PRELIMINARY PLAN OF CORRECTION
WASTE OIL TANK
1628 WEBSTER STREET

ALAMEDA, ALAMEDA COUNTY, CALIFORNIA

LRA ENVIRONMENTAL JOB NUMBER E8936

STEP ONE: Obtain soil samples from three (3) borings located adjacent to the sides of the tank, and at the fill end of the tank at a distance of eight (8) to ten (10) feet from the furthest extent of the tank removal excavation. Given the laboratory results of the soil analysis indicating concentrations of Total Petroleum Hydrocarbon and Oil and Grease below laboratory detection limits at the vent end of the tank no additional boring will be placed at that location.

Under the direction of a State of California Registered Engineering Geologist soil samples will be acquired from each of the three borings at intervals of five (5) feet or at every change in lithology. Collection of the samples will commence at the surface of the soil underneath the currently existing parking lot and will terminate at a depth of fifteen (15) feet. All borings will be drilled by utilizing truck mounted drilling equipment equipped with eight (8) inch outside diameter continuous flight augers.

In each boring the Engineering Geologist will log the soils encountered. The logs of the borings will be presented in the preliminary report. Upon terminating the drilling and sampling operation, the boring will immediately be backfilled with neat Portland cement to grade.

Soil samples from each major stratigraphic unit will be collected for particle size analysis and determination of vertical permeability. Samples will be acquired by advancing either a two and one half (2 1/2) inch diameter modified California or split-spoon sampler into the soils a minimum of eighteen (18) inches using a one hundred and forty (140) pound hammer dropped thirty (30) inches. Blow counts will be recorded for every six (6) inch segment of the eighteen (18) inch drive, and will be included in the boring logs.

The soil samples will be retained in six (6) inch brass tubes contained in the sampling device. Those samples acquired for the purpose of chemical analysis will be sealed at both ends with aluminum foil sheets and then sealed with plastic end caps and taped. The samples will then be stored and transported to the laboratory in an ice chest filled with dry ice. The samples not being subjected to chemical analysis will be analyzed by field methods for volatile organic compounds. This procedure will consist of emptying the contents of the brass tube into a "ziplock" style plastic bag. The bag and its contents will be placed in the direct sunlight for a period of time, and then the bag will be pierced and the "headspace " within tested for volatile organic compounds with a portable photoionizing hydrocarbon detection device. Results of the field analysis will be included in the preliminary report.

Based upon the headspace test results and field observations any sample with apparent contamination will be subjected to laboratory analysis. A sample from the first or second interval below the level believed to be affected will be analyzed to facilitate assessment of the vertical extent of contaminant migration. In event of no detectable contamination, those samples nearest the level of the bottom of the existing tank excavation will be arbitrarily analyzed in conjunction with those samples acquired from the first or second sampling interval below the level of suspected contamination.

Chemical analysis of the soil samples remanded to the custody of the analytical laboratory will consist of the following tests:

#1: Total Petroleum Hydrocarbons (diesel)
#2: Total Oil and Grease
#3: Benzene, Toluene, Xylene, Ethylbenzene
#4: Chloronated Hydrocarbons
#5: Detectable metals (Cd, Cr, Pb, Zn)
#6: Method 8270 (PCB's, PNA's, PCP, Creosote)

Drilling equipment including but not limited to samplers, drop hammer, drill rods, plugs, auger, etc. will be steam cleaned prior to use in each soil sampling location. Cleaning will be conducted in such a manner so as to contain the wash water, which will be contained in the appropriate drums, labeled, sealed and stored onsite prior to appropriate disposal. Sampler parts not subjected to steam cleaning will be triple rinsed in two tap water immersions and then distilled water after being decontaminated in a solution of Alconox and water. These rinse waters and the decontamination wash will also be contained in the proper drum, sealed, labeled, and stored onsite prior to appropriate disposal.

Auger cuttings (soil from the borings) produced during the drilling operations will be placed in approved drums which will be sealed, labeled, and stored onsite prior to appropriate disposal conditional upon the analytical results.

STEP 2: The environmental consultant will retain a properly licensed well driller to construct and develop a single groundwater monitoring well to be located within ten (10) feet of the fill end of the tank. Results of the particle size analysis and vertical permeability testing will be utilized for the selection of well screen slot size and well filter pack material. It is proposed to construct the monitoring well in accordance to A.S.T.M. Subcommittee D-18.21 proposed recommended practices for design and installation of groundwater monitoring wells. Soil samples will be continuously obtained as the auger is advanced. These soil samples will be subjected to the same testing protocols as the samples obtained from the soils borings.

All work will be under the direct supervision of a State of California licensed Registered Engineering Geologist. Decontamination procedures, soil and wash water storage and disposal will remain unchanged from those procedures utilized for the soils borings.

Prior to the collection of groundwater samples, the well will be purged of a minimum of five (5) wetted casing volumes prior to collection of the sample to be subjected to chemical analysis. Wetted volumes are to be determined in the field at the time the samples are collected.

Water quality parameters consisting of temperature, PH, and specific conductivity will be measured at the beginning and termination of the purging of the well. Appropriate well recovery will be allowed to take place based upon the static water level prior to collecting the sample to be analyzed in the laboratory.

STEP 3: In order to attempt to minimize future impacts to the surrounding environment it is proposed that a **LIMITED** soil removal program be implemented as soon as practicable. Soil from the existing tank excavation, including the material placed back into the excavation after the removal of the waste oil tank should be removed. The excavation should be limited to a depth of three (3) feet below the bottom of the waste oil tank, and extend no further than two (2) to three (3) feet beyond the existing walls of the waste oil tank excavation. Soil removed during this process will of necessity need to be disposed of in an appropriate manner, which will require your acquisition of a U.S.E.P.A. Identification number, retention of a properly licensed waste hauler, and making arrangements through the waste hauler to identify and access the proper disposal site.

