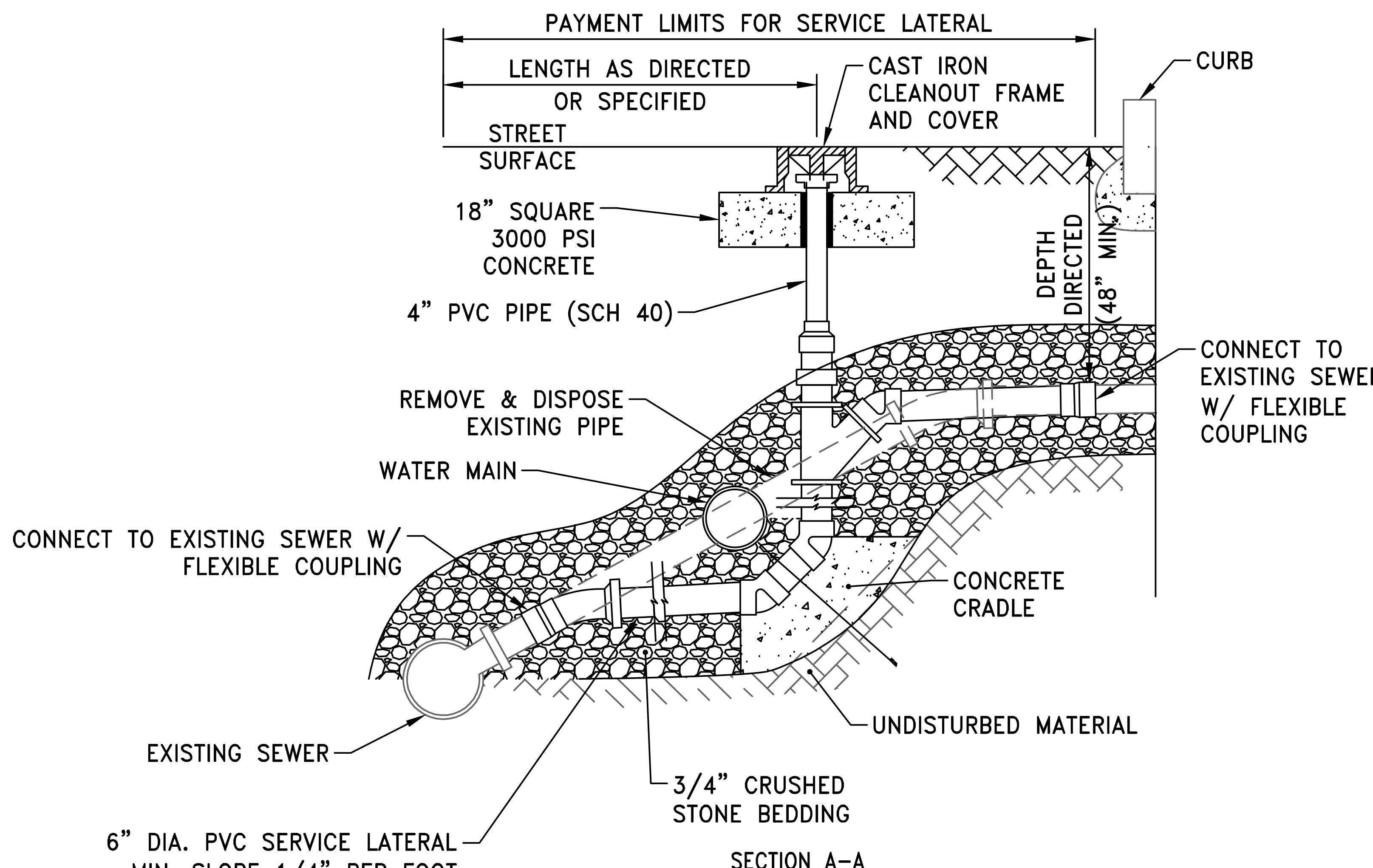
NOTES:

1. SEWER LATERAL SHALL ONLY BE INSTALLED OVER PROPOSED WATER IN CASES WHERE THE EXISTING SEWER MAIN HAS LESS COVER THAN THE PROPOSED WATER MAIN. DETAIL IS DRAWN SCHEMATICALLY.
2. INSTALL SLEEVE AND CONTROLLED DENSITY FILL AS DIRECTED OR AS REQUIRED PER WATER/SEWER CROSING DETAIL

GRAVITY SEWER SERVICE RELAY
(DEPTH OF SEWER MAIN<DEPTH OF WATER MAIN)

NOT TO SCALE

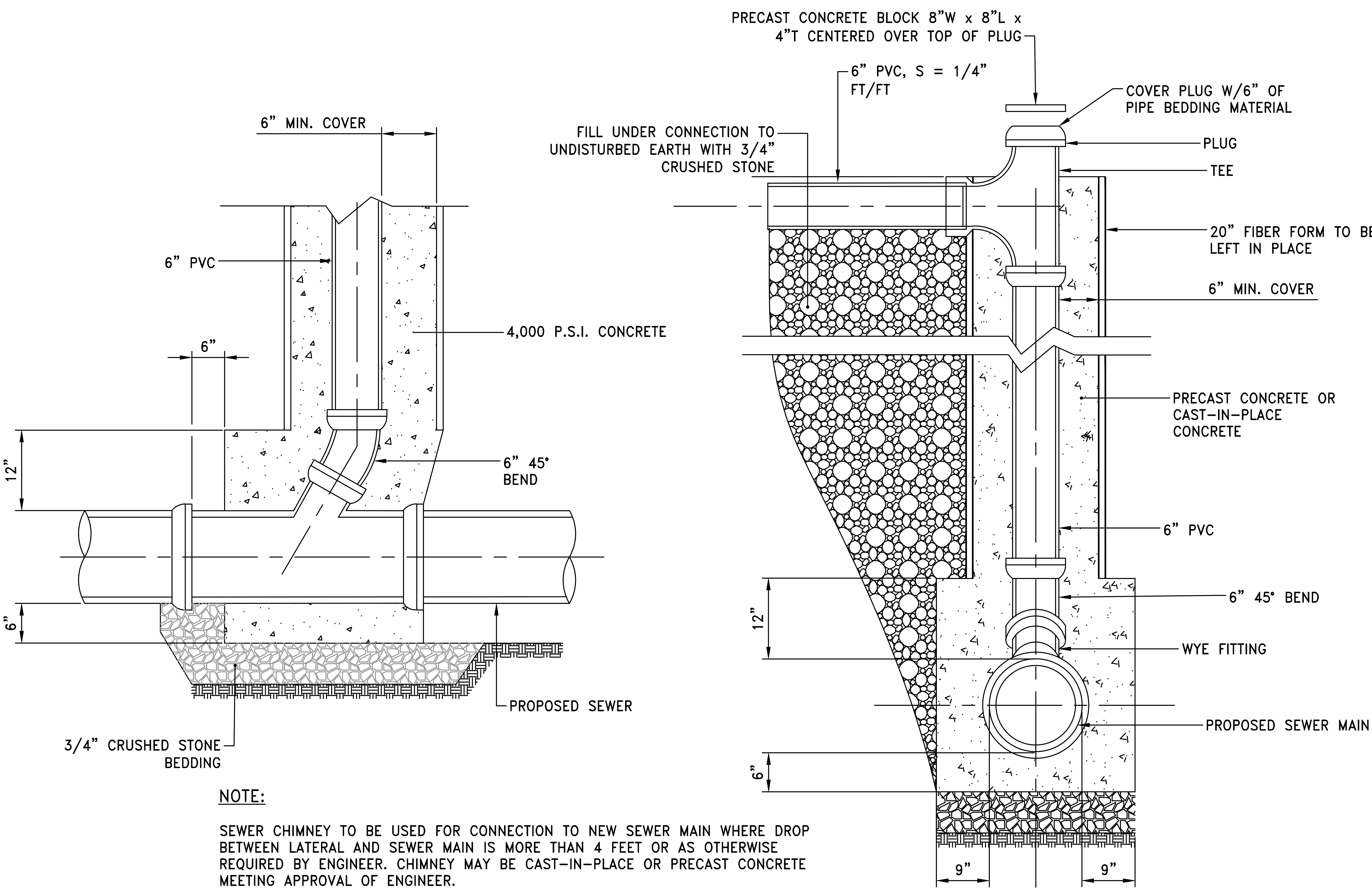




NOTES:

1. CLEANOUT COVER SHALL BE GENECO PRODUCTS CAST IRON FRAME AND COVER FOR 6" CLEANOUTS OR APPROVED EQUAL.
2. THE WORD "SEWER" SHALL BE CAST IN THE TOP OF THE CLEANOUT COVER.

GRAVITY SEWER SERVICE RELAY
(DEPTH OF SEWER MAIN>DEPTH OF WATER MAIN)
NOT TO SCALE

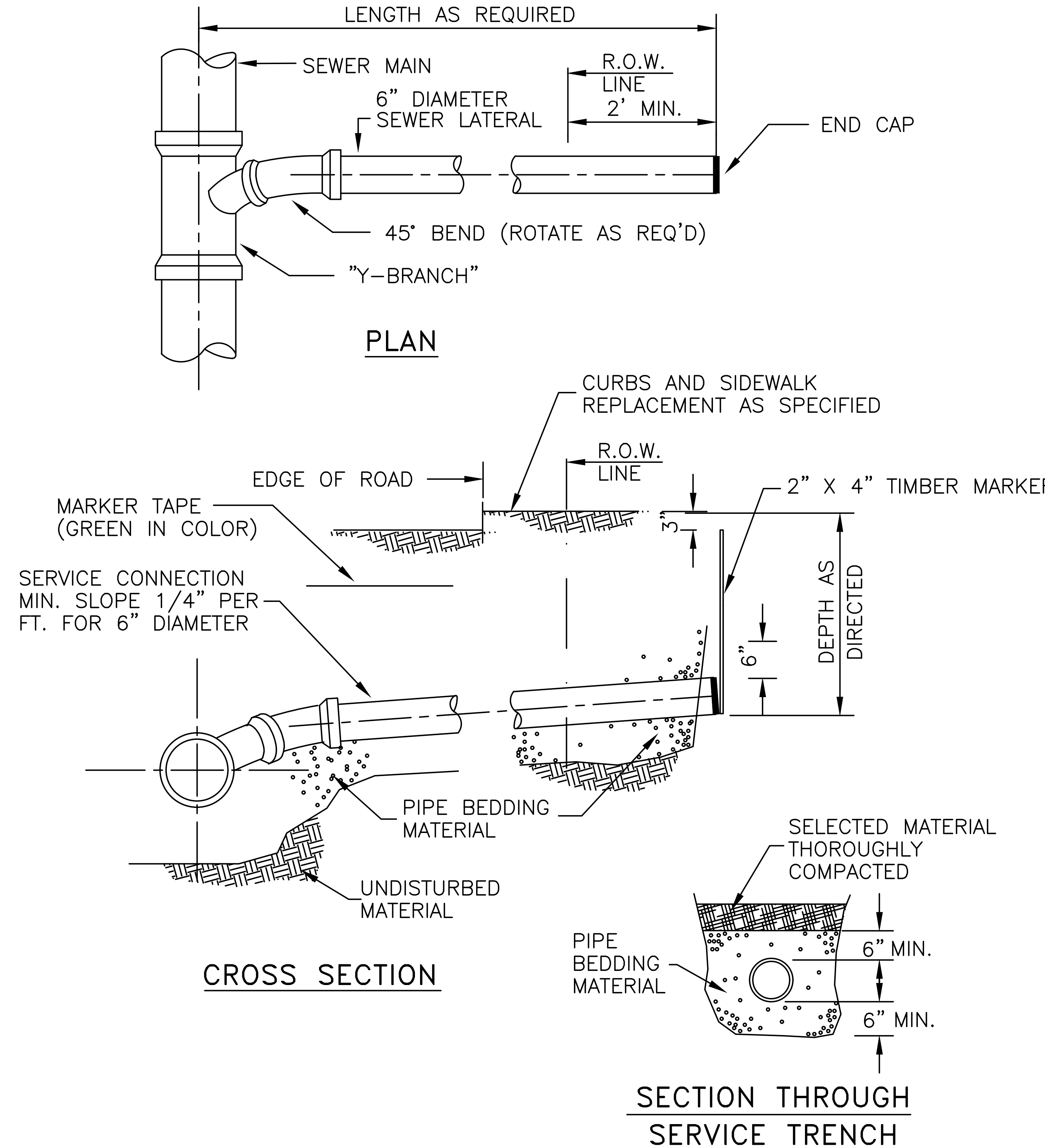


NOTE:

SEWER CHIMNEY TO BE USED FOR CONNECTION TO NEW SEWER MAIN WHERE DROP BETWEEN LATERAL AND SEWER MAIN IS MORE THAN 4 FEET OR AS OTHERWISE REQUIRED BY ENGINEER. CHIMNEY MAY BE CAST-IN-PLACE OR PRECAST CONCRETE MEETING APPROVAL OF ENGINEER.

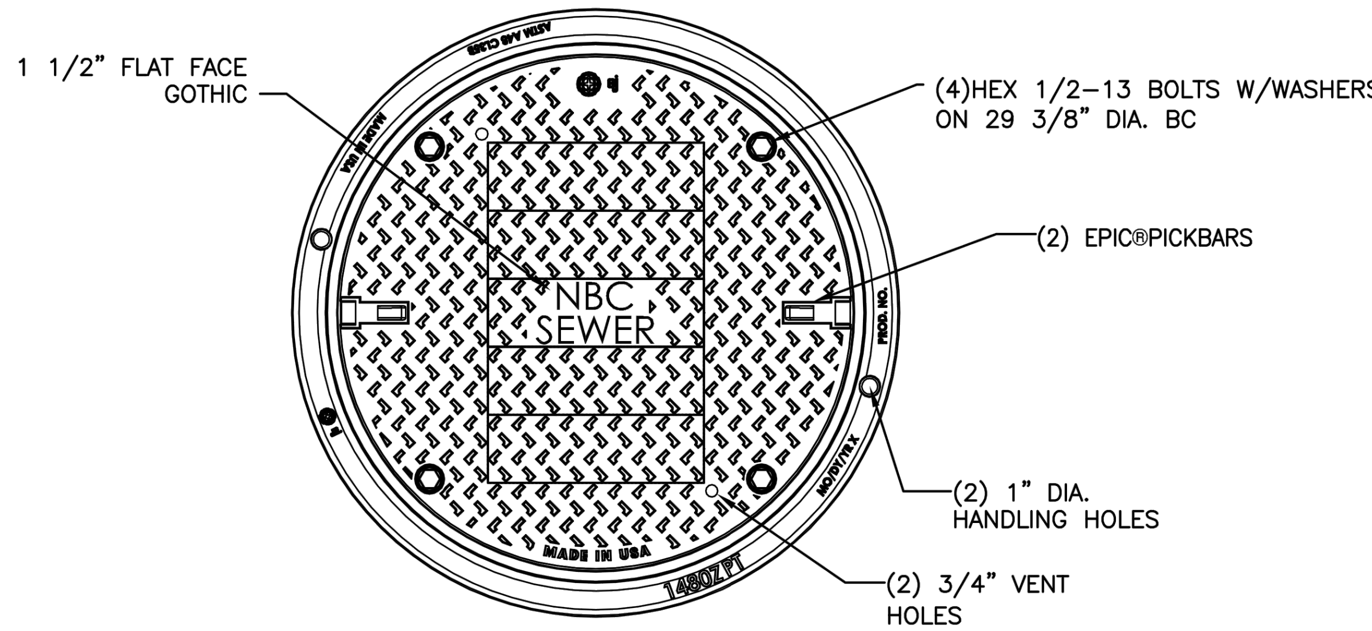
TYPICAL SEWER CHIMNEY DETAIL

NOT TO SCALE

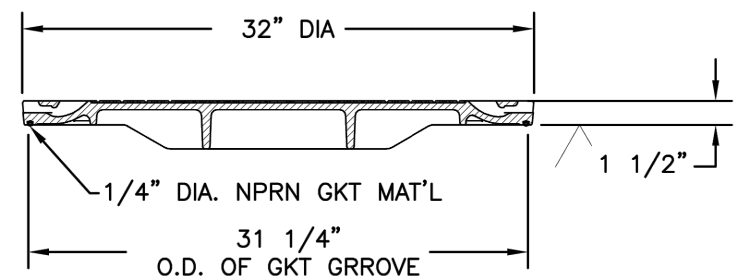


TYPICAL SEWER LATERAL CONNECTION DETAIL

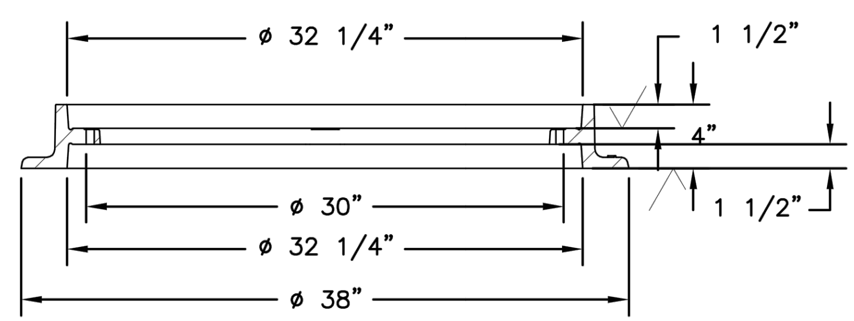
NOT TO SCALE



PLAN VIEW



SECTION



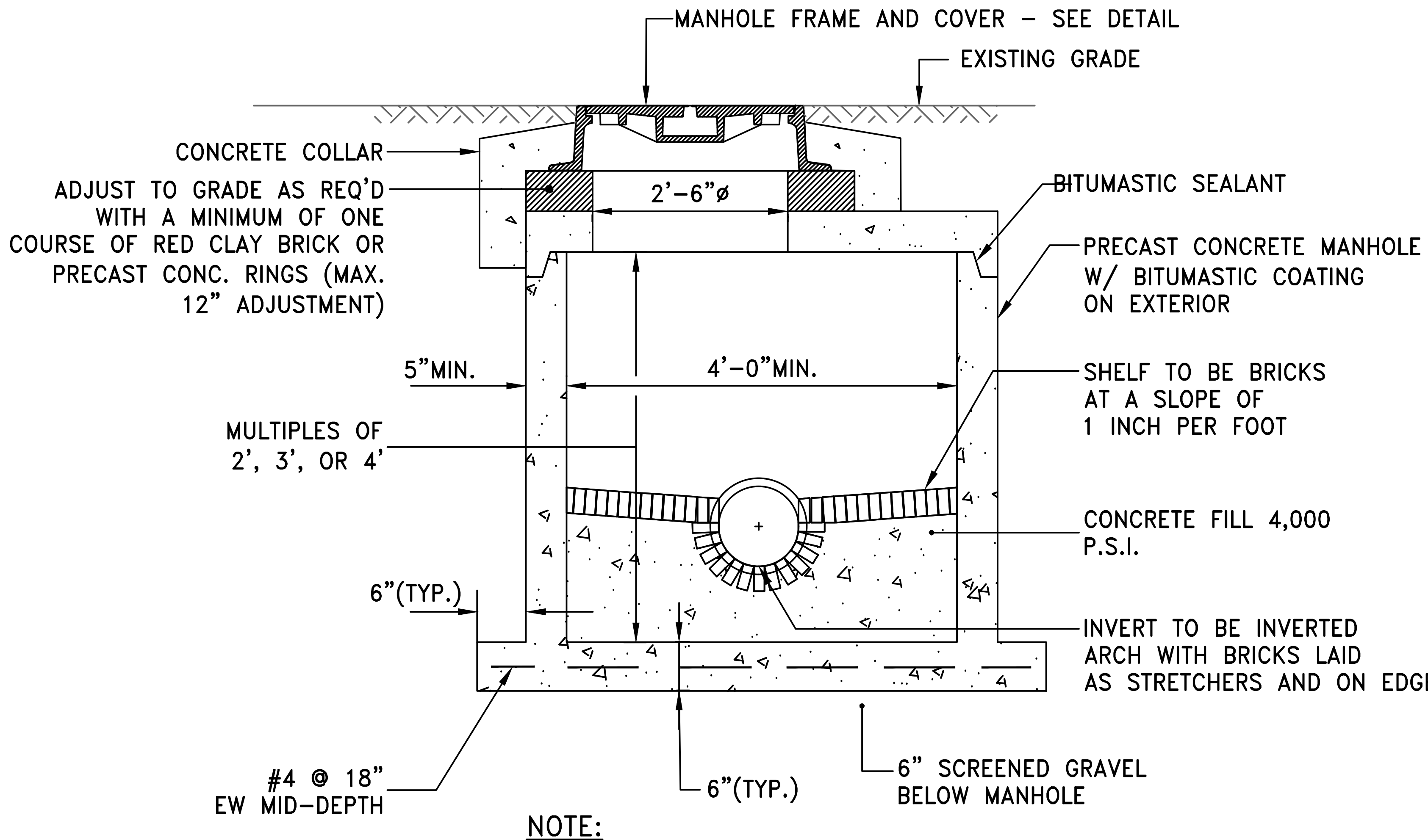
SECTION

NOTE:

EAST JORDAN IRON WORKS HEAVY DUTY MANHOLE FRAME AND COVER (PRODUCT # 00149577B02), OR APPROVED EQUIVALENT.

MANHOLE FRAME & COVER DETAIL

NOT TO SCALE

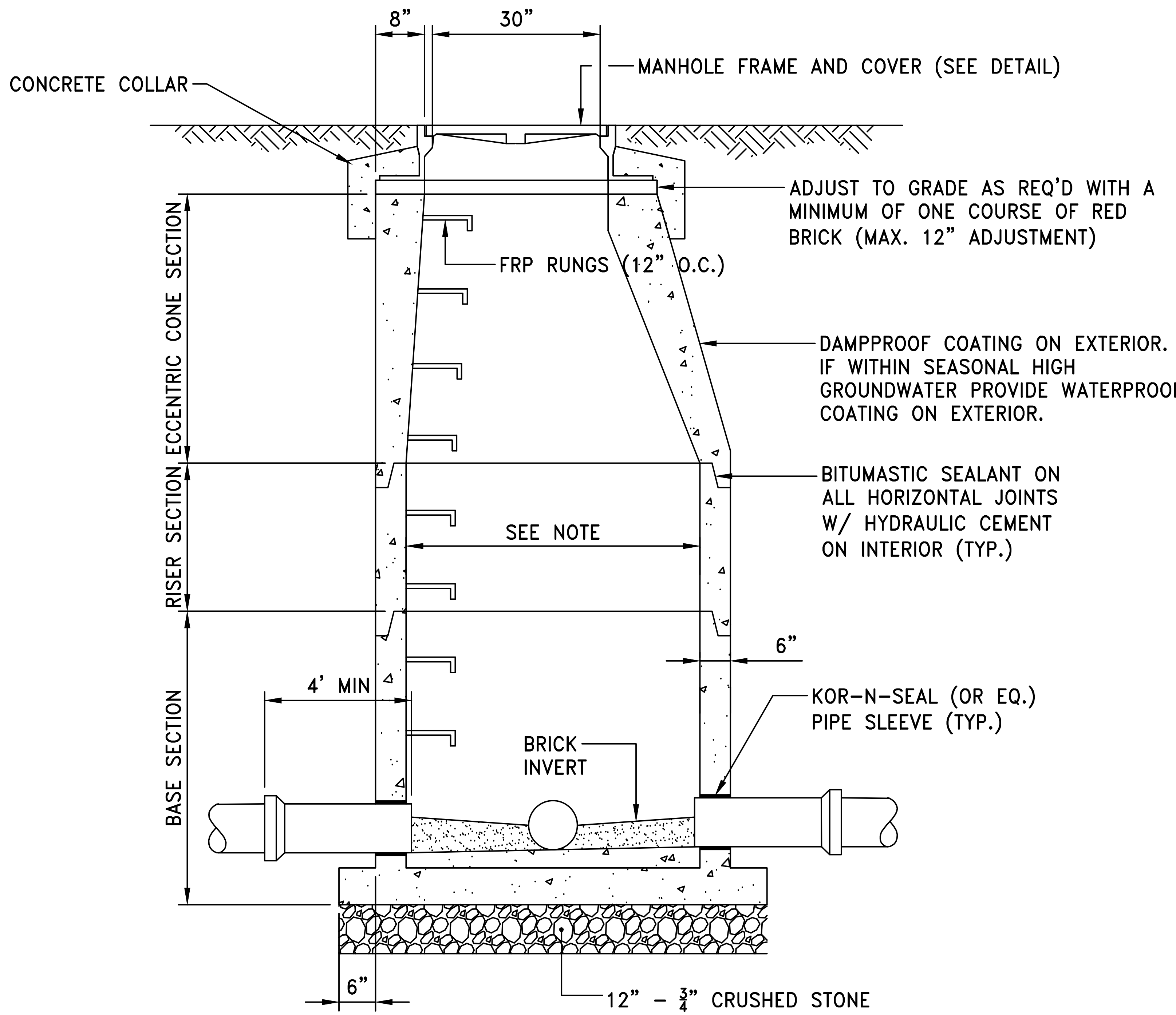


NOTE:

SHALLOW PRECAST CONCRETE MANHOLE TO BE USED WHERE DEPTH TO INVERT DOES NOT PERMIT USE OF STANDARD BASE AND CONE SECTIONS.

SHALLOW MANHOLE DETAIL

NOT TO SCALE



NOTE:

SEWER MANHOLES SHALL HAVE 4' MINIMUM INSIDE DIAMETER AND BE H-20 RATED.

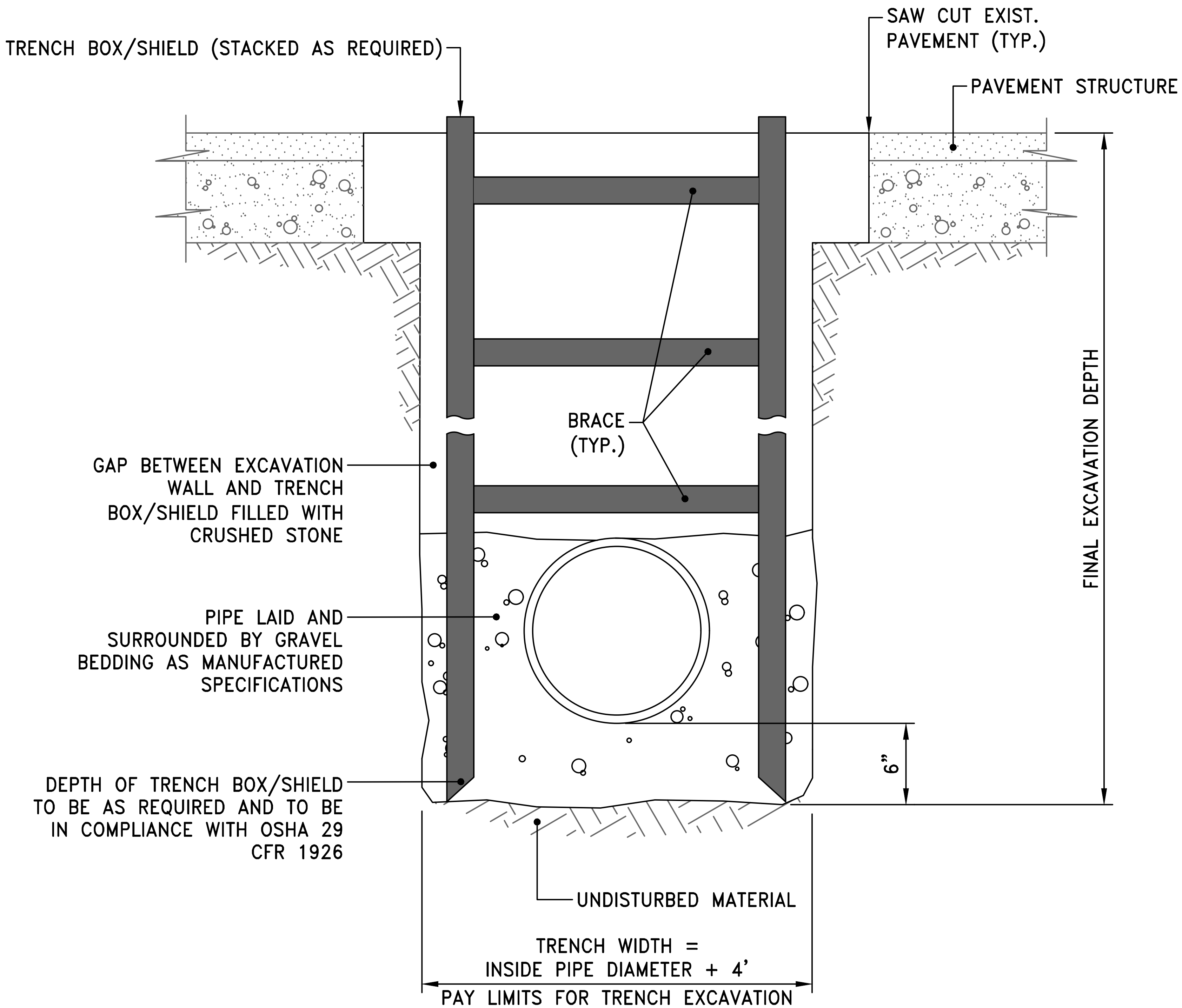
GRAVITY SEWER MANHOLE

NOT TO SCALE

MINIMUM RESTRAINED PIPE LENGTHS FOR RESTRAINED JOINTS	
FITTING	FEET OF PIPE REQUIRING RESTRAINT
6" 22° BEND	2 FEET PLUS ONE JOINT ON BOTH SIDES OF BEND
6" 45° BEND	4 FEET PLUS ONE JOINT ON BOTH SIDES OF BEND
6" BRANCH ON TEE	18 FEET PLUS ONE JOINT ON TEE BRANCH
6" DEAD END	18 FEET PLUS ONE JOINT
8" X 6" REDUCER	10 FEET PLUS ONE JOINT ON THE 8" SIDE
8" 22° BEND	2 FEET PLUS ONE JOINT ON BOTH SIDES OF BEND
8" 45° BEND	4 FEET PLUS ONE JOINT ON BOTH SIDES OF BEND
8" BRANCH ON TEE	23 FEET PLUS ONE JOINT ON TEE BRANCH
8" DEAD END	23 FEET PLUS ONE JOINT
12" X 8" REDUCER	19 FEET PLUS ONE JOINT ON THE 8" SIDE
12" 22° BEND	3 FEET PLUS ONE JOINT ON BOTH SIDES OF BEND
12" 45° BEND	6 FEET PLUS ONE JOINT ON BOTH SIDES OF BEND
12" 90° BEND	14 FEET PLUS ONE JOINT ON BOTH SIDES OF BEND
12" BRANCH ON TEE	33 FEET PLUS ONE JOINT ON TEE BRANCH
12" DEAD END	33 FEET PLUS ONE JOINT
16" X 12" REDUCER	18 FEET PLUS ONE JOINT ON THE 8" SIDE
16" 22° BEND	4 FEET PLUS ONE JOINT ON BOTH SIDES OF BEND
16" 45° BEND	8 FEET PLUS ONE JOINT ON BOTH SIDES OF BEND
16" BRANCH ON TEE	43 FEET PLUS ONE JOINT ON TEE BRANCH
16" DEAD END	45 FEET PLUS ONE JOINT
20" X 16" REDUCER	19 FEET PLUS ONE JOINT ON THE 8" SIDE
20" 22° BEND	5 FEET PLUS ONE JOINT ON BOTH SIDES OF BEND
20" 45° BEND	9 FEET PLUS ONE JOINT ON BOTH SIDES OF BEND
20" BRANCH ON TEE	52 FEET PLUS ONE JOINT ON TEE BRANCH
20" DEAD END	150 FEET (POLY WRAP) OR 52 FEET (BARE), PLUS ONE JOINT
30" 22° BEND	6 FEET PLUS ONE JOINT ON BOTH SIDES OF BEND
30" 45° BEND	13 FEET PLUS ONE JOINT ON BOTH SIDES OF BEND
30" BRANCH ON TEE	74 FEET PLUS ONE JOINT ON TEE BRANCH
30" DEAD END	74 FEET PLUS ONE JOINT

NOTES:

1. RESTRAINED JOINTS SHALL BE MECHANICAL OR PUSH ON WITH FIELD LOCK GASKET. TIE RODS AND FRICTION CLAMPS SHALL ONLY BE USED WHEN APPROVED BY ENGINEER.
2. TABLE ASSUMES BARE DUCTILE IRON PIPE IN A TYPE 5 TRENCH TESTED AT 150 PSI, IF CONTRACTOR SHOULD INSTALL A DIFFERNT SYTLE TRENCH, POLY WRAP DUCTILE IRON, C-900 SLEEVE, ETC. CONTRACTOR SHALL RECEIVE DIRECTION FROM THE ENGINEER ON RESTRAINED LENGTHS.



SHORING PRESSURES TABLE

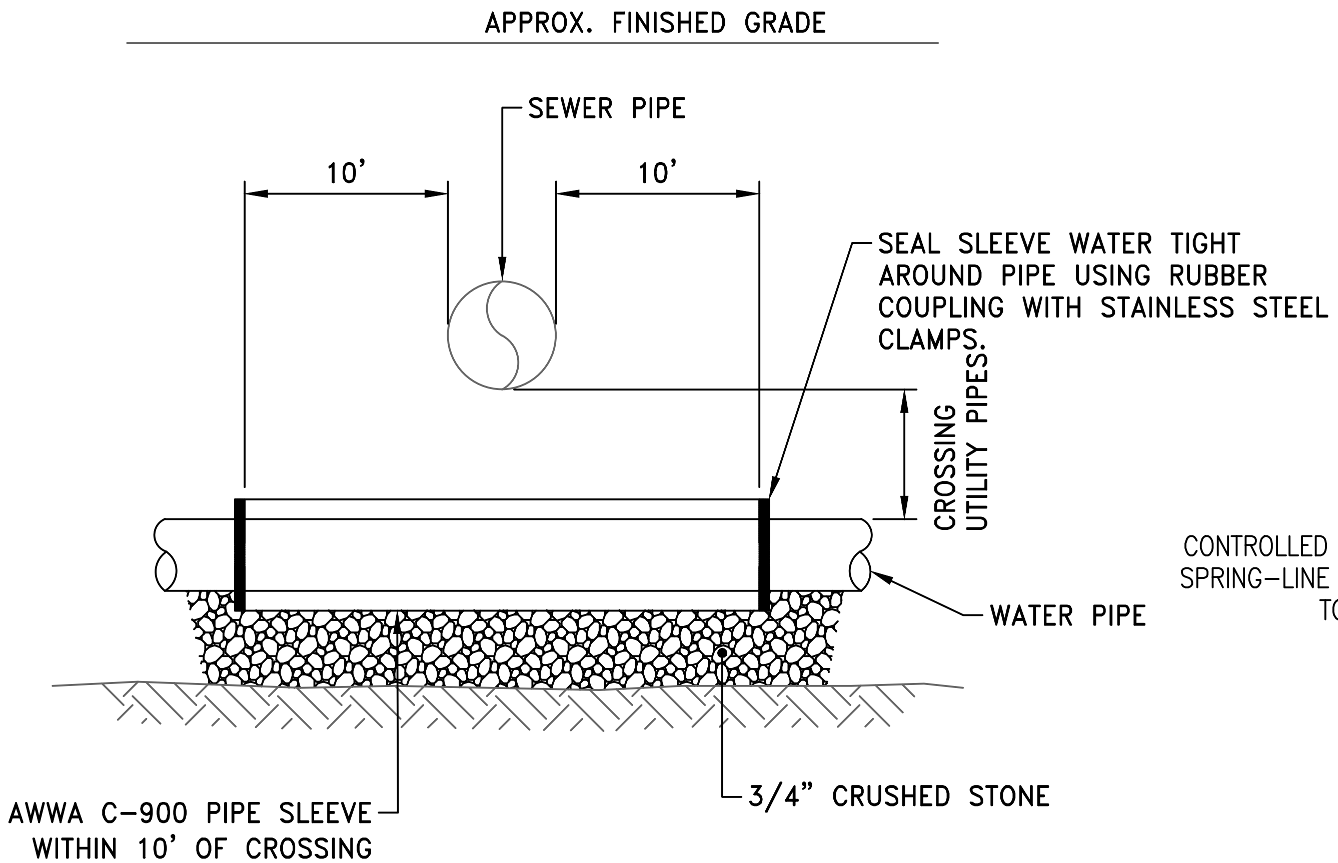
DEPTH OF EXCAVATION (FT)	CALCULATED MAXIMUM SOIL PRESSURE ON TRENCH BOX (PSF*)
0–8	475
8–16	950
16–24	1420

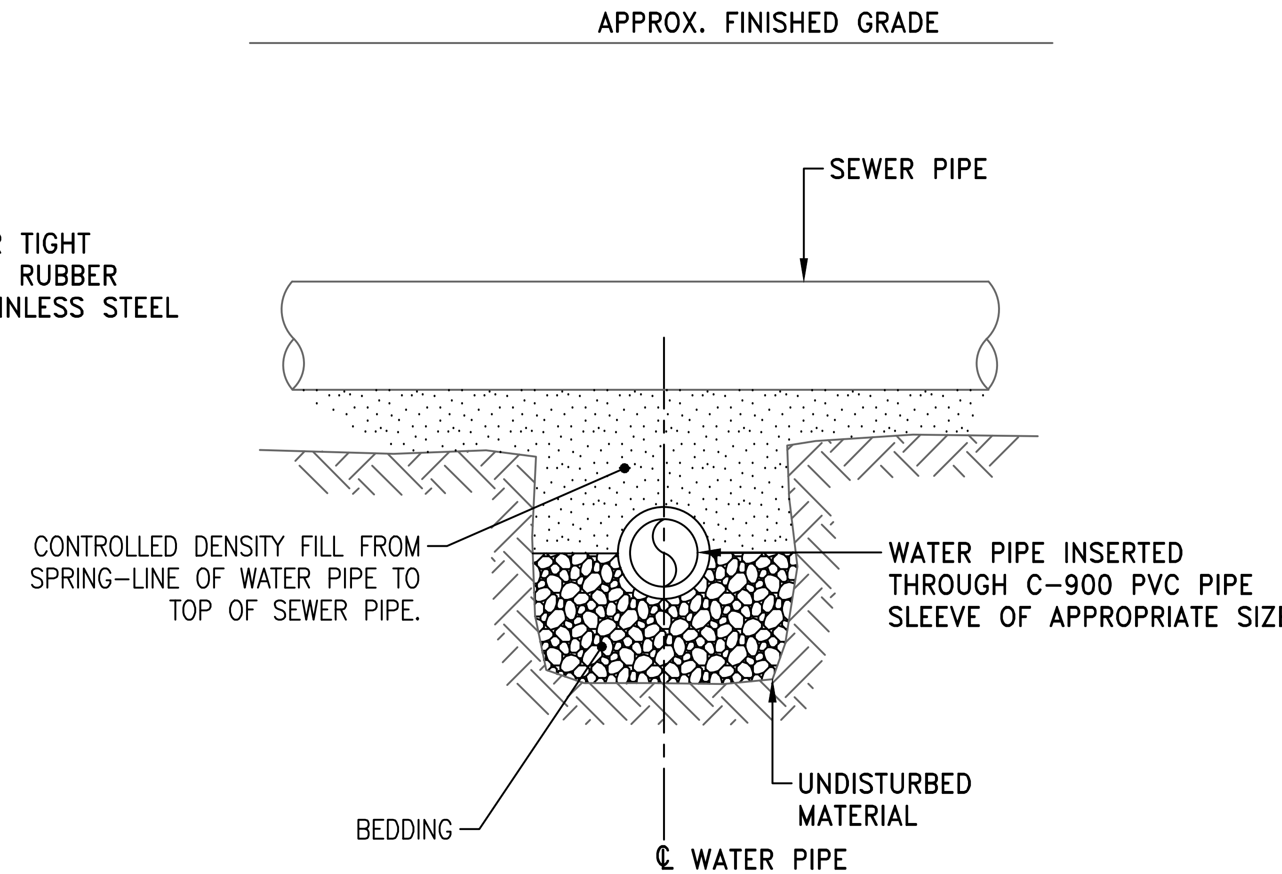
* CALCULATED USING $P = 0.65 \times K_a \times y \times H$ (AFTER TERZAGHI AND PECK, 1967)
WHERE: K_a = COEFFICIENT OF ACTIVE EARTH PRESSURE USING SOIL ANGLE OF FRICTION IN SATURATED CONDITIONS, φ,=17 DEGREES
y = 135 PCF
H = DEPTH OF EXCAVATION (FT)

ASSUMES C–60 CONDITIONS AND NO HYDROSTATIC PRESSURE BEHIND THE SHORING. IF THE PHREATIC SURFACE IS WITHIN THE FAILURE PLANE, THEN C–80 CONDITIONS WITH HYDROSTATIC CONDITIONS MUST BE ACCOUNTED FOR BY THE CONTRACTOR.