The California Department of Health Services can issue a one-time U.S.E.P.A. Number by telephone. You as the property owner must acquire the identification number. Our office cannot act on your behalf in this matter. Contact the Department of Health Services at 1-916-324-1781, or 1-916-324-1790. We have been advised by that agency that this U.S.E.P.A. Identification Number can be utilized for not only the disposal of the excavated soils from the waste oil tank, but also for the disposal of the wash water and auger cuttings from the soils borings and groundwater monitoring well installation. Further information concerning the use of your U.S.E.P.A. Identification Number can be obtained from the issuing officer at the time that you contact the Department of Health Services.

APPENDIX A

PROPOSED RECOMMENDED PRACTICE FOR DESIGN AND INSTALLATION OF GROUND WATER MONITORING WELLS IN AQUIFERS

PUBLISHED BY ASTM SUBCOMMITTEE D18.21

Proposed Recommended Practice for

DESIGN AND INSTALLATION OF GROUND WATER MONITORING WELLS IN AQUIFERS

This proposed recommended practice for the design and installation of ground water monitoring wells is under the jurisdiction of ASTM Subcommittee D18.21 on Ground Water Monitoring. This proposed recommended practice is published herein to provide exposure and solicit comments from users. Suggestions for revision and other comments should be sent to Martin N. Sara, Subcommittee D18.2105. The task group will fully consider all comments and suggestions that provide specific improvements to the proposed recommended practice.

Respectfully submitted,

Martin N. Sara
ASTM Subcommittee D18.21

INTRODUCTION

This recommended practice for the design and installation of ground water monitoring wells in aquifers will promote (a) durable and reliable construction, (b) the integrity of the water quality samples to be extracted, and (c) efficient and complete site hydrogeological characterizations. The guidelines established herein are affected by governmental regulations and by site specific geological, hydrogeological, climatological, topographical, and subsurface chemistry conditions. To meet these geoenvironmental challenges, this guidance promotes the development of a conceptual hydrogeologic model prior to monitoring well design and installation.

1. Scope

1.1 This recommended practice considers the selection and characterization (i.e., defining soil, rock types, and hydraulic gradients) of the target monitoring zone as an integral component of monitoring well design and installation. Hence, the development of a conceptual hydrogeologic model for the intended monitoring zone(s) is recommended prior to the design and installation of a monitoring well.

1.2 These guidelines are based on recognized methods by which monitoring wells may be designed and installed for the purpose of detecting the presence or absence of a contaminant, and collecting representative subsurface water quality samples in aquifers. The design standards and installation procedures herein are applicable to both detection and assessment monitoring programs for facilities.

1.3 The recommended monitoring well design, as presented in these guidelines, is based on obtaining representative ground water from strata that can be classified as an aquifer. The design standard would produce relatively turbidity-free samples for aquifer materials ranging from gravels to silty sand. Strata having grain sized distribution curves smaller than the recommended design for the smallest filter pack materials should be monitored by alternative monitoring well designs.

2. Applicable Documents

2.1 Proposed Standard Guide for the Use of:

Casing Advancement Drilling Methods in Geoenvironmental Site Characterization and the Installation of Subsurface Water Quality Monitoring Devices

Direct Air Rotary Drilling in Geoenvironmental Site Characterization and Installation of Subsurface Water Quality Monitoring Devices

Hollow-Stem Augers for Geoenvironmental Site Characterization and the Installation of Subsurface Water Quality Monitoring Devices

Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Site Characterization and Installation of Subsurface Water Quality Monitoring Devices

2.2 ASTM Standards

C 150	Standard Specifications for Portland Cement
C 294	Descriptive Nomenclature of Constituents of Natural Mineral Aggregates
D 1452	Practice for Soil Investigation and Sampling by Auger Borings
D 1586	Method for Penetration Test and Split-Barrel Sampling of Soils

D 1587 Practice for Thin-Walled Tube Sampling of Soils

D 2113 Practice for Diamond Core Drilling for Site Investigation

D 2487 Test Method for Classification of Soils for Engineering Purposes

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)

D 3282 Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes

3. Significance and Use

3.1 An adequately installed ground water monitoring well system for aqueous phase liquids provides essential information for decisions pertaining to one or more of the following subjects:

3.1.1 Aquifer and aquitard properties, both geologic and hydraulic;

3.1.2 Potentiometric surface of a particular hydrologic unit;

3.1.3 Water quality with respect to various indicator parameters;

3.1.4 Migration characteristics of a contaminant release;

3.1.5 Decommissioning of installations no longer needed.

4. Definitions

4.1 Annular Space, Annulus -- The space between two concentric tubes or casings, or between the casing and the borehole wall. This would include the space(s) between multiple strings of tubing/casings in a borehole installed either concentrically or adjacent to each other.

4.2 Aquifer -- A geologic formation, group of formations, or part of a formation that is saturated, and is capable of providing a significant quantity of water.

4.3 Aquitard -- A formation that impedes ground water movement and does not yield water freely to wells or springs but that may transmit appreciable water to or from adjacent aquifers. Where sufficiently thick, may act as a ground water storage zone. Synonymous with confining bed.

4.4 Assessment Monitoring -- An investigative monitoring program which is initiated after a release of a contaminant to ground water has been detected. The objective of this program is to quantify the rate and extent of migration and the hazardous constituent concentration gradients.

4.5 ASTM Cement Types -- A Portland cement meeting the requirements of ASTM C 150 (Standard Specifications for Portland Cement). Cement types have slightly different formulations that result in various characteristics which address different construction, physical, and chemical environments. They are as follows:

4.5.1 ASTM Type I (Portland) -- A general-purpose construction cement with no special properties.

4.5.2 ASTM Type II (Portland) -- A construction cement that is moderately resistant to sulfates and generates a lower heat of hydration at a slower rate than ASTM Type I.