TRENCH BOX/SHIELD DETAIL

NOT TO SCALE





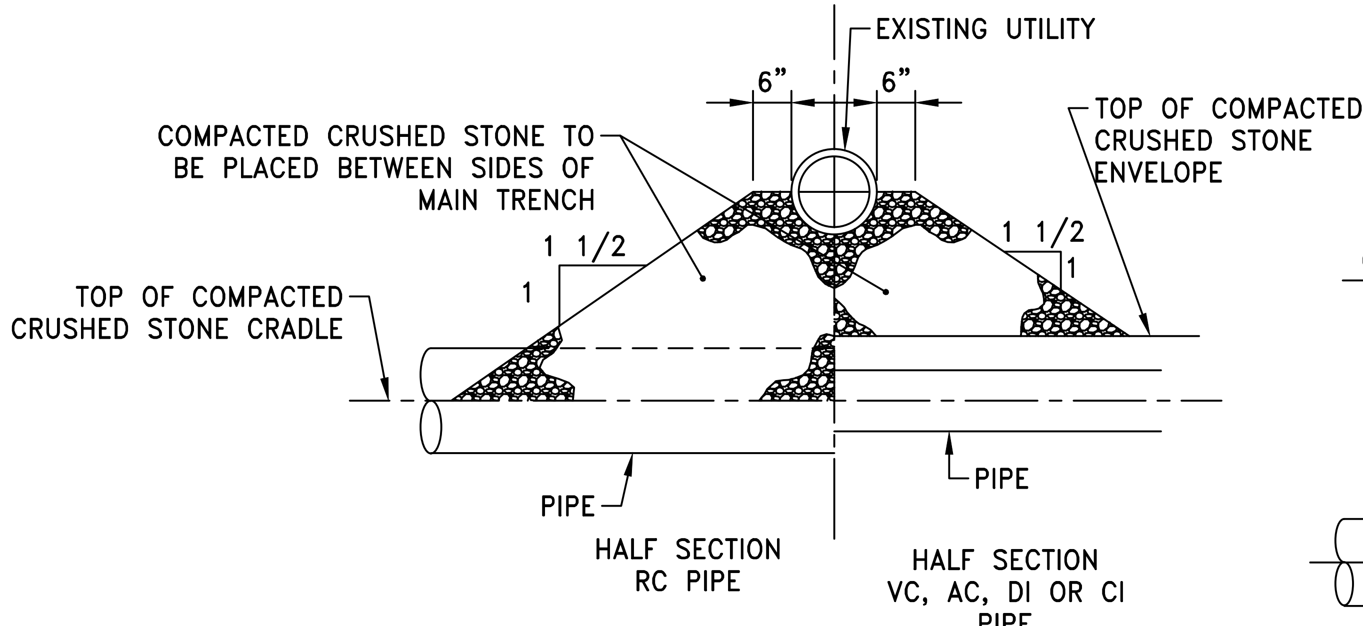
NOTES:

1. WHERE SEWER CANNOT BE INSTALLED 18" BENEATH WATER, OR WHERE SEWER AND WATER PIPING ARE WITHIN 10 FEET OF EACH OTHER, PROPOSED WATER OR SEWER PIPE SHALL BE SLEEVED INSIDE AN AWWA C-900 PVC PIPE OF APPROPRIATE DIAMETER WITHIN 10 FEET OF THE CROSSING.

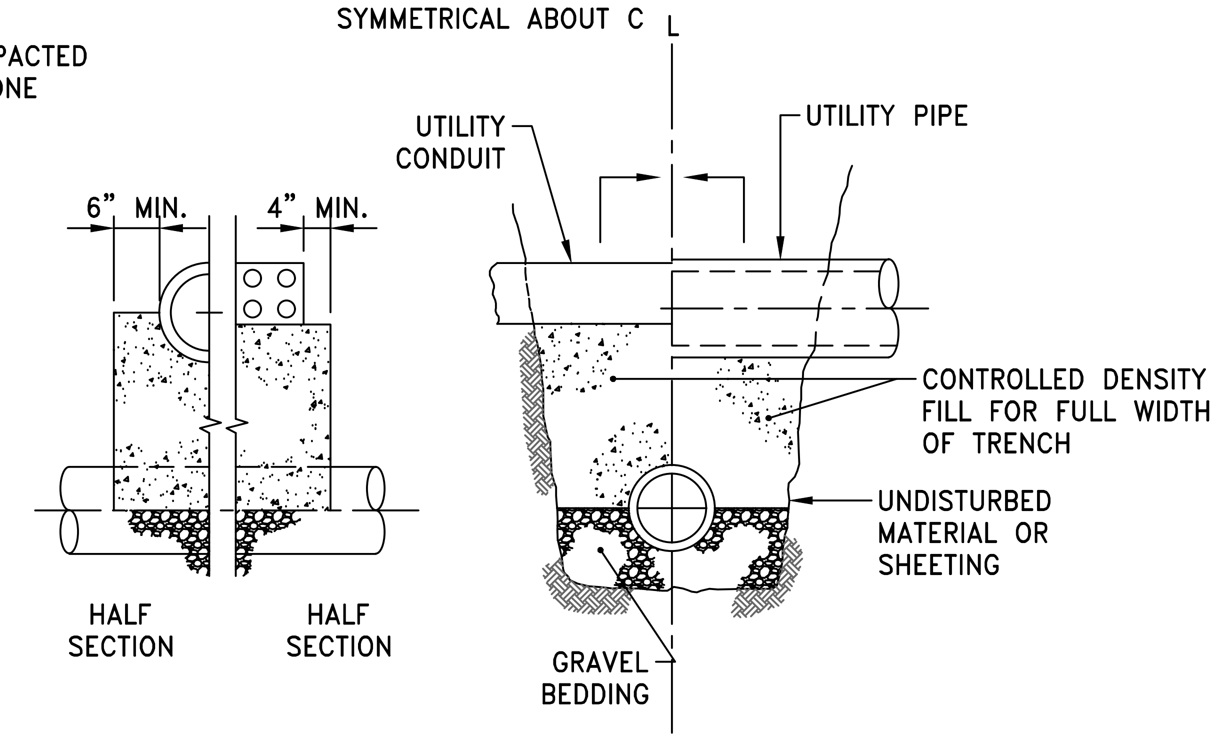
2. CONTRACTOR MAY ELECT TO ENCASE PIPE WITHIN CONCRETE INSTEAD OF USING PIPE SLEEVES, AT NO ADDITIONAL EXPENSE TO THE OWNER. CONCRETE SHALL HAVE A MINIMUM COMPRESSIVE STRENGTH OF 3,000 PSI AFTER 28 DAYS. CONCRETE ENCASEMENT SHALL EXTEND A MINIMUM OF 6" AROUND THE PIPE IN ALL DIRECTIONS.

WATER/SEWER CROSSING DETAIL

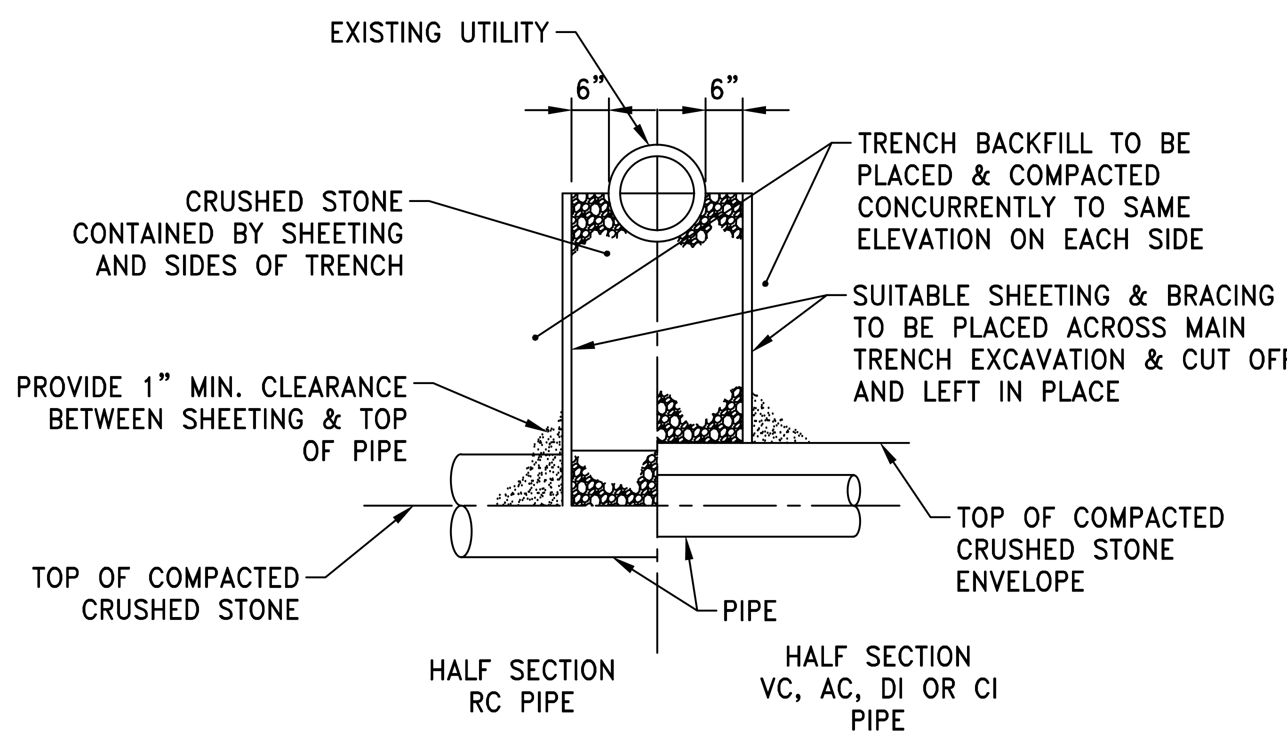
NOT TO SCALE



TYPE A



TYPE C



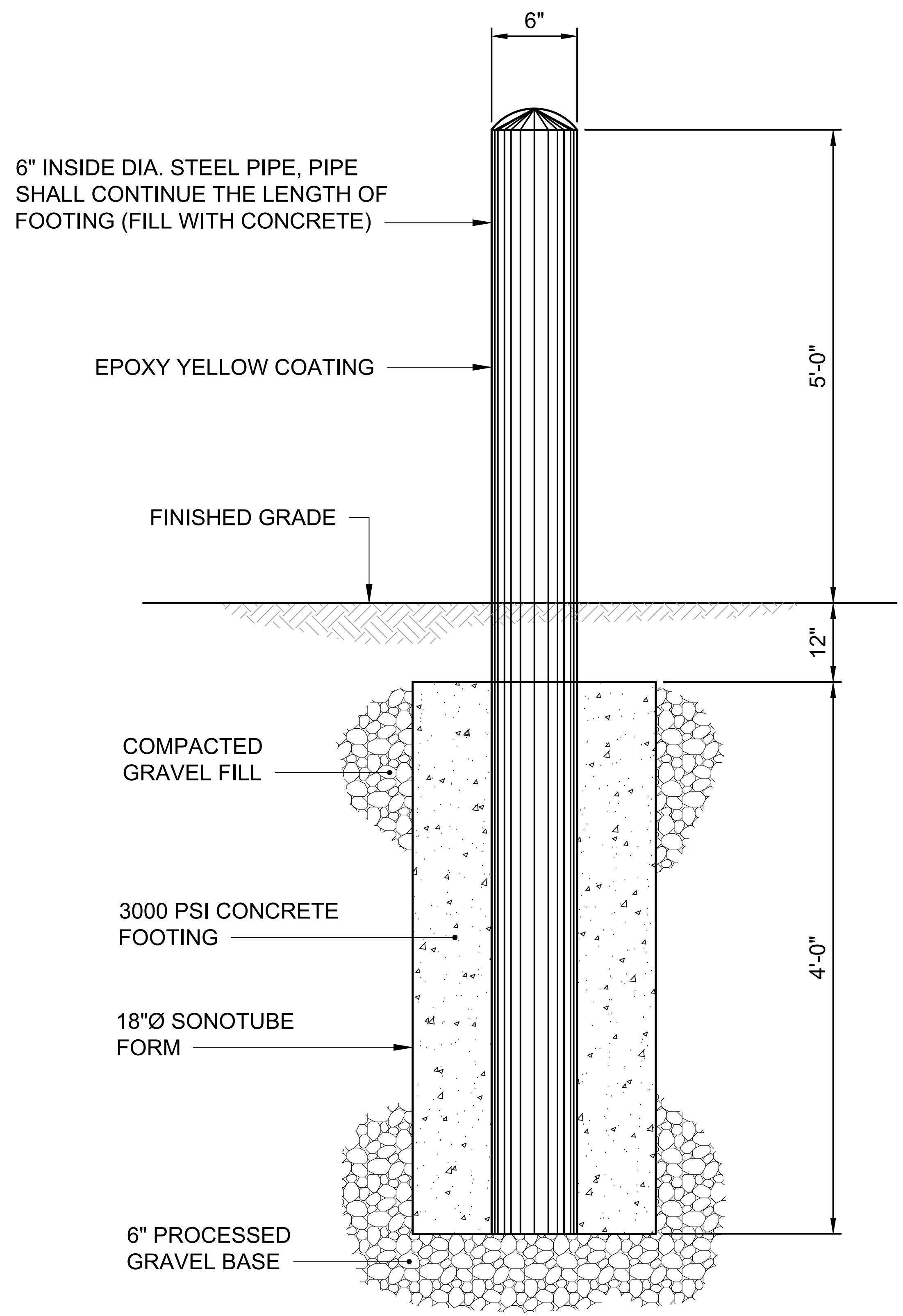
TYPE B

NOTE:

TYPE C SUPPORT TO BE PROVIDED WHERE DIRECTED

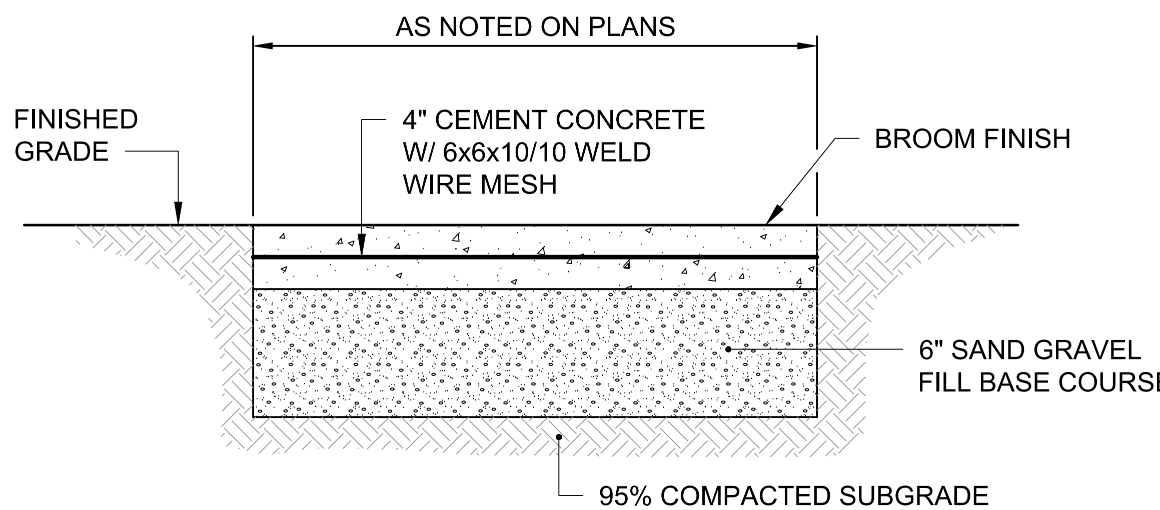
TYPICAL SUPPORTS FOR UTILITIES

NOT TO SCALE



BOLLARD DETAIL

NOT TO SCALE

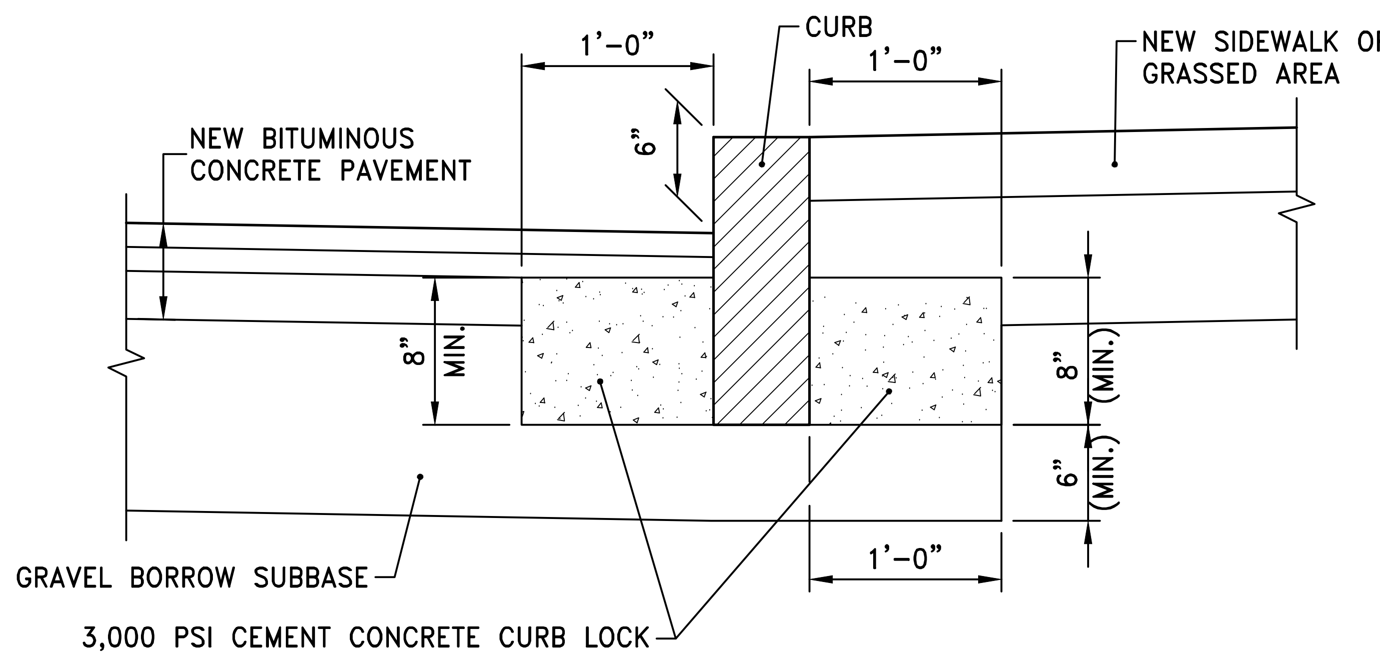


NOTES:

1. CONCRETE SIDEWALK SHALL BE CONSTRUCTED IN ACCORDANCE WITH SECTION 476 OF THE MASSHIGHWAY STANDARD SPECIFICATIONS.
2. WIRE MESH SHALL BE IN ACCORDANCE WITH SECTION M8.01.2 OF THE MASSHIGHWAY STANDARD SPECIFICATIONS.
3. EXPANSION JOINTS (E.J.) 20' O.C. UNLESS OTHERWISE NOTED.
4. CONTROL JOINTS (C.J.) 5' O.C. UNLESS OTHERWISE NOTED.

TYPICAL CEMENT CONCRETE SIDEWALK

NOT TO SCALE



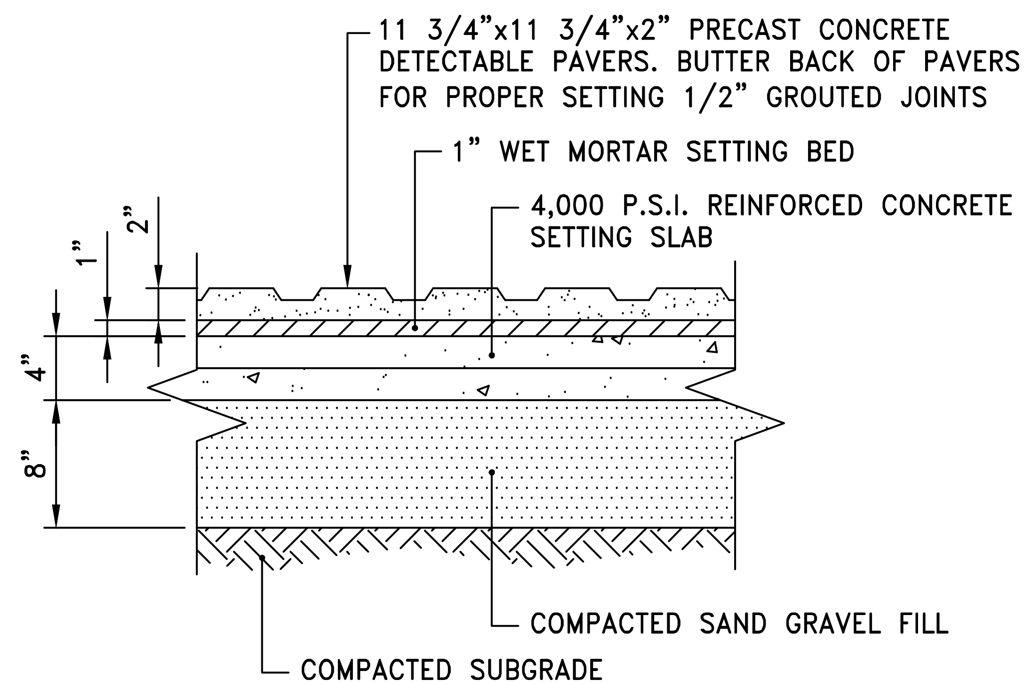
NOTES:

1. SHALL BE IN ACCORDANCE WITH SECTION 906 OF THE R.I. STANDARD SPECIFICATIONS.

2. PROVIDE CEMENT CONCRETE CURB LOCK ON ALL CURBS

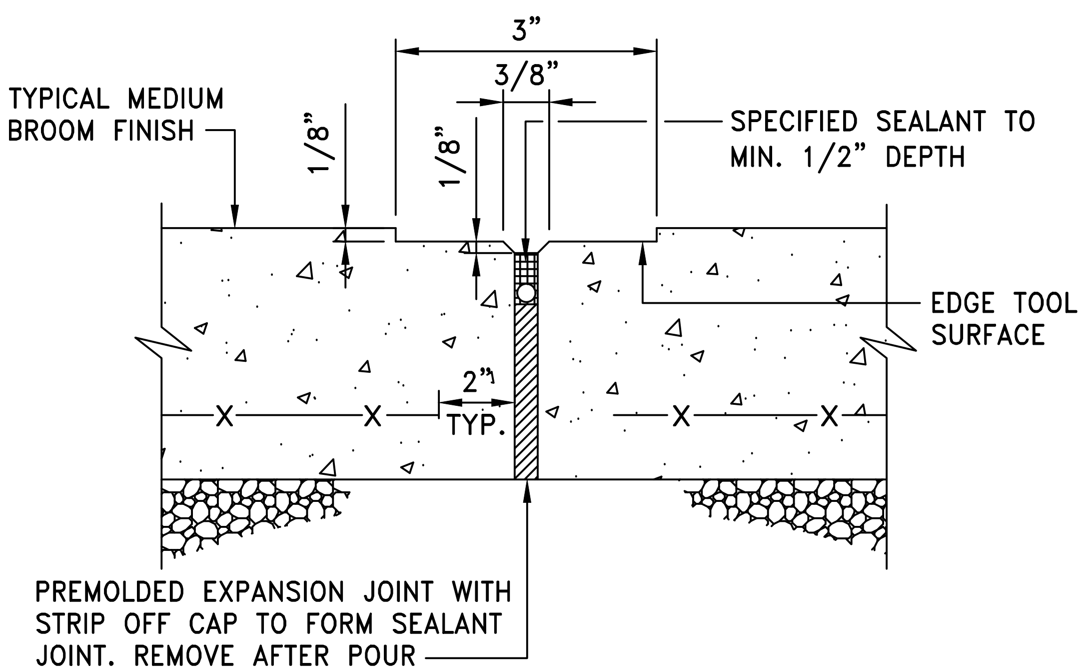
CURB SETTING DETAIL

NOT TO SCALE



DETECTABLE WARNING PAVER

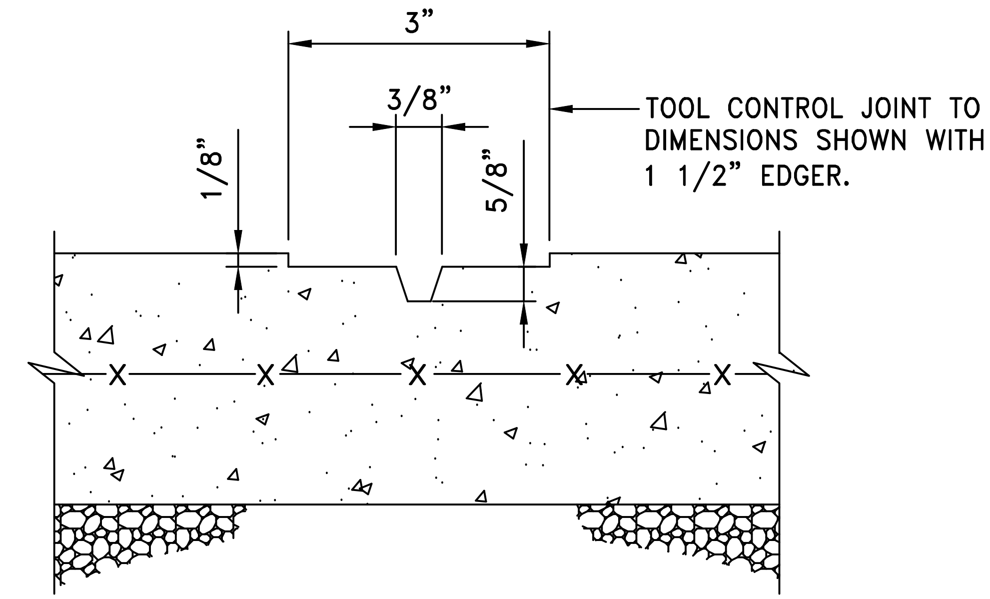
NOT TO SCALE



EXPANSION JOINT AT 20' O.C. (TYP)

NOTES:

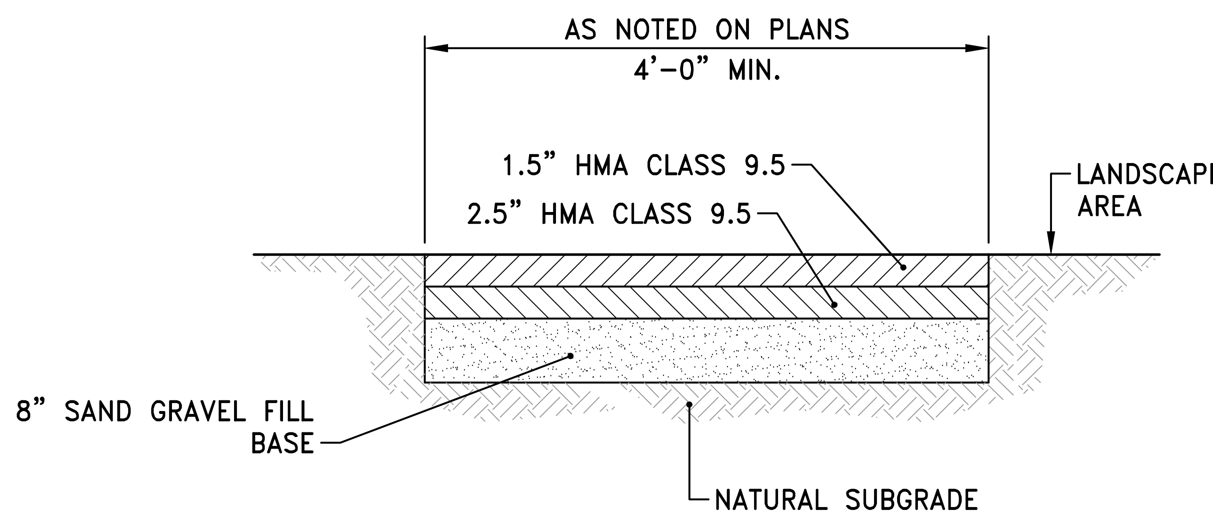
1. EXPANSION JOINTS (E.J.) 20 FEET O.C. UNLESS OTHERWISE NOTED.
2. CONTROL JOINTS (C.J.) 5 FEET O.C. UNLESS OTHERWISE NOTED.
3. WHERE EXISTING AND NEW CONCRETE SIDEWALKS MEET, SAWCUT EXISTING WALK AND INSTALL EXPANSION JOINT AND DOWELS AS SHOWN. DRILL EXISTING CONCRETE WALK EDGE TO RECEIVE STEEL DOWELS AT EXPANSION JOINT.



CONTROL JOINT AT 5' O.C. (TYP)

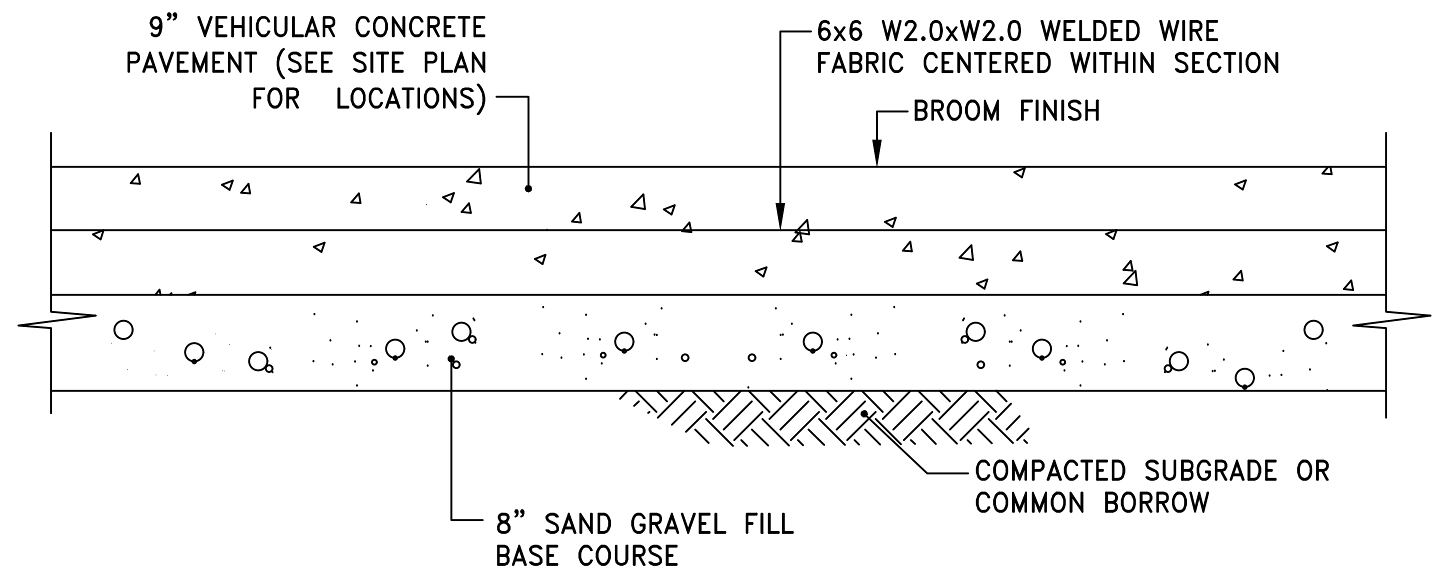
EXPANSION AND CONTROL JOINTS FOR SIDEWALK PAVING

NOT TO SCALE



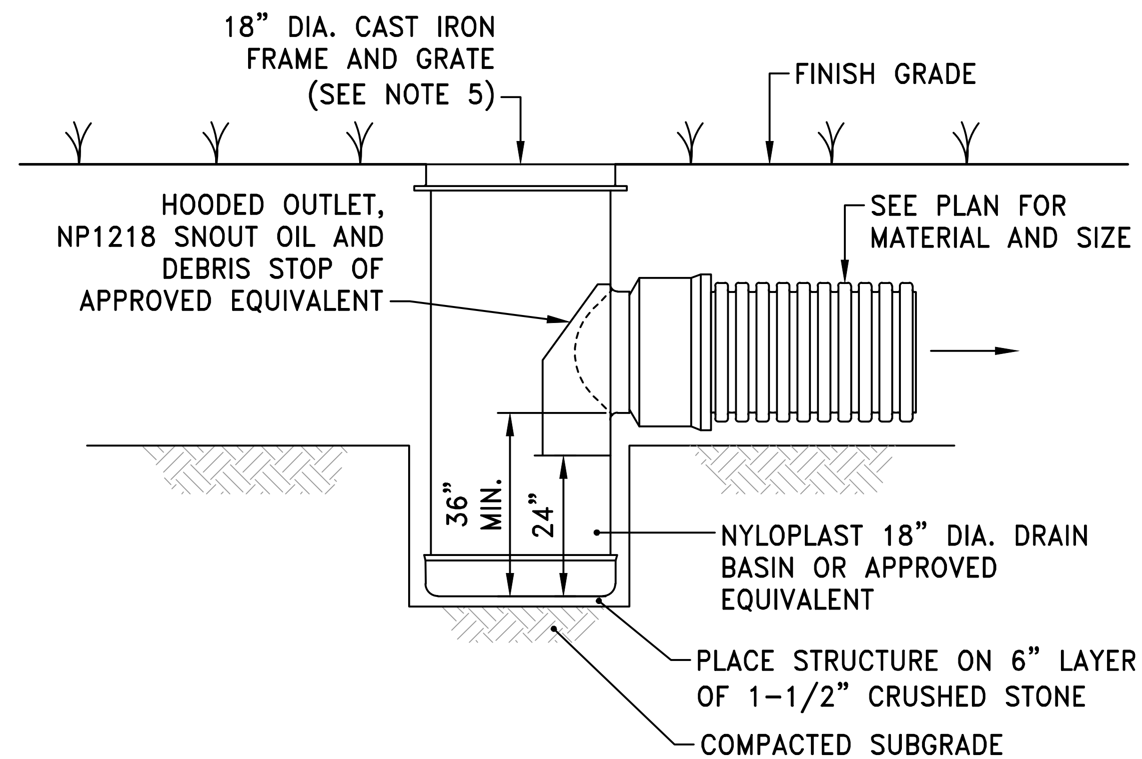
HOT MIX ASPHALT SIDEWALK

NOT TO SCALE



VEHICULAR CONCRETE PAVEMENT

NOT TO SCALE

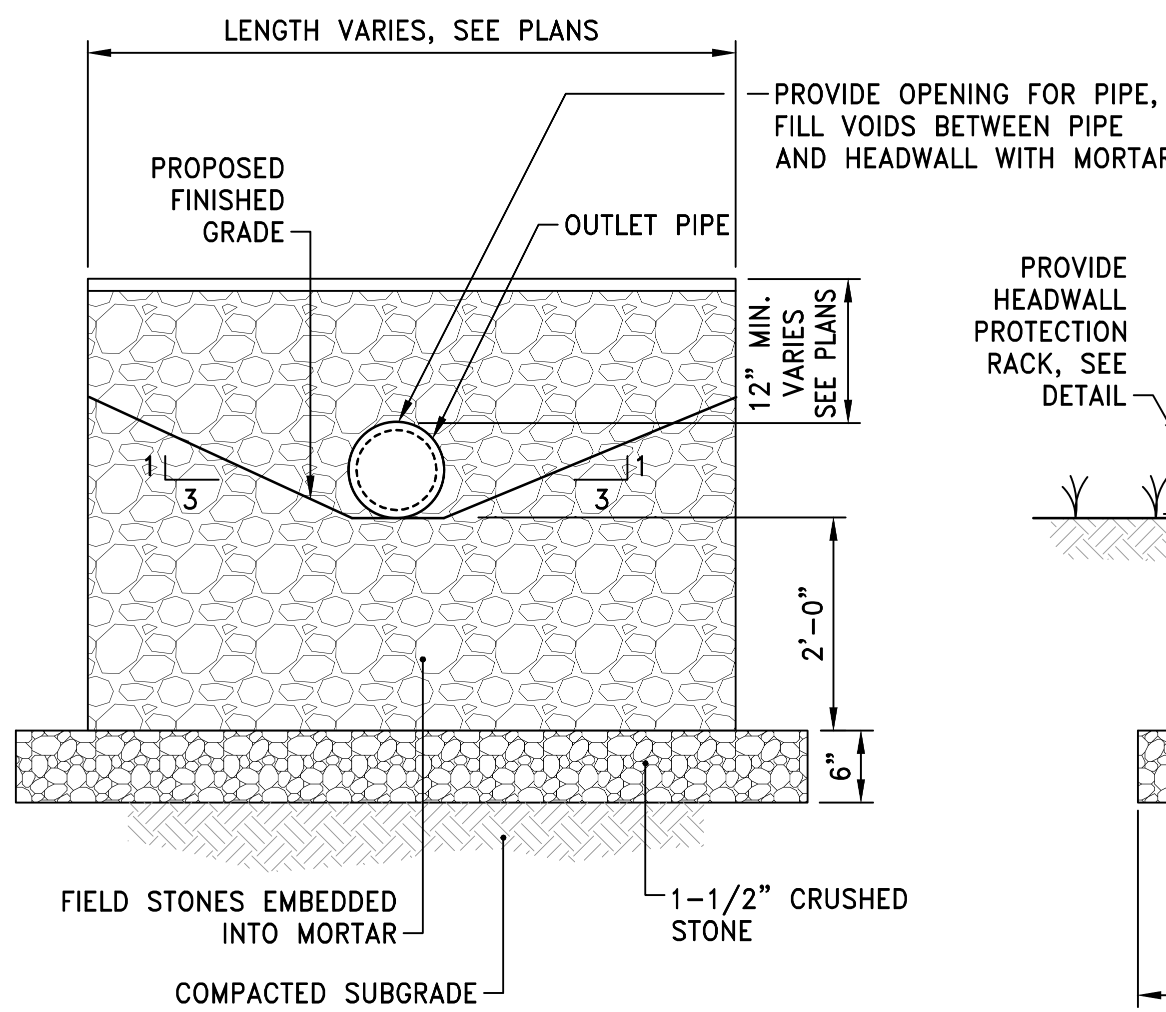


NOTES:

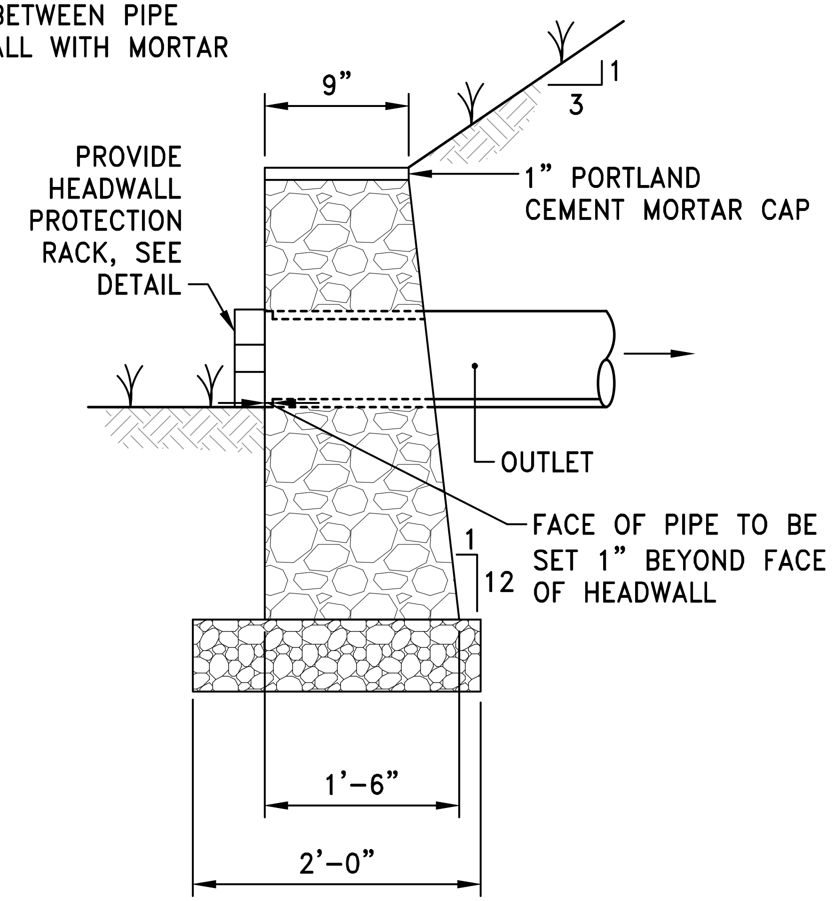
1. DRAIN BASIN SHALL BE CUSTOM MANUFACTURED FOR THE PROJECT WITH THE INLETS AND OUTLETS REQUIRED.
2. STRUCTURES SHALL BE CONSTRUCTED TO WITHSTAND LOADS IMPOSED BY CONSTRUCTION VEHICLES.
3. INSTALL DRAIN BASIN, FRAME AND GRATE IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS.
4. PROVIDE HOODED OUTLET ON ALL DRAIN BASINS.
5. FRAME AND GRATE SHALL BE CONSTRUCTED OF DUCTILE IRON AND CONFORM TO ASTM A536 GRADE 70-50-05.
6. PROVIDE PEDESTRIAN GRATE FOR AD-24, NYLOPLAST 1899CGP OR APPROVED EQUIVALENT. SET TOP OF FRAME AT RIM ELEVATION.