4.5.3 ASTM Type III (Portland; high early strength) -- A construction cement that produces a high early-strength. This cement reduces the curing time required when used in cold environments, and produces a higher heat of hydration than ASTM Type I.

4.5.4 ASTM IV (Portland) -- A construction cement that produces a low heat of hydration (lower than ASTM Types I and II) and develops strength at a lower rate.

4.5.5 ASTM V (Portland) -- A construction cement that is a high sulfate resistant formulation. Used when there is severe sulfate action from soils and ground water.

4.6 Bailer -- A tubular hollow receptacle used to facilitate withdrawal of fluid from a well or borehole.

4.7 Ballast -- Materials on devices used to provide stability to a buoyant object.

4.8 Bentonite -- An altered deposit of volcanic ash usually consisting of sodium montmorillonite clay.

4.9 Blow-In -- The inflow of ground water and sediment into a borehole or casing caused by differential hydraulic heads; that is, a hydraulic head greater outside of a borehole/casing than inside.

4.10 Borehole -- A circular open or uncased subsurface hole created by drilling.

4.11 Borehole Log -- The record of formations encountered, drilling progress, water level, length, volumes and types of materials used, and other recorded facts regarding drilling an exploratory borehole or well.

4.12 Bridge -- An obstruction to circulation.

4.13 Casing -- Pipe, finished in sections with either threaded connections or bevelled edges to be field welded, which is installed temporarily or permanently to counteract caving, to advance the borehole, and/or to isolate the zone being monitored.

4.14 Casing, Protective -- A section of pipe that is emplaced over the upper end of a monitoring well or well casing to provide structural protection to the well and restrict unauthorized entrance into the well.

4.15 Casing, Surface -- Pipe used to stabilize a borehole near the surface during and following the drilling of the hole.

4.16 Caving, Sloughing -- The inflow of sediment into a borehole which occurs when the borehole walls lose their cohesive strength.

4.17 Cement, Portland Cement -- Commonly known as Portland cement--it consists of calcareous, argillaceous, or other silica-, alumina-, and iron oxide bearing materials manufactured and formulated to produce various types which are defined in ASTM C 150. Portland cement is also considered a hydraulic cement since it must be mixed with water to form a cement-water paste which has the ability to develop strength and harden even if cured under water (see ASTM Type Cement).

4.18 Centralizer -- A device which assists in the centering of a casing or riser within a borehole or another casing.

4.19 Circulation (Drilling) -- The drilling fluid movement from the mud pit, through the pump, standpipe, hose, drill pipe, annular space in the hole, and circulating ditch back to the mud pit.

4.20 Conductance (Specific) -- A measure of the ability of the water to conduct an electric current at 77°F (25°C). It is related to the total concentration of ionizable solids in the water. It is inversely proportional to electrical resistance.

4.21 Confining Bed -- Is a term which will now supplant the terms "aquiclude," "aquitard," and "aquifuge" and is defined as a body of relatively less permeable material stratigraphically adjacent to one or more aquifers.

4.22 Contamination -- Denotes impairment of water quality by chemical or bacterial pollution to a degree that creates an actual hazard to public health or the environment.

4.23 Detection Monitoring -- A program of monitoring for the express purpose of determining if a contaminant release to ground water has occurred.

4.24 Drill Cuttings -- Fragments or particles of soil or rock, with or without free water, created by the drilling process.

4.25 Drilling Fluid -- A fluid (liquid or gas) which may be used in drilling operations to remove cuttings from the borehole, to clean and cool the bit, to reduce friction between the drill stem and the borehole wall, and to seal the borehole to deter loss of drilling fluids.

4.26 d-10 -- The diameter of a soil particle (usually in millimeters) at which 10% by weight of the particles of a particular sample are finer. This particle size is synonymous with the effective size or effective grain size.

4.27 d-60 -- The diameter of a soil particle (usually in millimeters) at which 60% by weight of the particles of a particular sample are finer.

4.28 Flow Path -- Represents flow lines along which ground water can flow.

4.29 Flush Joint or Flush Coupled -- Casing or riser with ends threaded such that a consistent inside and outside diameter is maintained across the threaded joints or couplings.

4.30 Gravel Pack -- Common nomenclature for the primary filter pack of a well.

4.31 Ground Water -- That part of subsurface water which is in the zone of saturation.

4.32 Grout -- A slurry (usually with thixotropic characteristics and of low permeability) placed between the well casing or riser pipe or both and the borehole wall, or between the riser and casing or both, to maintain the alignment of the casing and riser and to prevent interaquifer contamination or surface water infiltration or both.

4.33 Grout Shoe -- A "plug" fabricated of relatively inert materials that is positioned within the lowermost section of a permanent casing and fitted with a passageway, often with a flow check device, through which grout is injected under pressure to fill the annular space. After the grout has hardened, the grout shoe is usually drilled out.

4.34 Head (Static) -- The height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point.

4.35 Head (Total) -- The sum of three components: (1) elevation head, h_e, which is equal to the elevation of the point above a datum; (2) pressure head, h_p, which is the height of a column of static water that can be supported by the static pressure at the point; and (3) velocity head, h_v, which is the height the kinetic energy of the liquid is capable of lifting the liquid.

4.36 Hydraulic Conductivity -- Ratio of flow velocity to driving force for viscous flow under saturated conditions for a specified fluid in a porous medium.

4.37 Jetting -- When applied as a drilling method, water is forced down through the drill rods or casing and out through the end aperture.

The jetting water then transports the generated cuttings to the ground surface in the annulus of the drill rods or casing and the borehole.