AREA DRAIN DETAIL

NOT TO SCALE



ELEVATION



SECTION

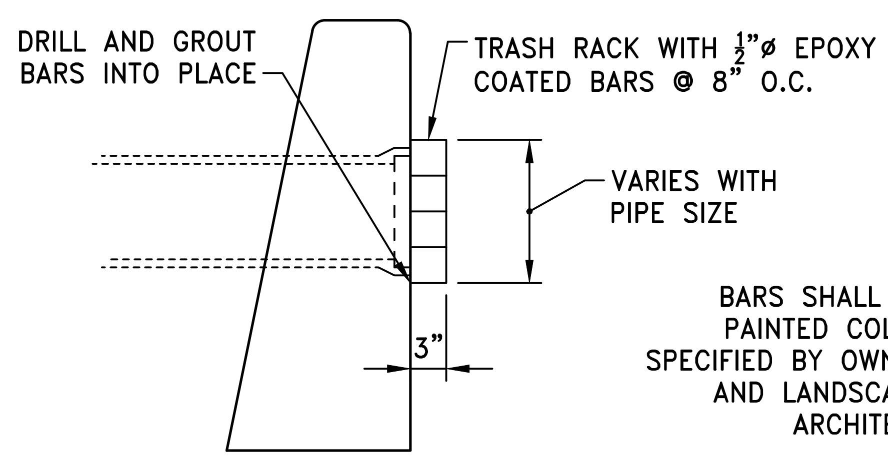
NOTES:

1. FIELD STONES SHALL BE OF SIMILAR SIZE AND COLOR TO FORM UNIFORM APPEARANCE.

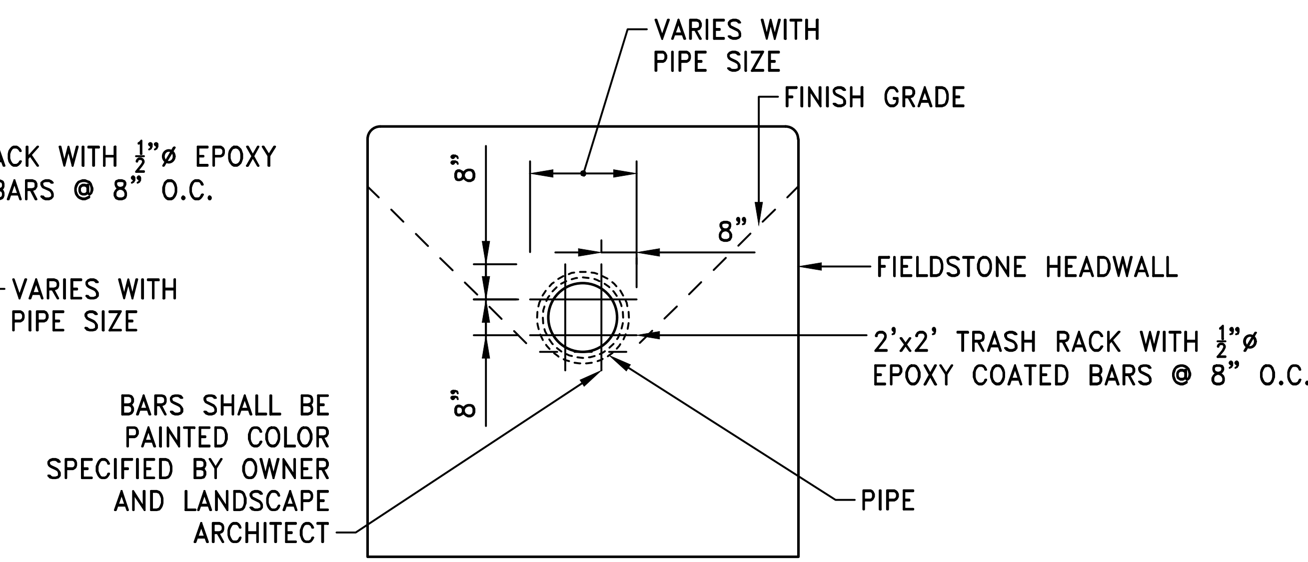
2. OWNER AND ENGINEER SHALL REVIEW STONE SAMPLES PROVIDED BY CONTRACTOR PRIOR TO COMMENCING HEADWALL CONSTRUCTION.

FIELD STONE HEADWALL DETAIL

NOT TO SCALE



SECTION VIEW



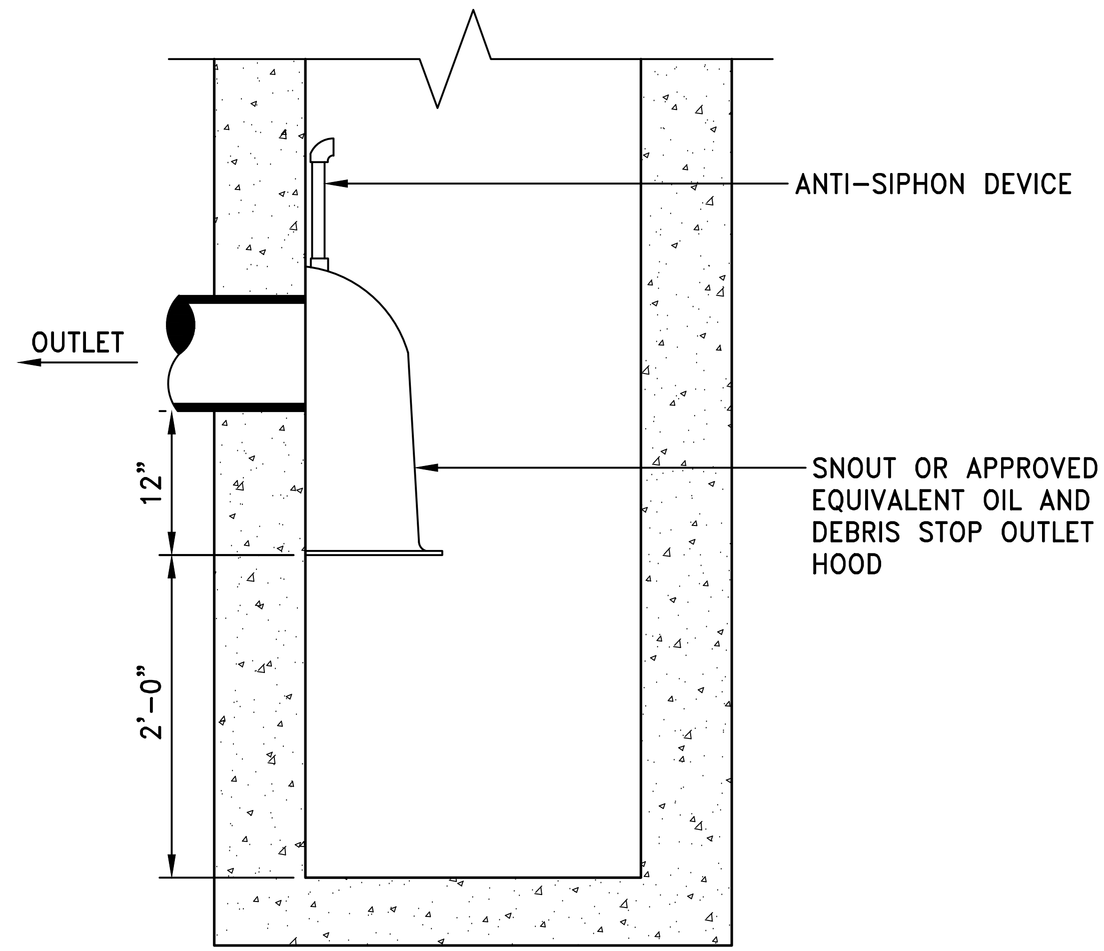
ELEVATION VIEW

NOTES:

1. CONTRACTOR SHALL PROVIDE NUMBER OF BARS REQUIRED TO CONSTRUCT RACK. NUMBER OF BARS WILL VARY WITH PIPE SIZE.

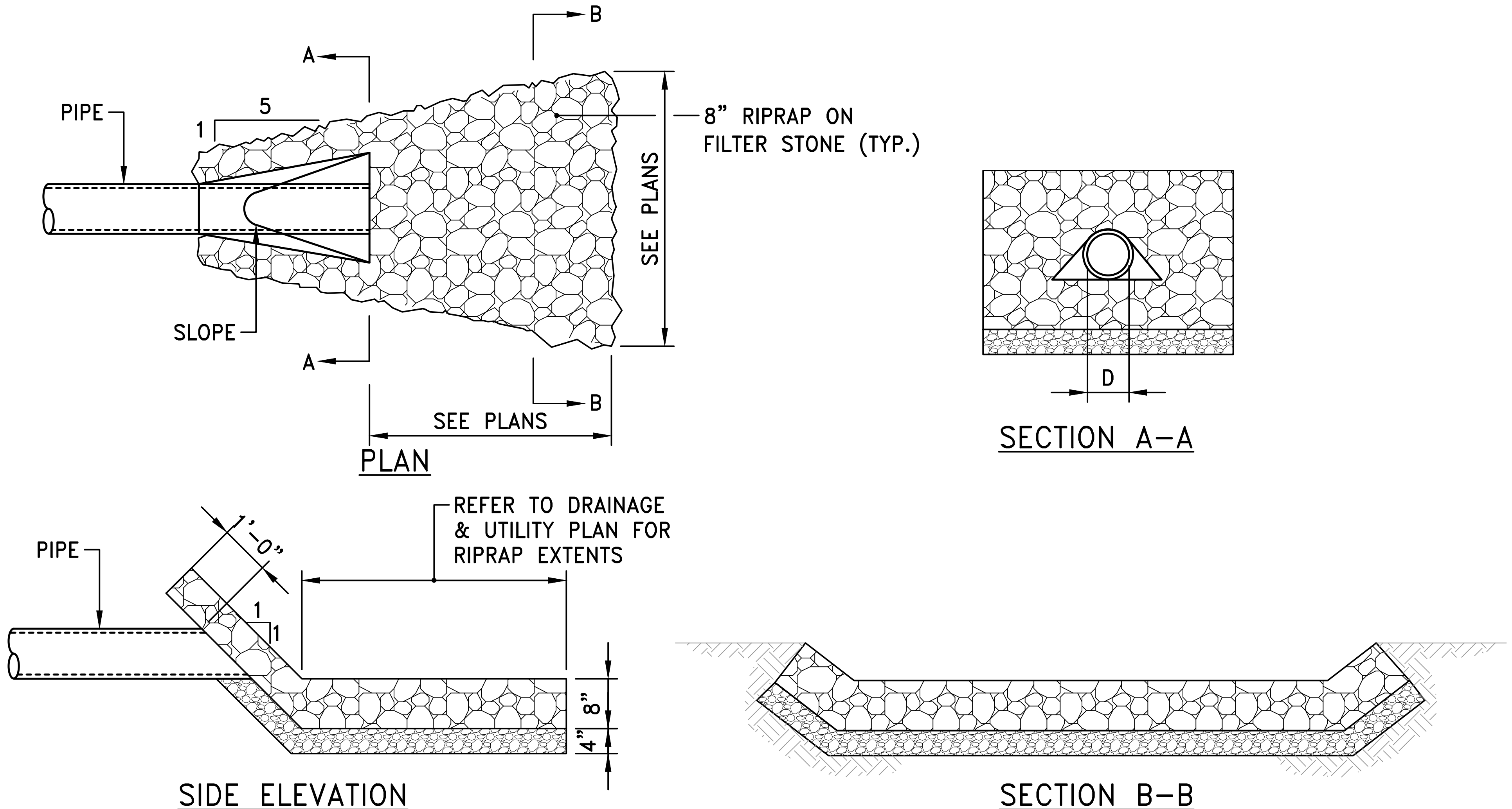
HEADWALL PROTECTION RACK DETAIL

NOT TO SCALE



OUTLET HOOD DETAIL

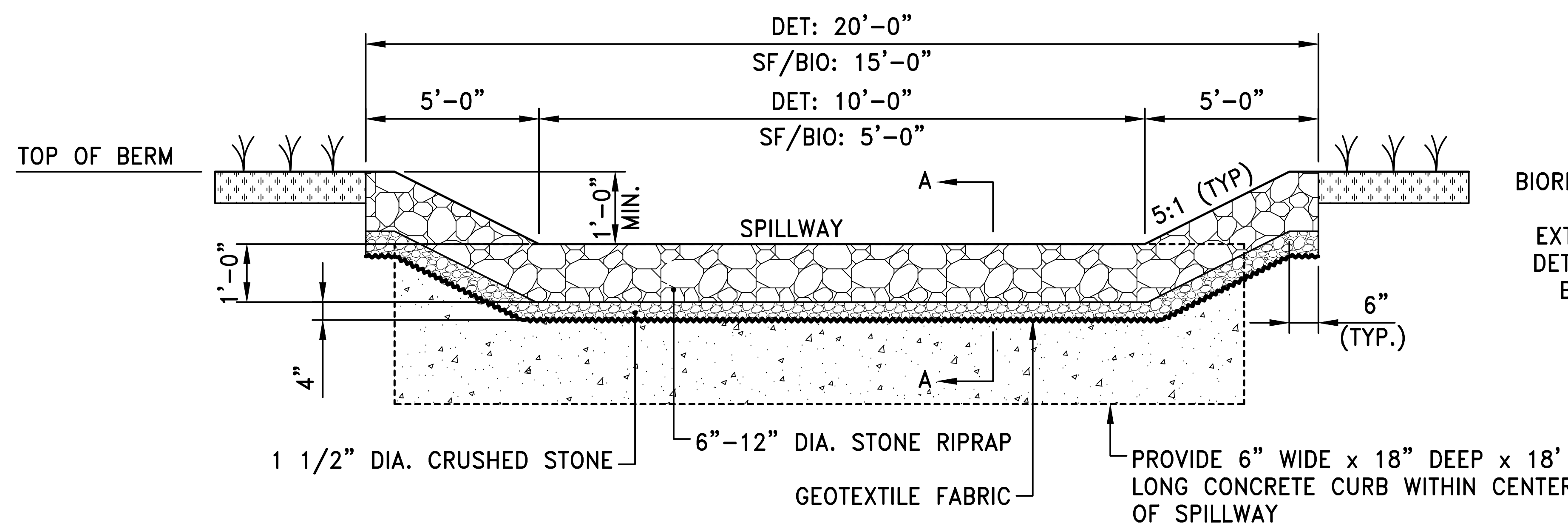
NOT TO SCALE

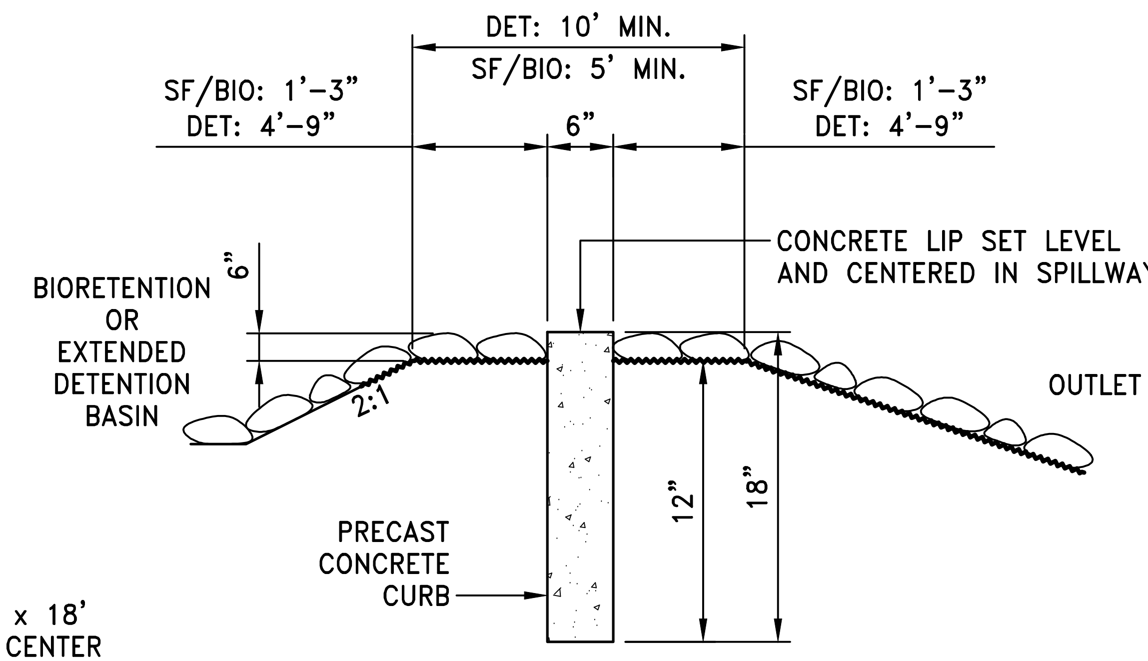


NOTE:
RIPRAP AND FILTER STONE
SIZE TO BE DETERMINED

RIPRAP LEVEL SPREADER

NOT TO SCALE





SECTION A-A

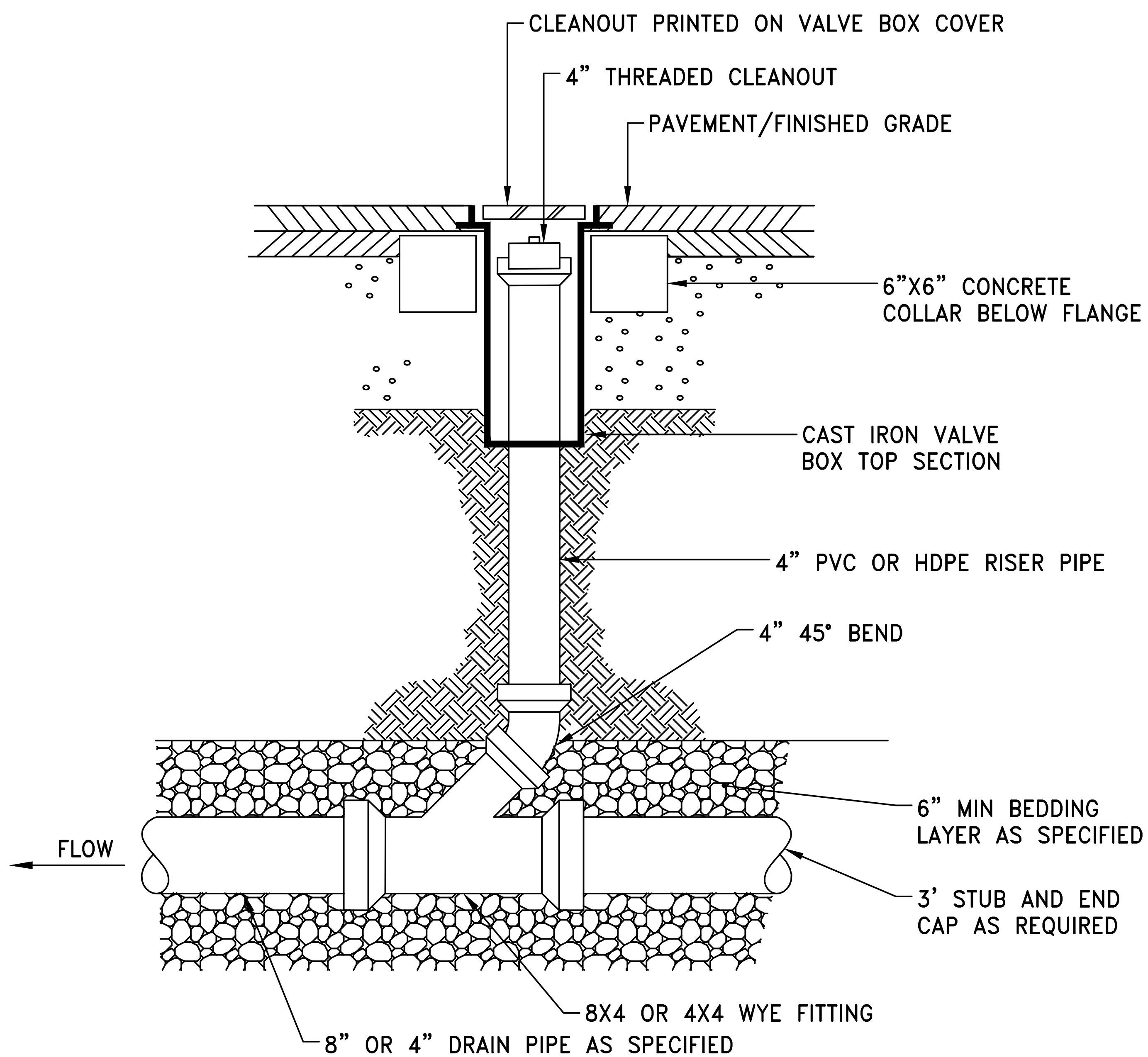
RIPRAP SPILLWAY DETAIL

NOT TO SCALE

NOTE:

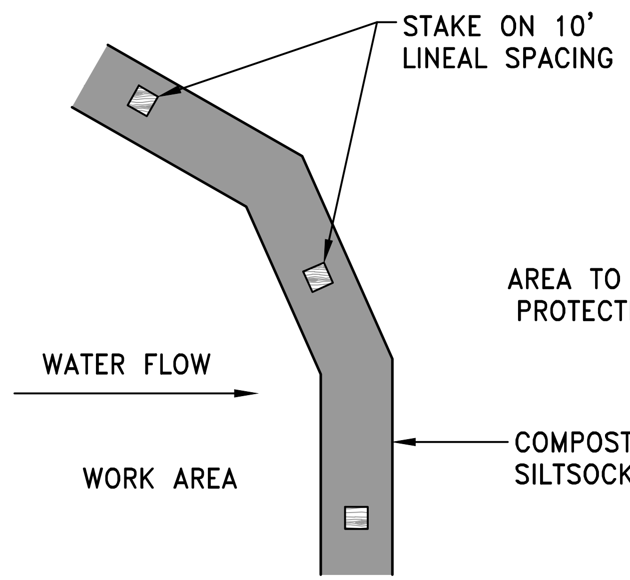
CONTRACTOR SHALL FILL VOIDS BETWEEN CURB SECTIONS WITH MORTAR

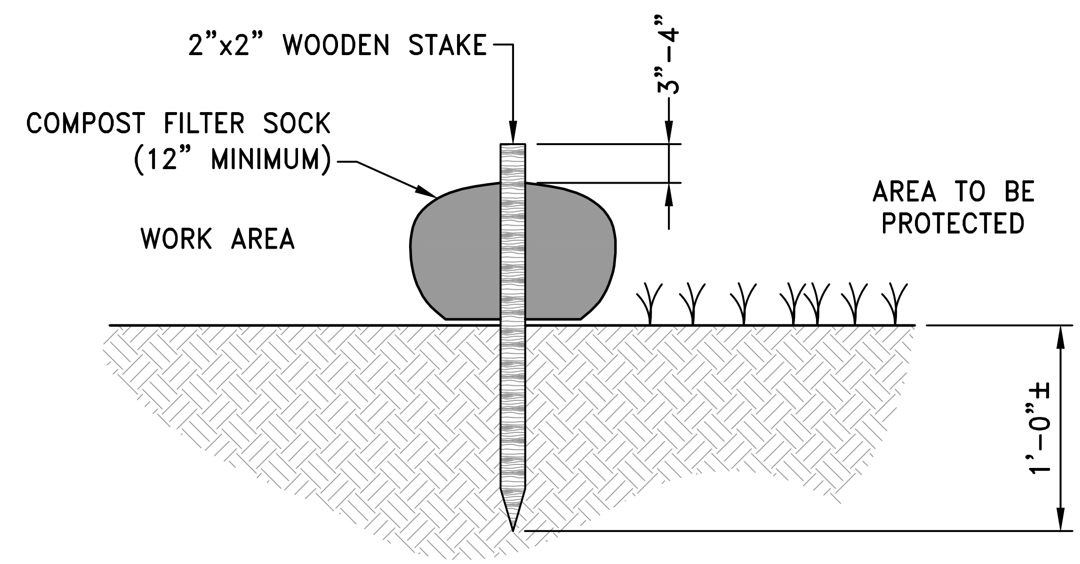
DET = DETENTION BASIN
BIO = BIORETENTION AREA
SF = SAND FILTER



DRAIN CLEANOUT DETAIL

NOT TO SCALE



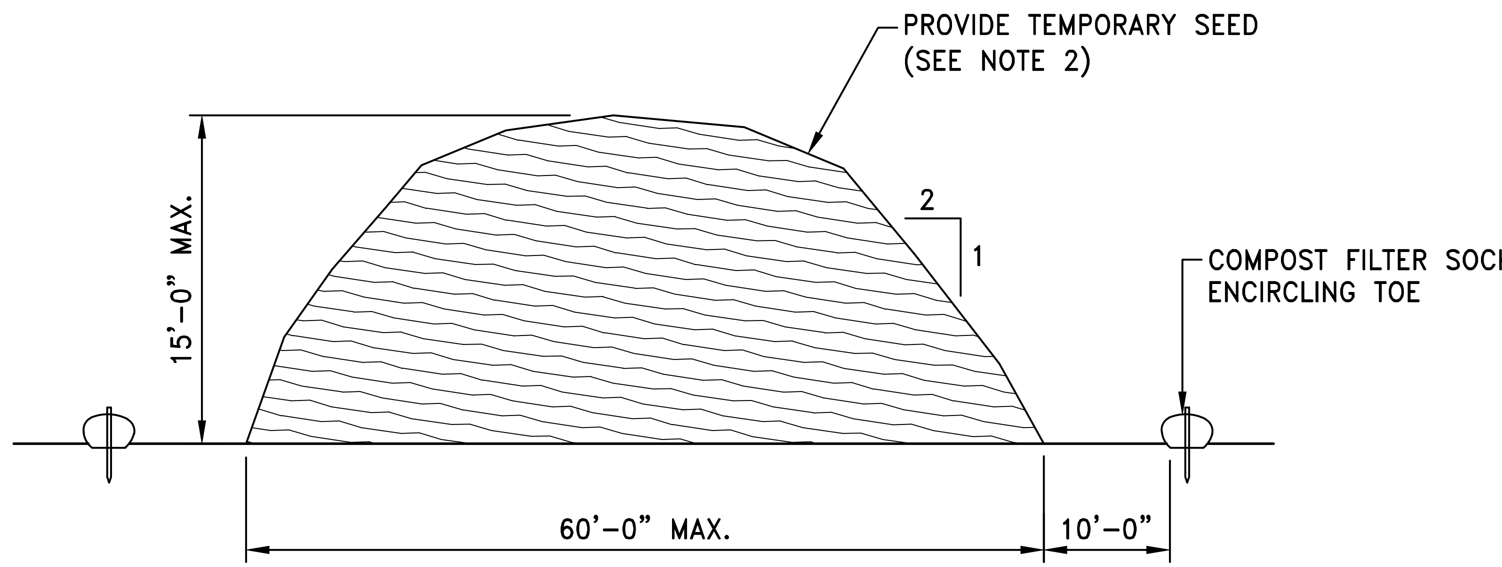


NOTES:

1. COMPOST/ SOIL/ ROCK/ SEED FILL TO MEET APPLICATION REQUIREMENTS.
2. COMPOST MATERIAL TO BE REMOVED OR DISPERSED ON SITE AS DETERMINED BY ENGINEER.
3. IF SOCK NETTING MUST BE JOINED, FIT BEGINNING OF NEW SOCK OVER END OF OLD SOCK, OVERLAPPING BY 2 FEET AND STACK OVERLAP. IF SOCK NETTING IS NOT JOINED, OVERLAP OLD SOCK WITH NEW ONE BY MINIMUM OF 2 FEET.

COMPOST FILTER SOCK DETAIL

NOT TO SCALE



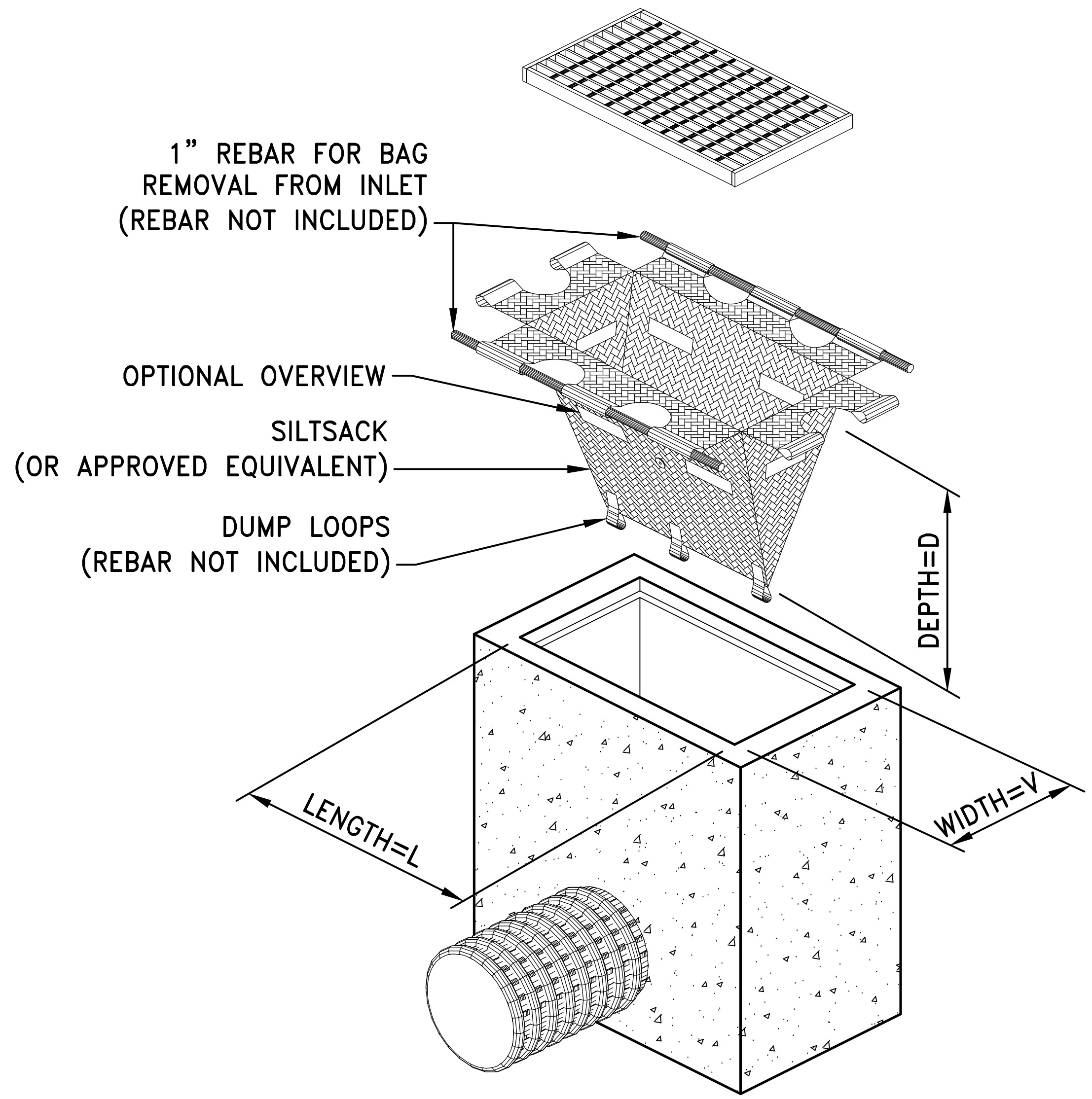
NOTES:

1. STOCKPILE AREA SHALL NOT EXCEED SPECIFIED DIMENSIONS WITHOUT APPROVAL FROM ENGINEER.

2. STOCKPILED ERODIBLE MATERIAL THAT WILL NOT BE USED FOR GREATER THAN 14 DAYS SHALL BE STABILIZED WITH TEMPORARY SEED IMMEDIATELY FOLLOWING PLACEMENT. USE RIDOT STD. M.18.10.5 SEED MIX.

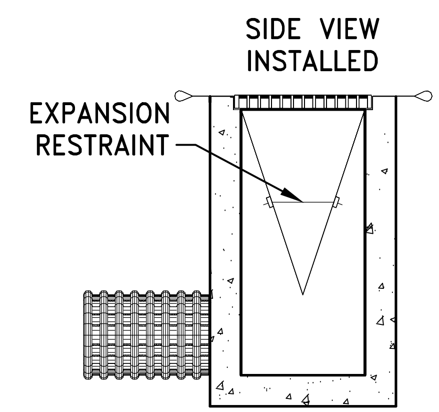
ERODIBLE MATERIAL STOCKPILE

NOT TO SCALE

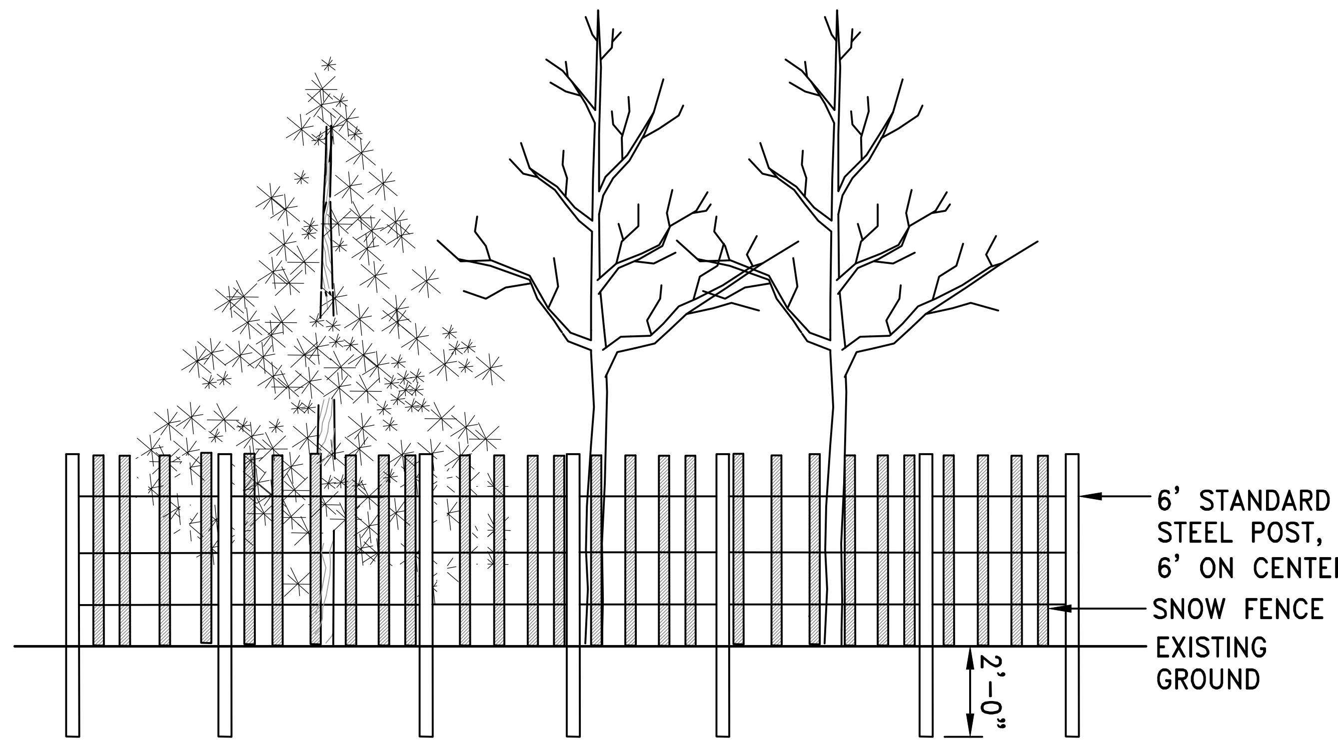


TEMPORARY INLET PROTECTION

NOT TO SCALE



INSTALLATION DETAIL



NOTES:
1. TREE GROUP PROTECTION SHALL BE INSTALLED AT THE DRIP LINE OF THE TREES TO BE PROTECTED.

TREE GROUP PROTECTION DETAIL

NOT TO SCALE

Appendix F – Design Consultant Instrument Guidelines



The Narragansett Bay Commission

Phase III CSO Program

Design Consultant Instrument Guidelines

Date: May 29, 2019

Stantec

PARE CORPORATION

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Revisions

Revision History

Date	Version	Description	Author(s)	Reviewer(s)	Date of Review(s)
4/15/2019	0.1	1st Internal Draft	Brad Sauder	L. Amaral	5/2/2019
5/6/2019	0.2	Draft	Brad Sauder	K. Gardner	5/10/2019
5/29/2019	0.3	Draft	Brad Sauder	B. Shea	5/29/2019

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TABLE OF CONTENTS

LIST OF TABLES

List of Abbreviations and Acronyms

BPSA	Bucklin Point Service Area
BPWWTF	Bucklin Point Wastewater Treatment Facility
BVI	Blackstone Valley Interceptor
CSA	Canadian Standards Association
CSO	Combined Sewer Overflow
EPL	Ethernet Private Line
FPSA	Fields Point Service Area
FPWWTF	Fields Point Wastewater Treatment Facility
GAC	Granular Activated Carbon
GSS	Gate and Screen Structure
HMI	Human Machine Interface
HVAC	Heating Ventilation Air Conditioning
I&C	Instrumentation and Control
I/O	Input/Output
LBVI	Lower Blackstone Valley Interceptor Relief Structure
NBC	Narragansett Bay Commission
OIT	Operator Interface Terminal
PLC	Programmable Logic Controller
PM/CM	Program Manager/Construction Manager
RIDEM	Rhode Island Department of Environmental Management
RIO	Remote Input/Output
RTD	Resistance Temperature Detector
SCADA	Supervisory Control and Data Acquisition
SOP	Standard Operating Procedures
TM	Technical Memorandum
TPS	Tunnel Pump Station
UBVI	Upper Blackstone Valley Interceptor Relief Structure
UPS	Uninterruptable Power Supply
VFD	Variable Frequency Drive

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Executive Summary

This TM describes and identifies the instrumentation required to implement control and monitoring of the project's four (4) new Gate and Screen Structures, the Receiving Shaft Structure, and one (1) modified Regulator Structure to maximize capture and treatment of Combined Sewer Overflows (CSOs) and to comply with the Phase III CSO control plan. Detailed design and specifications for project instrumentation shall support the key points of Instrumentation Selection included in this guidance document.