4.38 Loss of Circulation -- The loss of drilling fluid into formation pores or crevices.

4.39 Mud Pit -- Usually a shallow, rectangular, open, portable metal container with baffles into which drilling fluid and cuttings are discharged from a borehole and which serves as a reservoir and settling tank during recirculation of the drilling fluids. Under some circumstances, an excavated pit with a lining material may be used.

4.40 Multi-Cased Well -- A well constructed by using successively smaller diameter casings with depth.

4.41 Neat Cement -- A mixture of cement and water.

4.42 Observation Well -- A small diameter well used to measure changes in hydraulic heads usually in response to a nearby pumping well.

4.43 Oil Air Filter -- A filter or series of filters placed in the air flow line from an air compressor to reduce the oil content of the air to breathing or higher quality.

4.44 Oil Trap -- A device used to remove oil from the compressed air flowing out of an air compressor.

4.45 Packer -- A transient or dedicated device placed in a well which plugs or seals a portion of the well, well annulus, or borehole at a specific level.

4.46 Potentiometric Surface -- Replaces the term "piezometric surface;" is a surface which represents the static head. As related to an aquifer, it is defined by the levels to which water will rise in tightly cased wells. Where the head varies appreciably with depth in the aquifer, a potentiometric surface is meaningful only if it describes the static head along a particular specified surface or stratum in that aquifer. More than one potentiometric surface is then required to describe the distribution of head. The water table is a particular potentiometric surface.

4.47 Primary Filter Pack -- A clean sand or sand and gravel mixture of selected grain size and gradation which is installed in the annular space between the borehole wall and the well screen, extending the appropriate distance above the screen, for the purpose of retaining the particles from the adjacent formation and stabilizing the formation. The term is synonymous with gravel pack although, In some cases, it will contain no gravel size particles.

4.48 PTFE Tape -- Joint sealing tape composed of polytetrafluoroethylene.

4.49 Riser -- The pipe extending from the well screen to above the ground surface.

4.50 Secondary Filter Pack -- A clean, uniformly graded sand that is placed in the annular space between the filter pack and the overlying seal, or between the seal and overlying grout backfill or both, to retard movement of seal, or grout, or both into the primary filter pack.

4.51 Sediment Sump -- An extension beneath the well screen used to collect finer grained material from the filter pack and adjacent formation. The term is synonymous with rat trap.

4.52 Shear Strength -- A measure of the shear or gel properties of a drilling fluid or grout; also, the maximum resistance of a soil or rock to shearing stresses.

4.53 Single Cased Well -- A monitoring well constructed with a riser but without an exterior casing.

4.54 Static Water Level -- The elevation of the top of a column of water in a monitoring well or piezometer that is not influenced by pumping or conditions related to well installation or hydrologic testing or nearby pumpage.

4.55 Tamper -- A heavy cylindrical metal section of tubing that is operated on a wire rope or cable. It slips over the riser and fits inside the casing or borehole annulus and is used to tamp annular sealants or filter materials into place.

4.56 Target Monitoring Zone -- The zone within an aquifer identified as the primary flow path from a particular area or facility into which monitoring wells will be screened. The target monitoring zone should be a stratum (strata) in which there is a reasonable expectation that a vertically placed well will intercept migrating contaminants.

4.57 Test Pit -- A shallow excavation made to characterize the subsurface of an area.

4.58 Transmissivity -- The rate at which a fluid of prevailing kinematic viscosity is transmitted through a unit width of an aquifer of known saturated thickness under a unit hydraulic gradient.

4.59 Tremie Pipe -- A pipe or tube that is used to transport grout or other materials from the ground surface into the borehole annulus of a monitoring well.

4.60 Uniformity Coefficient -- The ratio of the 60% finer (d-60) grain size to the 10% (d-10) finer grain size of a sample of granular material (refer to ASTM Standard Test Method D 2487).

4.61 Uniformly Graded -- A quantitative definition of the particle size distribution of a soil which consists of the majority of particles being of the same approximate diameter. A granular material is considered uniformly graded when the uniformity coefficient is less than 5 (refer to ASTM Standard Test Method D 2487).

4.62 Washout Nozzle -- A tubular extension with a check valve utilized at the end of a string of casing through which water can be injected to displace drilling fluids and cuttings from the annular space of a borehole.

4.63 Water Cement Ratio -- The amount of mixing water in gallons used per sack of cement.

4.64 Water Table -- The ground water surface in an unconfined aquifer at which the pressure is equal to that of the atmosphere; the surface between the zone of saturation and the zone of aeration.

4.65 Weep Hole -- A small diameter hole (usually 1/4 in.) drilled into the protective casing above the ground surface which serves as a drain hole for water that may enter the protective casing annulus.

4.66 Well Completion Diagram -- A record that illustrates the details of well installation.

4.67 Well Screen -- A filtering device used to keep sediment from entering a monitor well or piezometer; usually a cylindrical pipe with slots of a uniform width, orientation, and spacing.

4.68 Well Screen Jetting -- When jetting is used for development, a jetting tool with nozzles and a high pressure pump is used to force water outwardly through the screen, the filter pack, and sometimes into the adjacent geologic unit.

4.69 Zone of Saturation -- A hydrologic zone in which all the interstices are filled with water under pressure greater than that of the atmosphere.

5. Site Characterization

5.1 General -- Soil mechanics, geomorphological concepts, stratigraphy, and sedimentary concepts must be combined with a knowledge of ground water movement to make a complete application of the results of the monitoring well design and installation guidance. Therefore, development of a conceptual hydrogeologic model that identifies potential flow paths and the target monitoring zone(s) is recommended prior to monitoring well design and installation. The development of the conceptual model is accomplished in two phases--an initial reconnaissance and a field investigation. When the hydrogeology of a project area is relatively uncomplicated and well documented in the literature, the initial reconnaissance may provide sufficient information to identify flow paths and the target monitoring zone(s). However, where little research is available or the geology is complicated, a field investigation may be necessary to completely develop a conceptual hydrogeologic model.