Key points for Instrumentation Selection include the following:

- Provide instrumentation as summarized herein where:
    (1) it is necessary for regulatory reporting
    (2) it is necessary for control
    (3) it is necessary for equipment protection or personnel safety, or
    (4) the NBC specifically requests it.
- Redundant instruments shall be used to provide the level of reliability dictated by the controls.
- Instrument selection and installation methods shall support cost effective maintenance and accessibility of equipment.
- NBC preferred instruments shall be utilized to the extent possible. The Design Consultant shall be responsible to verify instrument suitability for each project specific application and to define project specific instrument requirements.
- Instrument selection and installation shall conform to the General Instrument Requirements and Governing Codes.

The sites included in this work are as follows:

- Gate and Screen Structure GSS-218, and Drop Structure DS-218, *804 School St. Pawtucket, RI.*
- Gate and Screen Structure GSS-213 and Drop Structure DS-213 *between 50 Pleasant St, Pawtucket, RI and 4 Pleasant St, Pawtucket, RI.*
- Gate and Screen Structure GSS-205 and Drop Structure DS-205, *5 Central Ave, Pawtucket, RI.*
- Upper Blackstone Valley Interceptor (BVI) Gate and Screen Structure GSS-UBVI and Drop Structure DS-UBVI, *555 Roosevelt Ave, Central Falls, RI.*
- Receiving Shaft, Tunnel Odor Control, and tunnel level measurements, *660 Roosevelt Ave, Pawtucket, RI*
- Regulator structures throughout BPSA in Central Falls, RI and Pawtucket, RI

Section 1.0 Design Consultant Instrument Guidelines

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1.0 Instruments

1.1 General

Instrumentation shall be provided where (1) it is necessary for regulatory reporting, (2) it is necessary for control, (3) it is necessary for equipment protection or personnel safety, or (4) the NBC specifically requests. Redundant instruments shall be used to provide the level of reliability dictated by the controls. In addition to functionality, instrument selection must also take into account mounting locations that are accessible for maintenance.

The summary below lists multiple instrument manufacturers for comparison of features. Where multiple manufacturers are named for reference, the NBC preferred instrument selection for each application is described in greater detail with further description of model numbers, features, and installation requirements. The NBC preferred instrument selection is also included in the Instrument Summary Table in Section 2.

1.2 Open-Channel Flow Measurement (Tunnel Inflow at Drop Shafts)

Open-Channel Flow measurement applies to wet weather flows measured in the approach channel prior to a drop shaft.

- Several configurations of area-velocity type meters are available for open channel measurement. Technologies and features are noted below for several manufacturers.
    a. Teledyne Isco Signature Flowmeter and LaserFlow Sensor
        - Velocity: Non-contact Doppler Laser senses velocity at single or multiple points below the water surface.
        - Level: Non-contact ultrasonic and surcharge pressure transducer
        - Estimated Accuracy: ± 4.0%
        - Certifications: The intrinsically safe model of the sensor with barrier device received IEC certification for use in Class I, Division 1 area hazardous locations and is available from the manufacturer. UL certification is pending.
        - Mounting hardware and installation pole allow maintenance removal or installation of sensor without entering the confined space.

    b. Accusonic Technologies 8510
        - Velocity: Submerged multi-path transit time velocity sensor pairs sense average velocity at multiple depths within the flow. Typically, up to four velocity paths may be monitored.
        - Level: Non-contact ultrasonic and surcharge pressure transducer
        - Estimated Accuracy: ± 1.0%
        - Certifications: FM Explosion Proof transducers are available
        - High Accuracy measurement suitable for large channels and pipes

    c. ADS Flowshark
        - Velocity: Submerged continuous wave velocity sensor senses peak velocity.

- Level: Submerged ultrasonic and surcharge pressure transducer
- Estimated Accuracy: ± 5.0%
- Certifications: CSA Intrinsically safe models available
- Maintenance access is not equal to the preferred instrument.

d. Hach Flo-Tote 3
- Hach Sigma 920 Flowmeters are in use elsewhere in the NBC collection system but are listed as obsolete by the manufacturer
- Velocity: Submerged electromagnetic velocity sensor.
- Level: Submerged pressure transducer
- Transmitter: FL900 Series Flow Logger
- Estimated Accuracy: ± 5.0%
- Certifications: Manufacturer data sheets indicate his instrument is not approved for use in hazardous locations. This is not equal to the preferred instrument.
- Maintenance access is not equal to the preferred instrument.

e. Hach Flo-Dar
- Velocity: Non-contact Doppler radar senses surface velocity only.
- Depending on the application, accuracy may be reduced.
- Level: Non-contact ultrasonic and surcharge pressure transducer
- Estimated Accuracy: ± 5.0%
- Certifications: UL Intrinsically safe models available
- Mounting hardware and installation pole allow maintenance removal or installation of sensor without entering the confined space.
- Past NBC experience indicates reliability in this application is not equal to the preferred instrument.

- The preferred instrument is the **Teledyne Isco TIENet 360 LaserFlow Ex sensor and Signature flowmeter**. General specification and installation guidelines for the preferred instrument are noted below.

a. Provide remote mounted meter with multi-parameter data logging, summary reports, USB interface, and Modbus communications.
b. The meter shall be remote mounted in the control structure housing electrical, hydraulic, power, and SCADA equipment. The enclosure shall meet or exceed IP 66 / NEMA 4X rating.
c. Non-contact Doppler Laser sensor shall provide velocity measurements at multiple points below the water surface.
d. Permanent mounting hardware with sensor retrieval arm shall be provided for installation and removal without confined space entry.
e. The sensor shall be certified for use in a Class I, Division 1 hazardous location with the use of intrinsically safe barriers.

1.3 Tunnel Level Measurement (Tunnel volume):

Tunnel level measurement applies at the Launch Shaft/Screening Shaft and at the Receiving Shaft Structure. Tunnel Level Measurement at the Launch/Screening and Receiving Shafts shall be provided through the use redundant level measurements. Technologies and features are noted below.

- Bubbler system: Bubblers level measurement senses head pressure on the end of a bubbler tube. Bubblers provides a means to locate pressure transmitters, switches, gauges, compressors, and control solenoids in a controlled area, accessible for maintenance. Only the tubing is located in the process area. A bubbler arrangement is beneficial in deep structures, such as drop shafts to provide local level measurement. The local measurement of tunnel depth can be used for gate control, if communications to the tunnel pump station were interrupted. Bubbler design requires redundant systems and standby UPS power for solenoid controls. Use of larger air tanks provides extended operating time, in the event of a power outage.
- Radar: Non-contact radar level measurement works well in areas with water vapor or surface foaming. While both non-contact radar level measurement and non-contact ultrasonic level measurement provide the desirable features of reduced maintenance and simplified maintenance access, ultrasonic sensors may experience signal interruptions under water vapor and foaming conditions. For this reason, radar level measurement has been selected. NBC has successfully installed VEGAPULS 69 (Narrow beam – Silo Application) transmitters for Tunnel Volume in installations similar to requirements for this project.

Note: While submersible Hydrostatic level sensors can serve to measure a wide range of depths and process fluid conditions, they are not recommended in this instance. NBC had several installations that are no longer functional or have been removed. Accessibility, as well as potential physical damage or interference from debris and grit, has been an issue.

- The preferred Primary instrument is the **VEGAPULS 69** as manufactured by **VEGA**. General specification and installation guidelines for the preferred instrument are noted below.

  a. Provide long range (up to 120 meters), narrow beam radar sensor with integral display.
  b. Provide sensor mounted in accessible location at the surface for maintenance.
  c. The transmitter enclosure shall be an aluminum housing that meets or exceeds IP 66 / NEMA 4X rating.
  d. The sensor shall be certified for use in a Class I, Division 1 hazardous location.

- The preferred Secondary instrument is the bubbler level system, constructed around standard components and configuration. General specification and installation guidelines for the preferred instrument are noted below.

  a. Where tunnel level measurement is required, one or two complete bubbler assemblies shall be provided. Bubbler assemblies include filter regulator, differential regulator, air flow meter, pressure relief, differential pressure transmitter with local display, isolation and purge solenoid valves, and manual isolation and bleed valves. Standardized bubbler assemblies shall be provided under the fit-out Contract.
  b. Each bubbler assembly shall include a 3/8" bulkhead union for interface to the bubbler tubing provided under Gate and Screen Structure Contracts.
  c. The Tunnel DB Contract shall provide bubbler tubes (2) carrier pipes for the receiving shaft. The bubbler tubing shall be 3/8" ID HDPE tubing with stainless steel fitting at the tip of the bubbler tube.
  d. The rigid, corrosion resistant, carrier pipes may be surface mounted on the shaft wall if designed to withstand impact and load from debris. The carrier pipes may also be embedded in the shaft wall. Carrier pipes and any related stilling wells or end bells shall be rigid metal.
  e. After installation, the bubbler tube shall be tested at 135 psi and the final elevation of the end of the bubbler tube documented for coordination with the fit-out Contract.
  f. An air compressor with upper operating pressure of 135 psi and 30-gallon receiver, minimum, shall supply air to the bubbler assemblies under the fit-out contract. Gate and Screen Structure Contracts shall allow space for compressor, receiver and bubbler panel approximately 30" W x 48" H x 16"D.

1.4 Diversion Structure Level Measurement:

Level measurement applies to wet weather flows measured in Diversion Structures.

a. Non-contact radar level measurement is preferred in gate diversion structures and other structures near grade. Radar works well in areas with water vapor or surface foaming. While both non-contact radar level measurement and non-contact ultrasonic level measurement provide the desirable features of reduced maintenance and simplified maintenance access, ultrasonic sensors may experience signal interruptions under water vapor and foaming conditions. For this reason, radar level measurement has been selected..

- The preferred instrument is the **VEGAPULS 66** as manufactured by **VEGA.** General specification and installation guidelines for the preferred instrument are noted below.

a. Provide radar sensor with range and mounting integral display.
b. Provide sensor mounted in accessible location at, or near, the surface for maintenance.
c. The transmitter enclosure shall be an aluminum housing that meets or exceeds IP 66 / NEMA 4X rating.
d. The sensor shall be certified for use in a Class I, Division 1 hazardous location.

1.5 Tunnel, Diversion Structure, Control Vault Level Switches:

Float type level switches provide an effective back-up indication of high level, flooding, and sump pump controls.

- The preferred switches are as manufactured by **Flygt, Kari, or equal**. General specification and installation guidelines for the preferred instrument are noted below.

a. Float Switches in hazardous locations shall be provided in intrinsically safe barriers.
b. Float switches shall be mechanical type switches.

1.6 Gas Monitoring Measurement (Health and Safety Occupancy Monitoring):

Gas Monitoring Measurement applies to structures related to Gate and Screen or Division facilities.

a. The Design Consultant shall review each structure within the design to evaluate requirements for Combustible Gas Monitoring under NFPA 820 code requirements, as well as personnel safety and equipment protection. Where combustible Gas monitoring is required, sensors shall be placed both high and low in the station to monitor for methane as well as other combustible gases.
b. The Design Consultant shall review each structure within the design to evaluate use of oxygen and toxic H_2S monitoring for personnel safety. It is anticipated permanent sensors shall not be installed and confined space entry procedures

shall provide monitoring for personnel protection. However, each structure shall be reviewed independently during design.

c. When available, infrared type sensors are preferred over catalytic bead type for length of life and simplified maintenance.
d. The gas monitor system shall be connected to alarm stations visible to operations and maintenance personnel. Alarm station enclosures shall be rated for the area in which they are located. Interior alarms shall include an audible horn.

- The preferred instrument for combustible gas monitoring is the **MSA Ultima XIR**. The preferred instrument for oxygen and toxic gas monitoring is the **MSA Ultima X Series, Model XE**. General specification and installation guidelines for the preferred instrument are noted below.
  a. The transmitter enclosure shall be an aluminum housing that meets or exceeds IP 66 / NEMA 4X rating.
  b. The sensor shall be stainless steel certified for use in a Class I, Division 1 hazardous location
  c. Sensors not accessible at operator level shall be provided with weather cap and calibration tubing.
  d. Provide calibration/test kit including calibration gases.

1.7 Gate Position Measurement:

Gate Position Measurement applies to Gate and Screen Structures

a. If hydraulic gate actuators are used, gate end of travel switches and gate position transmitters shall be required for control feedback.
b. Position switches and transmitters must be either rated for Hazardous locations or provided with intrinsically safe barriers.

- The preferred instrument for gate position is the **MTS R-Series** analog position sensor with **type HPH** high pressure housing. The preferred instrument for gate end of travel switches is the TopWorx **Go-Switch Precision Sensing** switches. General specification and installation guidelines for the preferred instrument are noted below.

  a. The position sensor enclosure shall be a stainless housing that meets or exceeds IP 68 rating.
  b. End of travel switches shall be stainless steel with submersible wiring connector.
  c. The position sensor and end of travel switches shall be certified for use in a Class I, Division 1 hazardous location.
  d. The position monitoring installation shall allow for maintenance access to the sensor and the required clearance for removal and replacement of the sensor and sensor rod.
  e. Monitoring switches and sensor shall be mounted above maximum elevation of flows through the gate structure.

f. Alternate, equal, means to monitor gate position as recommended by the gate manufacturer may be submitted for NBC review and consideration at the time of design.

1.8 Monitoring Requirements for Hydraulic Power Units for Gate Actuation:

Monitoring Requirements for Hydraulic Power Units applies to Gate and Screen Structures

a. Design requirements for HPUs must clearly define the pressure monitoring and level monitoring instruments for operation and monitoring of the packaged system.
b. The vendor package shall include instruments to provide the following points: Hydraulic Pump Lead Start, Lag Start, and Stop pressures, High and Low-Pressure Alarms, High Temperature Alarms, High and Low Tank Level, and Leak Alarm.

- The preferred instrument providers are as recommended by the manufacturer, in conformance to specification guidelines. General specification and installation guidelines for the preferred instrument are noted below.

  a. Transmitter and switch enclosures shall be aluminum or stainless steel housing that meets or exceeds IP 66 / NEMA 4X rating.

1.9 Control Building / Vault for Gate and Screen Structure / Drop Structure General Requirements:

The following monitoring Requirements apply to Gate and Screen Structure.

a. Remote buildings and vaults and exposed enclosures shall include intrusion limit switches suitable for the location
b. Remote sites shall, at a minimum, include power monitoring or loss of power relays for remote monitoring of loss of power, undervoltage, and phase imbalance conditions.
c. Facility room temperature measurements and switches shall be as required by the HVAC design.

- The preferred instrument for control vault intrusion is **Square D 9007**. General specification and installation guidelines for the preferred instrument are noted below.

  a. The enclosure shall be heavy duty with switch housing that meets or exceeds IP 66 / NEMA 4X rating.

1.10 General Instrument Requirements.

In addition to requirements listed above, the following General Instrument Requirements apply:

a. "Smart" instruments may be utilized where cost effective, with hardwired instruments in all other cases. Analog signals shall be 4-20mA/HART.
b. Outdoor instruments must be designed with appropriate environmental considerations
c. Instruments located in Class I, Division 1 and 2 hazardous locations must be designed with appropriate environmental considerations.
d. 24VDC, loop-power instruments shall be the preferred when available.
e. Provide surge protection on all panels and generate a signal alarm back to SCADA. Phoenix Contact PlugTrab preferred by NBC based on the current installed base.

1.11 Governing Codes.

At a minimum, the listed codes and standards shall be followed:

- Underwriters Laboratory (UL)
- International Society of Automation (ISA)
- National Electrical Code (NEC)
- National Electrical Manufacturer's Association (NEMA)
- National Fire Protection Association (NFPA)
- NEC 2017 (NFPA 70-2017): National Electrical Code
- NFPA 820-2016 – Standard for Fire Protection in Wastewater Treatment and Collection Facilities

Section 2.0
Instrument Summary

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2.0 Instrument Summary

Provided below is an initial recommendation of targeted instrumentation to serve as basis of design. It is acknowledged that State procurement rules shall govern in defining product specifications, design criteria, acceptable manufacturers, etc. A sole source strategy may be warranted in specific instances to assure proper integration and consistency in product operating experience. Where a specific model or series is listed in Section 1 as the preferred instrument, the model or series is repeated in the table below. Some instruments listed below may not apply to the Gate and Screen or regulator sites, but are included here from program reference.

Table 2-1 Instrument Selection

Measurement	Sensor Type	Preferred Manufacturers and Model
Flow Measurements	Open Channel	Teledyne TIENet 360 LaserFlow Ex sensor and Signature flowmeter
Flow Switches	Thermal	Fluid Components, Inc. FTL93
Level Measurements	Radar	Vega VEGAPULS 69 (Tunnel Level Primary)
Level Measurements	Radar	Vega VEGAPULS 66 (Diversion Structure)
Level Measurements	Bubbler	Rosemount, Endress and Hauser Differential pressure and Various components (Tunnel Level Secondary secondary)
Flood Switches	Float	Flygt, Kari
Pressure Measurements	Gage Pressure	Endress Hauser, Rosemount 3051C
DP Measurements	Differential Pressure	Endress Hauser, Rosemount 3051CD
Pressure Gages	Bourdon	Ashcroft, Ametek
Pressure Switches	Pressure	Ashcroft, United Electric
Gas Monitoring Measurements	Combustible	MSA Ultima XIR
Gas Monitoring Measurements	Oxygen, H_2S	MSA Ultima XE
Gate Position Measurement	Continuous	MTS R-Series with HPH housing
Gate Position Switch	End of Travel Limit	TopWorx Go Switch Precision Sensing

Appendix G – Design Opinion of Probable Construction Costs (OPCC) Guidelines

Phase III CSO Program
Technical Memorandum

To:	Design Consultants	**Date:**	September 24, 2019
		CC:	Sean Searles, Stantec Melissa Carter, Stantec Chris Feeney, Stantec Brandon Blanchard, Pare Corp.
From:	Todd Moline MWH Constructors Construction Manager		
Reviewed by:	Chris Feeney, Stantec		
Subject:	Opinion of Probable Construction Costs (OPCC) Guidelines		

This memorandum presents additional guidelines for the preparation of opinions of probable construction costs (OPCC) for the NBC Phase III CSO Program. For NBC and the Program Manager to compare unit and total costs between different projects of the Program, it is important that the cost data and organization of each OPCC be developed using identical procedures. The following guidelines are provided for the preparation and reporting of OPCCs:

1. All costs anticipated to be included in the general contractor's bid must be itemized and listed in the OPCC including general requirements (office trailers, on-site supervision, temporary utilities, general contractor's vehicles, phone and IT, etc.), permits, insurance and any other applicable items.
2. All line items listed in the OPCC must be identified by major structure (i.e., gate & screening structure, 60" consolidation conduit, 48" consolidation conduit, etc.) and CSI code. OPCCs must be sortable by structure and by CSI code. Items that pertain to all structures or the entire site should be coded as general requirements, sitework, electrical or other appropriate name.
3. General requirements, permits, and some insurance costs may be estimated as a percentage of the total cost of construction. However, these costs are to be listed as distinct line items in the OPCC without any markup.
4. ***For the unit cost and total cost of each item of the OPCC, do not include any markups to account for general requirements, other indirect costs, any other contractor expenses, or general contractor's overhead and profit.***
5. Except for work that is assumed to be subcontracted (i.e., electrical, paving, etc.), all unit costs and total costs in the OPCC will assume the task is self-performed by the general contractor. The costs will include only those elements listed in Item 6. Costs will not include markups for any other indirect costs or for overhead and profit. See Item 6e for work assumed to be performed by a subcontractor.
6. None of the unit costs or total costs listed in the OPCC will include markup. Costs will include only:
   a. Labor – Wages, fringes, vacation, holidays, payroll taxes and insurance (workers comp, general liability and unemployment).
   b. Material – Cost of materials (no tax on permanent materials), transportation and storage, and any other costs associated with materials.
   c. Equipment – All costs of construction equipment either rented or owned. Rental costs include rental costs plus and operating costs. Owned equipment costs include ownership and operating costs.

   d. Subcontractors – Quoted costs from subcontractors. If the OPCC for an assumed subcontracted item is estimated by the Design Consultant, the subcontractor cost will be estimated using the above costs for labor, equipment and materials, plus 15% for subcontractor's other indirect costs and 10% markup for subcontractor's overhead and profit.
   e. Services and other expenses – Cost of other insurances, permits, supplies and equipment.
7. Mobilization costs may only be listed for actual mobilization costs for equipment such as cranes, site work equipment, or other specialized equipment with transportation and/or setup costs.
8. When using weighted average unit prices (WAUP) data and other published or historical cost data, it is essential to understand if the unit costs include markup. If a unit cost contains a markup, the markup must be removed from the unit cost. Otherwise, the OPCC of the project will be inflated by markups in the unit cost compounded by the markup in the OPCC. In addition, it is important for the Program Manager to compare costs of items within an OPCC with those of earlier OPCCs or OPCCs performed by others. Proper comparisons cannot be made if the items of some OPCCs contain markups and others do not.
9. The only markup applied to the OPCC is the general contractor's overhead and profit which will be approximately 12%. It is applied to the total cost of the work.
10. An appropriate contingency will be included in the OPCC based on the total cost excluding the general contractor's overhead and profit.
11. Do not include costs for engineering services during construction.

A template for the organization of OPCC is provided in Figure 1.

Figure 1 - OPCC SUMMARY TEMPLATE
NBC Phase IIIA CSO Program

CSI Section	Description	Unit	Quantity	Unit Cost	Total
GENERAL REQUIREMENTS					
	Supervision (GC Staff Labor)	month			
	Temporary Facilities & Office Equip./Supplies	month			
	Temporary Utilities	month			
	Site Security	month			
	Insurance	LS			
	Bonds	LS			
	Permits	LS			
	Health and Safety Equipment & Supplies	LS			
	Mobilization (Site Setup)	LS			
	Security	month			
	Condition Survey	LS			
	Subsurface Explorations	LS			
	Weather Protection/Temporary Heat	LS			
	Geotechnical Monitoring	month			
	Erosion Controls	LS			
	Traffic Management	LS			
	Soil and Concrete Testing	LS			
	Pipe Testing	LS			
	TV Inspections	LS			
	Final Cleaning	LS			
SITE					
02000	Site Work				
	Clearing and Grubbing	SY			
	Paving	SY			
	Landscaping	SY			
	Sidewalks and Curbing	SY			
16000	Electrical				
	Electrical	LS			

GATE & SCREENING STRUCTURE					
02000	Site Work				
	Temporary Support of Excavation	LS			
	Dewatering	LS			
	Excavation	CY			
	Backfill and Compaction	CY			
	Soil Mangement and Disposal	CY			
03000	Concrete				
	Cast-in-Place Concrete	CY			
	Precast Concrete	LS			
04000	Masonry	SF			
05000	Miscellaneous Metals	LS			
110000	Equipment	LS			
	Gates	Each			
	Screens	LS			
15000	Mechanical	LS			
16000	Electrical	LS			
17000	Instrumentation and Controls	LS			
DIVERSION STRUCTURE					
	Breakdown by CSI sections as above				
CONSOLIDATION CONDUIT					
	Breakdown by CSI sections as above				
APPROACH CHANNEL					
	Breakdown by CSI sections as above				
LOWER BVI RELIEF STRUCTURE					
	Breakdown by CSI sections as above				
				Subtotal	
				General Contractor's Overhead & Profit (10%-12% of Subtotal)	
				Contingency (20% of Subtotal)	
				Total	

Appendix H – Design Program Standards – Slide Gates & Actuators

Phase III CSO Program
Memorandum

To: Design Consultants (DC)

CC: Kathryn Kelly, Sean Searles, Melissa Carter

Date: February 24, 2020

From: Chris Feeney, Lin Lang

Reviewed by: Keith Gardner

Subject: Program Standardization – Slide Gates and Actuators

Introduction

This Technical Memorandum (TM) provides information to assist NBC in developing a program standard for the control gates located in the gate and screening structures (GSS) to isolate flow to the tunnel. Each design consultant (DC) shall be responsible for developing a site-specific design based on the program standards.

There are four (4) GSS structures to control flow into the tunnel at each of the drop shafts: OF-218, OF-213, OF-205, and Upper BVI. Each GSS has an influent and an effluent isolation gate located on the upstream and downstream side of the GSS, respectively. The purpose of the control gates is to isolate flow to the Pawtucket Tunnel to prevent overfilling during large storm events (i.e. >3-month). The gates are operated by a central SCADA system based on the water level in the tunnel. The gates are normally in the open position unless the tunnel is full. The gates are strictly isolation gates; modulation is not a requirement.

The gates shall be designed in accordance with the following criteria. Any deviation from these criteria shall be presented to the PM and NBC prior to incorporating into a design. Provided below is a summary of design goals/criteria organized in the following heading:

- Gate Type/Material
- Gate Sizing and Design Head
- Gate Installation
- Actuator
- Closure Time/Travel Speed
- Gate Operation and Control

Gate Type and Material

For the purposes of this memo, the terms slide gate and sluice gate will be used interchangeably. It is noted that AWWA has updated standards and moved in the direction of using the term “slide gate”. Gates are chosen based on intended function and location/environment. The recommended gate material is stainless steel. Cast iron gates (AWWA Standard C560) would only be considered at locations where the maximum operating heads dictated usage.

The gate shall be Type 316L stainless steel slide gate meeting ANSI/AWWA C561-14: Fabricated Stainless-Steel Slide Gates. Type 316L is required to resist corrosion associated with sewage and elevated chloride content from roadway de-icing salt application in winter.

Field leakage test shall be performed to meet the requirements in the AWWA C561-14 standards.

Available slide gate manufacturers are listed below:

- Rodney Hunt Inc
- Whipps, Inc.
- Waterman
- Hydro Gate
- Golden Harvest, Inc.
- RW Gates

Gate Size and Design Head

The upstream gate shall be sized to correspond to the incoming consolidation conduit dimensions. The downstream gate shall be sized to correspond to the outgoing approach channel dimensions. Both gates shall be designed to the maximum head condition (seating or unseating) listed below (Table 1).

There are a total of four (4) GSS structures to control flow at the following drop shafts: OF-218, OF-213, OF-205, and Upper BVI. Provided below in Table 1 is a summary of gates and operating conditions at each outfall location.

Table 1 – Gate Sizing by Location[1]

Location	Gate Size/Opening (influent)	Gate Size/Opening (effluent)	Max Head (feet)
OF-218	8-ft by 10-ft 5-ft by 5-ft	8-ft by 8-ft	32.0
OF-213	6-ft by 6-ft	6-ft by 6-ft	15.4
OF-205	6-ft by 6-ft	6-ft by 6-ft	11.2
Upper BVI	5-ft by 5-ft	6-ft by 6-ft	15.0

[1]It shall be the responsibility of DCs to verify maximum operating head based upon site specific conditions and modeling parameters. Each team shall submit an RFI to verify maximum operating head conditions.

Actual gate sizes to be finalized to isolate flows based on final pipe/channel opening sizing of incoming consolidation conduit and approach channels. Design Consultants shall coordinate with manufacturers to size gates based on opening dimensions.

Gate Installation

The gates shall be mounted to Type 316L wrought stainless steel wall thimbles embedded into the structure wall with flush bottom closure.

Actuators

During Phase II, NBC moved from electric actuators to hydraulic actuators. The primary basis for the change in actuators was to eliminate the need for stand-by generators. The hydraulic reservoirs for the actuator can be specified to have reservoir capacity to provide fail safe operation. The gate would be programmed to fail in the closed position during loss of power. The actuator and gate in operation at G-8, located at Paul Cauffee School, is manufactured by Rodney Hunt.

Placement of the actuator is a primary driver in selecting hydraulic actuator type and style. The height of the GSS and long-term end use at surface factor into decision making. The minimum distance from top of opening to roof slab needs to accommodate the gate in a full open position and fit an enclosed hydraulic cylinder for submerged applications (if applicable). If future land-use can accommodate gate stems above grade, the actuator can be located above grade. For this application, the actuator components can be located above grade, which is preferable. If future land-use cannot accommodate above grade installation, then the actuator would need to be either a sealed or a split system. Below grade actuator components would require rating for NEMA 7 and full submergence.

The slide gates shall be equipped with hydraulic actuators to open and close the gates. The hydraulic actuation system shall comply with the requirements in AWWA C540 – Power Actuating Devices for Valves and Sluice Gates. Using hydraulic actuators eliminates the need for stand-by generators required for electric actuators.

The actuator shall be designed for fail safe operation (i.e. close under loss of power). The actuator can be mounted above grade or under the roof slab of the GSS, depending on site-specific project limitations.

The hydraulic reservoirs for the actuator shall be specified to have reservoir capacity for one cycle. As previously noted, the actuator shall be programmed to fail in the gate close position during loss of power. The actuator shall have the option for manual operation using power drills (preferred) or hand pumps. The actuator shall be operable under submerged condition under maximum operating head conditions.

For OF-218 and OF-205, the actuator can be located on top of the GSS for easy access and maintenance. For OF-213, the actuator can be located either above or below grade depending on the future end use of the site. For Upper BVI, the actuator shall be located below grade within the GSS. It is noted that headroom may be a limiting factor at this location.

The hydraulic power units shall be located inside of the proposed headhouse near the GSS.

High grade petroleum-based hydraulic oil is preferred for operational reliability. Biodegradable or “food” grade hydraulic fluid may be an option given containment requirements and proximity to river.

Available actuator manufacturers are listed below:

- Rodney Hunt
- Trident
- Rexa

Closure Time/Travel Speed

Gate closure time is considered while developing a control strategy to initiate gate closure at a defined tunnel elevation to achieve the targeted storage volume. Balancing closure time with prediction of inflow rates is an important factor to the control strategy to avoid under or overfilling the tunnel. The hydraulic actuator shall be designed to achieve a travel speed of 2-ft/min. Variable speed shall only be considered if site-specific conditions are warranted. Hydraulic actuators can be equipped with VFDs, resulting in increased cost and complexity. At this stage, VFDs are not necessary to meet the proposed controlled strategy.

Gate Operation and Control

The GSS structures in Providence are equipped with a heavy-duty sluice gate (i.e. primary control gate) at the effluent side of GSS and a lighter duty gate (i.e. maintenance/isolation gate) on the influent side. The purpose of the influent gate is to protect operators from entrapment during an unanticipated high flow event. The lighter duty gates are not designed to withstand maximum operating head without damage. The primary control/sluice gates are designed for maximum head conditions without risk of unseating.

An early recommendation adopted for the Pawtucket Tunnel is to utilize heavy duty gates both upstream and downstream of GSS for flow isolation purpose. A Program requirement is to maintain redundancy at each drop shaft structure with two means of isolation. Each gate shall be designed withstand maximum operating head without damage. This revised standard would also meet the safety objective of protecting against entrapment during unanticipated high flow events.

The site-specific control strategy can assign each gate as primary or secondary. The operator can designate the upstream or downstream slide gate as the primary isolation gate and the other as standby isolation gate. During normal operation, all gates are in open position. When the water level in the tunnel reaches defined maximum operating elevation, closing of the primary isolation gate will be initiated until it is fully closed. The standby isolation gate can remain open. During man-entry maintenance of GSS, both gates will be closed. During loss of power, both gates will be automatically closed via the hydraulic actuator. Hydraulic actuators shall be equipped with an accumulator to provide fail safe operation.

Conclusion

The purpose of this TM is to provide program standardization of gates used at each of the four (4) GSS. DCs shall review the materials presented to gain an understanding of the design criteria to be utilized. The general goal is to provide standardized approach to gate design. DCs shall retain full design responsibility to design and specify gate and gate actuators based on site-specific conditions. Site specific limitations or opportunities may warrant deviations from this guidance. It is recommended that the individual design teams notify the PM/CM and NBC accordingly.

In general, NBC has a strong preference for installing actuator components above-grade to the maximum extent practical. If actuator components are to be installed below grade, then components shall be sited in a manner to maximize access to aid equipment removal. NBC has concluded that gate stems can protrude above grade for the structures located at OF-218, OF-213, and OF-205.

Appendix I – American Iron and Steel (AIS) Requirements

Phase III CSO Program
Technical Memorandum

To:	DCs, PMs	**Date:**	April 14, 2020
From:	Chris Feeney, Dara Wais	**CC:**	Kathryn Kelly, Melissa Carter
Reviewed by:	Brandon Blanchard		
Subject:	American Iron and Steel Requirements		

Introduction

This Technical Memorandum (TM) provides information and clarity on the Environmental Protection Agency (EPA) American Iron and Steel (AIS) provision that will assist in choosing products for the construction of Phase III Facilities as part of the Narragansett Bay Commission (NBC) Combined Sewer Overflow (CSO) Program. These projects will be funded by the Water Infrastructure Finance and Innovation Act (WIFIA) loans and/or State Revolving Funds (SRF). Both of these programs have like requirements for domestic iron and steel. This TM will list products that need to comply with AIS, manufacturers that comply and provide products needed on the Program, approved waivers, and how to request a waiver. The information included is current as of the date of this TM; therefore, designers should always refer to the EPA AIS web site for the most recent updates.

AIS Compliance

Since January 17, 2014, all plans and specifications issued to a state agency authorizing funds under the SRF program requires domestic iron and steel provisions except where otherwise allowed, as noted herein. The SRF AIS website, https://www.epa.gov/cwsrf/state-revolving-fund-american-iron-and-steel-ais-requirement, states that this requirement applies to projects for the construction, alteration, maintenance, or repair of a public water system or treatment works. According to Section 212 Definitions 2A of the Clean Water Act, "the term "treatment works" means any devices and systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature to implement section 201 (Purpose) of this act, or necessary to recycle or reuse water at the most economical cost over the estimated life of the works, including intercepting sewers, outfall sewers, sewage collection systems, pumping, power, and other equipment, and their appurtenances; extensions, improvements, remodeling, additions, and alterations thereof; elements essential to provide a reliable recycled supply such as standby treatment units and clear well facilities; and any works, including site acquisition of the land that will be an integral part of the treatment process (including land use for the storage of treated wastewater in land treatment systems prior to land application) or is used for ultimate disposal of residues resulting from such treatment."

The EPA issued an Implementation Memorandum in 2014 that uses the term "iron and steel products" to refer to products made primarily of iron or steel, meaning products greater than 50 percent iron or steel, measured by cost. The following iron and steel products are subject to AIS requirements:

- Lined or unlined pipes and fittings
- Manhole covers and other municipal castings
- Hydrants
- Tanks
- Flanges
- Pipe clamps and restraints
- Valves
- Structural steel
- Reinforced precast concrete
- Construction materials (articles, materials, or supplies made primarily of iron and steel that are permanently incorporated into the product, not including mechanical and/or electrical components, equipment and systems).

Production in the United States requires that all manufacturing processes, including melting, refining, forming, rolling, drawing, finishing, fabricating, and coating, must take place in the United States, with the exception of metallurgical processes involving refinement of steel additives. A domestic iron and steel product taken out of the United States for any part of the manufacturing process becomes foreign source material. Raw materials such as iron ore, limestone, and iron and steel scrap are not covered by the AIS requirement. Non-iron and steel components do not have to be of domestic origin.

Sluice gates, needed at each gate and screening structure for the NBC CSO project, are listed in EPA's Implementation Memorandum as non-construction materials, so they are not subject to AIS requirements. Gate valves are subject to AIS compliance.

Approved National Waivers

If a national waiver is granted, it does not need to be applied for again. The EPA has approved the following national waivers:

- De Minimis Waiver: Allows use of products when they occur in de minimis incidental components. These funds cumulatively comprise of no more than 5 percent of the total cost of materials used in and incorporated into a project; cost of an individual item may not exceed 1 percent of total cost.
- National Product Waiver for Minor Components within Iron and Steel Products (with Cost Ceiling): Allows use of non-domestically produced miscellaneous minor components within an otherwise domestically produced iron and steel product for up to 5 percent of the total material cost of the product.
- Final Extension of Short-Term National Product Waiver for Stainless Steel Nuts and Bolts used in Pipe Couplings, Restraints, Joints, Flanges, and Saddles (sunsets Feb 24, 2020): Permits the purchase and use of non-domestically produced stainless steel nuts and bolts in bolting-type pipe couplings, restraints, joints, and repair saddles in iron and steel products.
- National Product Waiver for Pig Iron and Direct Reduced Iron: Permits the use of pig iron and direct reduced iron manufactured outside of the United States in domestic manufacturing processes for iron and steel products.
- Plans and Specifications Waiver: Permits use of non-domestic iron and steel products where plans and specifications were submitted to a state agency prior to and including January 17, 2014.

Approved Project Waivers

Product specific project waivers apply only to the specified product and proposed project referenced in the waiver. A separate waiver would have to be applied for if wishing to use a similar product on the Program. For example, if a butterfly valve has been approved for in the past, a new project specific waiver would have to be applied for any project. The EPA has repeatedly approved project waivers that involve the following products:

- Butterfly, insertion, air release/vacuum, plug, gate, plunger, ball, check valves (most requests for valves)
- Flex-ring and flex pipe fittings
- Steel fiber reinforcement
- Ductile iron flanges

It should be noted that steel fiber reinforcement has been procured domestically in recent years. See description below.

Requesting a Waiver

The EPA can issue waivers when applying AIS requirements would be inconsistent with the public interest, iron and steel products are not produced in the United State in sufficient and reasonably available quantities and of a satisfactory quality, or inclusion of iron and steel products produced domestically will increase the cost of the overall project by more than 25 percent. A waiver may be granted if a CWSRF or DWSRF recipient can justify one of the above claims. The following EPA website provides general steps to request a waiver: https://www.epa.gov/cwsrf/american-iron-and-steel-requirement-waiver-request-process.

First, the community prepares the waiver request, including project specifications for the product, and submits it to the State SRF. The State SRF then reviews and submits the request to the EPA; cwsrfwaiver@epa.gov for

CWSRF waiver requests. Following the email submission, the EPA posts the waiver request for public comment for 15 days. EPA then provides a response and posts it on the website.

The waiver needs to include the following information:

- Description of the foreign and domestic construction materials
- Unit of measure
- Quantity
- Price
- Time of delivery or availability
- Location of the construction project
- Name and address of the proposed supplier
- A detailed justification for the use of foreign construction materials
- Demonstration of good faith effort made to solicit bids for domestic iron and steel products
- Comparison of overall cost of project with domestic iron and steel products to overall cost of project with foreign iron and steel products
- Relevant excerpts from bid documents used by the contractors to complete the comparison
- Supporting documentation indicating that the contractor made a reasonable survey of the market
- Supporting documentation necessary to demonstrate the availability, quantity, and/or quality of the materials for which the waiver is requested:
  - Supplier information or pricing information from a reasonable number of domestic suppliers indicating availability/delivery date for construction materials
  - Documentation of the assistance recipient's efforts to find available domestic sources, such as a description of the process for identifying suppliers and a list of contacted suppliers
  - Project schedule
  - Relevant excerpts from project plans, specifications, and permits indicating the required quantity and quality of construction materials
- Statement from the prime contractor and/or supplier confirming the non-availability of the domestic construction materials for which the waiver is sought

Approved AIS Manufacturers

Specific to the Pawtucket Tunnel, there were questions regarding the doweling system suggested by both DB teams, as well as the steel fiber reinforcing. The following manufacturers are AIS compliant and are therefore options to consider for products to construct the Pawtucket Tunnel.

Klug Construction Systems, LLC manufacturers AIS compliant products if requested. Their SOF FIX ASY 110 dowel system and Vertex Removable and Replaceable Anchored Gasket (RRAG) System are examples of AIS compliant products.

Bekaert complies with AIS requirements, as indicated by their certificate of compliance for Dramix steel fibers for use in reinforcing concrete segments.

Red Valve Company is compliant to AIS stipulations. All iron and steel hardware components in Red Valve and Tideflex products are poured and cast in the United State. This includes all rings and clamps used in TideFlex and CheckMate UltraFlex Check Valves. Their diffusers are AIS compliant options for the marine outfall.

Conclusion

The purpose of this TM is to provide guidance for Design Consultants (DCs) when considering and selecting products and specifications that require compliance with AIS requirements. DCs are responsible for identifying any products that may not be available domestically that may require a waiver. In general practice, it is difficult to receive an approved waiver. Other options should be heavily considered before applying for a waiver. It is important to identify these issues during design.

Please feel free to contact the program team with any questions.