5.2 Initial Reconnaissance of Project Area -- The goal of the initial reconnaissance of the project area is to identify and locate those zones with the greatest potential to transmit a fluid from the project area. Identifying these flow paths is the first step in selecting the target ground water monitoring zone(s).

5.2.1 Literature Search -- Every effort should be made to collect and review all field and laboratory data from previous investigations of the project area. Data such as, but not limited to, topographic maps, aerial imagery, site ownership and utilization records, geologic maps and reports, water supply papers, mineral resource surveys, water well logs, personal information for local well drillers, agricultural soil reports, geotechnical engineering reports, and other engineering soil maps and reports related to the project area should be reviewed as part of the initial field reconnaissance.

5.2.2 Field Reconnaissance -- Early in the investigation, the soil and rocks in open cut areas in the vicinity of the project should be studied, and various soil and rock profiles noted. Special consideration should be given to soil color and textural changes, landslides, seeps, and springs within or near the project area.

5.2.3 Preliminary Conceptual Model -- The distribution of the predominant soil and rock units likely to be found during subsurface exploration may be hypothesized at this time in a preliminary hydrogeologic conceptual model using data obtained in the literature search and field reconnaissance. In areas where the geology is uniform, well documented in the literature, and substantiated by the field reconnaissance, further refinement of the conceptual model may not be necessary unless anomalies are discovered in the well drilling stage.

5.3 Field Investigation -- The goal of the field investigation is to refine the preliminary conceptual hydrogeologic model so that the correct target monitoring zone(s) is selected prior to monitoring well installation.

5.3.1 Exploratory Borings and Test Pits -- Characterization of the flow paths conceptualized in the initial reconnaissance involves defining the porosity, permeability, gradation, stratigraphy, lithology, and structure of each formation. The characteristics are defined by conducting an exploratory boring program which may include test pits. Exploratory borings and test pits should be deep enough to develop the required engineering and hydrogeologic data for the flow path(s), target monitoring zone, or both.

5.3.1.1 Sampling -- Soil and rock properties should not be predicted wholly on field identifications or classification, but should be checked by laboratory and field tests made on samples. Representative soil or rock samples, or both, of each material that is significant to the analysis and design of the monitoring system should be obtained. Sample extraction should be conducted according to American Society of Testing and Methods (ASTM) Standards D 1452, D 1586, or D 1587, whichever is appropriate given the anticipated characteristics of the soil samples. Rock samples should be extracted according to ASTM D 3282. Soil samples obtained for evaluation of hydraulic properties should be containerized and identified for shipment to a laboratory. Special measures to preserve either the continuity of the sample or the natural moisture is not usually required. However, soil and rock samples obtained for evaluation of chemical properties often require special field preparation and preservation to prevent significant alteration of the chemical constituents during transportation to a laboratory. Rock samples for evaluation of hydraulic properties are usually obtained using a split-inner-tube core barrel. Evaluation of the core samples is usually made in the field before the core is removed from half of the inner tube.

5.3.1.2 Boring Logs -- Care should be taken to prepare and retain a complete boring log and sampling record for each exploratory borehole and test pit. Boring logs should include the location, geotechnical, and sampling information for each material encounter shown either by symbol or word description. Identification of all soils should be based on ASTM Standard Practice D 2488 or D 3282. Identification of rock material should be based on ASTM Descriptive Nomenclature C 294. Observations of seepage, free water, and water levels should also be noted. The boring logs should be accompanied by a report that includes a description of the area investigated; a map illustrating the vertical and horizontal location (with reference to nearest National Geodetic Vertical Datum [NGVD] and to a standardized survey grid, respectively) of each exploratory borehole or test pit or both; and color photographs of rock cores, soil samples, and exposed strata labeled with a date and identification.

5.3.2 Geophysical Exploration -- Geophysical surveys may be used to supplement borehole and outcrop data and to aid in interpolation between holes. Surface geophysics such as seismic and electrical-resistivity surveys can be particularly valuable when distinct differences in the properties of contiguous subsurface materials are indicated. Borehole methods such as resistivity, gamma, gamma-gamma, neutron, and caliper logs can be useful to confirm subsurface geologic conditions. Gamma logs are particularly useful in existing cased wells.

5.3.3 Gradient Determination -- Ground water flow direction is determined by measuring the hydraulic gradient within each conceptualized flow path. This is accomplished by installing piezometers in the exploratory boreholes. The depth and location of the piezometers will depend upon anticipated hydraulic connections between conceptualized flow paths and their respective lateral direction of flow. Following careful evaluation, it may be possible to utilize existing private or public wells to obtain water level data. The construction integrity of such wells should be verified to ensure that the water levels obtained from the wells are representative only of the zones of interest.

5.4 Completing the Conceptual Model -- A series of hydrogeologic section profiles should be developed to define the conceptual model. This phase of the monitoring well design is accomplished by first plotting logs of soil and rock observed in the exploratory borings, and interpolating between these logs using the geologic and engineering interrelationships between other soil and rock data discovered in the initial reconnaissance or with geophysical techniques. Extrapolation of data into local areas not surveyed and tested should be done only where geologically uniform subsurface disposition of soil and rock are known to exist. The second step is to integrate the profile data with the piezometer data for both vertical and horizontal hydraulic gradients. Plan view and cross-sectional flow nets should also be constructed. Following the assimilation of these data, judgments can be made as to which flow path(s) is the appropriate target monitoring zone(s).

NOTE 1 -- Groundwater monitoring is difficult and may not be a reliable technology in fine grain/low permeability strata because of a) the disportionate influence that microstratigraphy has on ground water flow in fine grain strata; b) flow lines are usually vertical in low permeability strata; and c) indigenous metal and inorganic concentrations make water quality data evaluation difficult.

6. Monitoring Well Construction Materials

6.1 General -- The materials used in the construction of a monitoring well that come in contact with the water sample should not alter the chemical quality of the sample for the constituents being examined using the appropriate sampling protocols. Furthermore, the riser, well screen, and annular sealant injection equipment should be steam cleaned immediately prior to installation. Samples of the water, filter pack, seals, and mixed grout should be retained to serve as quality control until the completion of at least one round of water quality analysis.

6.2 Water -- Water used in the drilling process, to prepare grout mixtures and to steam clean the well screen, riser, and annular sealant injection equipment, should be obtained from a source of known chemistry that does not contain constituents that could compromise the integrity of the installation.

6.3 Well Screen:

6.3.1 Materials -- The well screen should be new, machine slotted or wrapped and constructed of PVC, stainless steel, fiberglass, or fluorocarbon resins--whichever type of material(s) is most suited for the monitoring environment and site characterization findings. The screen should be plugged at the bottom. This assembly must have the capability to withstand installation and development stresses without becoming dislodged or damaged. The length of the well screen should reflect the interval to be monitored. Immediately prior to installation, the well screen should be steam cleaned with water from the approved source.

6.3.2 Diameter -- The minimum nominal internal diameter of the well screen should be chosen based on the particular application. However, in most instances, a minimum of 2 in. is needed to allow for the introduction and withdrawal of sampling devices.

6.3.3 Slot Size -- The slot size of the well screen should be determined relative to the grain size analysis of the formation interval to be monitored and the gradation of the filter pack material. The slot size and arrangement should retain at least 90% of the filter pack. The method for determining the correct gradation of filter pack material is described in Section 6.8.2.

6.4 Riser:

6.4.1 Materials -- The riser should be new and composed of materials that will not alter the quality of water samples for the constituents of concern. The riser should have adequate wall thickness and coupling strength to withstand installation and development stresses, and may be constructed of PVC, stainless steel, fiberglass, or fluorocarbon resins--whichever type of material(s) is appropriate for the monitoring environment. Each section of riser should be steam cleaned using water from the approved source immediately prior to installation.

6.4.2 Diameter -- The minimum nominal internal diameter of the riser should be chosen based on the particular application. However, in most instances, a minimum of 2 in. is needed to accommodate sampling devices.

6.4.3 Joints (Couplings) -- Threaded joints are recommended. Glued joints of any type are not recommended since glues may alter the chemistry of the water samples. Thread configuration should be in accordance with ASTM F 480 standards. In most cases, threaded joints should be PTFE taped to prevent leakage. Alternatively, O-rings composed of materials that would not impact the water sample for the constituents of concern may be selected for use on flush joint threads. Risers consisting of fluorocarbon resins generally do not require a seal at the threaded joint.

6.5 <u>Casing</u> -- Where conditions warrant, the use of permanent casing installed to prevent communication of subsurface water between shallower and deeper water-bearing zones is encouraged. The following subsections address both temporary and permanent casings.

6.5.1 <u>Materials</u> -- The exterior casing (temporary or permanent) is generally composed of steel, although other appropriate materials may be used. The material type and minimum wall thickness of the casing should be adequate to withstand the forces of installation. All casing that is to remain as a permanent part of the installation (i.e., multi-cased wells) should be new and free of interior and exterior protective coatings.

6.5.2 <u>Diameter</u> -- Several different casing sizes may be required depending on the subsurface geologic conditions encountered. The diameter of the casing should be selected so that a minimum annular space of 2 in. is maintained between the casing and riser. In addition, the diameter of the casings in multi-cased wells should be selected so that a minimum annular space of 2 in. is maintained between the casing and the borehole (i.e., a 2 in. diameter screen will require first setting a 6 in. diameter casing in a 10 in. diameter boring).

6.5.3 <u>Joints (Couplings)</u> -- The ends of each casing section should be either flush threaded or bevelled for welding.

6.6 <u>Protective Casing</u>:

6.6.1 <u>Materials</u> -- Protective casings may be made of aluminum, steel, stainless steel, cast iron, or a structural plastic. The protective casing should have a lid capable of being locked shut by some type of locking device.

6.6.2 Diameter -- The inside dimensions of the protective casing should be a minimum of 2 in. and preferably 4 in. larger than the outside diameter of the riser to facilitate the installation and operation of sampling equipment.

6.7 Annular Space Sealants -- The materials used to seal the annulus may be prepared as a grout slurry or used unmixed in a dry pellet or chip form. Sealants should be designed and installed to account for ambient geologic, hydrogeologic, and climatic conditions.

6.7.1 Bentonite -- Bentonite should be powdered, granular, pelletized, or chipped sodium montmorillonite furnished in sacks or buckets from a commercial source and free of chemicals. Pellets consist of roughly spherical or disk shaped units of compressed bentonite powder. Chips are large, irregularly shaped, and coarse granular units of unaltered bentonite. The diameter of pellets or chips selected for monitoring well construction should be less than one-fifth the width of the annular space into which they are placed. Granules consist of coarse particles of unaltered bentonite, typically smaller than 0.197 in. (5.0 mm).

6.7.2 Cement -- Each type of cement has slightly different characteristics which may be used under various physical and chemical conditions. Cement should be one of five Portland cement types that are in conformance with ASTM C 150. The use of quick setting cements containing additives is not recommended for use in monitoring well installation. Additives may leach from the cement and alter the chemistry of the water sample.

6.7.3 Grout -- The grout backfill that is placed above the seal and secondary filters is ordinarily a liquid slurry consisting of either a bentonite (powder and/or granules) base and water, or a Portland cement base and water. Often, bentonite base grouts are used when it is desired that the grout remain flexible during the life of the installation. Cement base grouts are often used when penetration of cracks, adherence to rock units, or a rigid setting is desired.

6.7.3.1 Mixing -- The mixing (and placing) of a backfill grout should be performed with precise recorded weights and volumes of materials, and according to stipulated procedures which often include the order of component mixing. The grout should be thoroughly mixed with a paddle type mechanical mixer or by recirculating the mix through a pump until all lumps are disintegrated. Grout which is lumpy should not be used in the construction of a monitoring well.

NOTE 2 -- Lumps do not include lost circulation materials that may be added to the grout if excessive grout losses occur.

6.7.3.2 Typical Bentonite Base Grout -- When a bentonite base grout is used, bentonite, usually unaltered, must be the first additive placed in the water. A typical bentonite base grout consists of about 1 lb to 1.25 lb of unaltered bentonite to each 1 gal of water. After the bentonite is mixed and allowed to "yield," up to 2 lb of Type I Portland cement (per gallon of water) is often added to stiffen the mix. Bentonite grouts should not be used in the vadose zone of arid regions because of their propensity to desiccate.

NOTE 3 -- Other bentonite base grouts may contain granular bentonite to increase the solids content and other additives to either stiffen or retard stiffening of the mix. All additives to grouts should be evaluated for their effects on subsequent water quality testing.

6.7.3.3 Typical Cement Base Grout -- When a cement base grout is used, cement is usually the first additive placed in the water. A typical cement base grout consists of about 6.0 gal to 8.0 gal of water per 94 lb bag of Type I Portland cement. From 0 to 10% (by weight) of unaltered bentonite powder is often added after the initial mixing of cement and water to retard shrinkage and provide plasticity. The bentonite is added "dry" to the cement-water slurry without first mixing it with water.

6.8 Primary Filter Pack:

6.8.1 Materials -- The filter pack (gravel pack) consists of a nonreactive granular material of known chemistry and selected grain size and gradation which is installed in the annular space between the screen and the borehole wall. The filter pack is usually selected to have a 30% finer (d-30) grain size that is about 4 to 10 times greater than the 30% finer (d-30) grain size of the hydrologic unit being filtered. Usually, the filter is selected to have a low uniformity coefficient. The grain size and gradation of the filter are selected to stabilize the hydrologic unit adjacent to the screen and permit only the finest soil grains to enter the screen during development. Thus, after development, a correctly filtered monitoring well is relatively sand-free, and a thin zone of the hydrologic unit adjacent to the filter has its permeability increased to some degree.

6.8.2 Gradation -- The filter pack should be uniformly graded and comprised of hard durable particles washed and screened with a particle size distribution derived by multiplying the d-30 size of the finest-grained screened stratum by a factor between 4 and 10. Use a number between four and six as the multiplier if the formation is fine and uniform; use a factor between six and ten where the formation material has highly nonuniform gradation and includes silt sized particles. The grain-size distribution of the filter pack is then plotted using the d-30 size as the control point on the graph. The selected filter pack should have a uniformity coefficient of approximately 2.5. The gradation of the filter material should be as uniform as possible and include particles coarser than the 40% size and finer than the 90% size.

NOTE 4 -- Although not recommended as standard practice, often a project requires drilling and installing the well in one phase of work. Therefore, the filter pack materials must be ordered and delivered to the drill site before soil samples can be collected. In these cases, the following well screen slot size and filter pack materials are suggested:

Table 1. Recommended Filter Pack Gradation

Anticipated Strata	Well Screen Slot Size	Filter Pack Material (approximate range of standard U.S. sieve sizes)
Sand and Gravel	0.030	20 to 4
Silt and Sand	0.020	30 to 8
Clay and Silt	0.010	50 to 16

6.9 Secondary Filter Packs:

6.9.1 Materials -- A secondary filter pack is a layer of material which is placed in the annular space between the filter pack and the bentonite seal, and between the bentonite seal and the grout backfill (see Figs. 1 and 2).

6.9.2 Gradation -- The secondary filter pack should be uniformly graded fine sand with a 100% by weight passing the No. 30 sieve, and less than 2% by weight passing the 200 sieve.

6.10 Annular Seal Equipment -- The equipment used to inject the annular seals and filter pack should be steam cleaned using water from the approved source prior to use. This procedure is performed to prevent the introduction of materials that may ultimately alter the water sample quality.

7. Drill Methods

7.1 The type of equipment required to create a stable, open, vertical borehole for installation of a monitoring well depends upon the site geology, hydrology, and the intended use of the data. Engineering and geological judgment is required for the selection of the drilling methods utilized for drilling the exploratory boreholes and monitoring wells. Whenever possible, drilling procedures should be utilized that do not require the introduction of water or liquid fluids into the borehole, and that do optimize cuttings control at ground surface. Where the use of drilling fluid is unavoidable, the selected fluid should not alter the water samples for the constituents being sought. It is recommended that if an air compressor is used, it is equipped with an oil air filter or oil trap. Several drilling methods and procedures are available. Refer to ASTM Standard Guides D ____, D ____, D ____, and D ____ on drilling procedures (currently in draft).

8. Monitoring Well Installation

8.1 Stable Borehole -- A stable borehole must be constructed prior to attempting to install the monitoring well screen and riser. If the borehole tends to cave or blow-in or both, steps must be taken to stabilize the borehole before attempting installation. Procedures for drilling and temporary stabilization of the borehole are covered in ASTM D ____, D ____, D ____, and D ____ (currently in draft). Boreholes which are not straight or are partially obstructed should be corrected prior to attempting the installations described herein.

8.2 Assembly of Well Screen and Riser:

8.2.1 Handling -- The well screen, bottom plug, and washout nozzles should be steam cleaned using water from the approved source immediately prior to assembly. Personnel should take precautions to assure that grease, oil, or other contaminants that may ultimately alter the water sample do not contact any portion of the well screen and riser assembly. As one precaution, personnel should wear a clean pair of cotton or surgical (or equivalent) gloves while handling the assembly.

8.2.2 Riser Joints (Couplings) -- The male threaded part of each required riser coupling should be wrapped with PTFE tape. Alternatively, O-rings of known chemistry, selected on the basis of prevailing environmental or physical conditions, may be used to assure a seal of flush-joint couplings. Couplings are often tightened by hand; however, if necessary, steam cleaned wrenches may be utilized. Precautions should be taken to prevent damage to the threaded joints during installation.

8.3 Setting the Well Screen and Riser Assembly -- When the well screen and riser assembly is lowered to the predetermined level and held into position, the assembly may require ballast to counteract the tendency to float in the borehole. Ballasting may be accomplished by continuously filling the riser with water from the approved source or, preferably, water which was previously removed from the borehole. Alternatively, the riser may be slowly pushed into the water in the borehole with the aid of hydraulic rams on the drill rig and held in place as additional sections of riser are added to the column. The assembly must be installed straight to allow for the introduction and withdrawal of sampling devices. Difficulty in maintaining a straight installation may be encountered where the weight of the well screen and riser assembly is significantly less than the buoyant force of the water in the borehole. The riser should extend above grade and be capped temporarily to deter entrance of contaminants during completion operations.

8.4 Installation of the Primary Filter Pack:

8.4.1 Volume of Filter Pack -- The volume of filter pack required to fill the annular space between the well screen and borehole should be computed, measured, and recorded on the well completion diagram during installation. The filter pack should extend above the screen for a distance of about 2% of the length of the well screen but not less than 2 ft (see Figs. 1 and 2). Where there is hydraulic connection between the zone to be monitored and the overlying formation, this upward extension should be shortened to prevent vertical seepage into the filter pack. Seepage from other forma-tions may alter the water sample.

8.4.2 Placement of Primary Filter Pack -- Placement of the well screen is preceded by placing no less than 2% and no more than 10% of the filter pack into the bottom of the borehole using a clean, flush threaded, 1 in. minimum internal diameter tremie pipe. The well screen and riser assembly is then centered in the borehole and temporary casing using a centralizer located not more than 10 ft above the bottom of the well screen (see Figs. 1 and 2). The remaining primary filter pack is then placed in increments. As primary filter pack material is poured into the tremie pipe, water from the approved source may be added to help move the filter pack. The tremie pipe or a weighted line inserted through the tremie pipe can be used to measure the top of the primary filter pack as work progresses. Additional centralizers (or centering disks) are installed as required to ensure that the assembly is centered. The location, volume, and gradation of primary filter pack is recorded on the well completion diagram.

8.4.3 Withdrawal of the Temporary Casing/Augers -- The temporary casing or hollow stem auger is withdrawn, usually in stipulated increments, while holding the riser with the drill rig. Usually the casing or hollow stem is withdrawn until the lowermost point on the casing or hollow auger is at least 2 ft, but no more than 5 ft, above the filter pack for unconsolidated materials; or at least 5 ft, but no more than 10 ft, for consolidated materials. In highly unstable formations, withdrawal intervals may be much less. After each increment, a weighted measuring rod is inserted into the annulus to ascertain that the filter pack has not bridged or raised during the withdrawal operation. If bridging of the filter pack has occurred, it should be broken mechanically prior to proceeding with the addition of more filter pack material.

8.5 Placement of First Secondary Filter -- A secondary filter pack may be installed above the primary filter pack to deter the intrusion of the bentonite seal into the primary filter pack (see Figs. 1 and 2). A measured and recorded volume of secondary filter material should be added to extend 1 ft to 2 ft above the primary filter pack. As was the case with the primary filter, a secondary filter must not extend into an overlying permeable formation (see Section 8.4.1). The designer should evaluate the need for this filter pack by considering the gradation of the primary filter pack, the hydraulic heads, and the potential for grout intrusion into the primary filter pack. The secondary filter material is poured into the annular space through a clean, flush threaded, 1 in. minimum internal diameter tremie pipe lowered to within 3 ft of the placement interval. Clean water from the approved source may be added to help move the filter pack. The tremie pipe or weighted line inserted through the tremie pipe can be used to feel the top of the secondary filter pack as work progresses. The location, volume, and gradation of the secondary filter pack is recorded on the well completion diagram.

8.6 Installation of the Bentonite Seal -- The bentonite pellet or slurry seal is placed in the annulus between the borehole and the riser pipe on top of the secondary or primary filter pack (see Figs. 1 and 2). This seal retards the movement of grout backfill into the filter pack(s). The bentonite seal should extend above the filter pack(s) approximately 3 ft to 5 ft--depending on local conditions. The bentonite seal should be installed using a tremie pipe lowered to the top of the filter pack(s) and slowly raised as the bentonite pellets or slurry fill the annular space. As the bentonite seal is poured into the tremie pipe, water from the approved source may be poured in to help move the bentonite seal material. The tremie pipe or a weighted line inserted through the tremie pipe can be used to measure the top of the bentonite seal as the work progresses. If a bentonite pellet seal is being constructed above the water level, approximately 5 gal of water from the approved source can be poured into the annulus to ensure that the pellets hydrate. Sufficient time should be allowed for the bentonite pellet seal to hydrate or the slurry seal to expand prior to grouting the remaining annulus. The volume and location of the bentonite seal material is measured and recorded on the well completion diagram.

8.7 Final Secondary Filter Pack -- A 6 in. to 1 ft secondary filter may be placed above the bentonite seal in the same manner described in Section 8.5 (see Figs. 1 and 2). This filter pack will provide a confining force on the bentonite seal and limit the downward movement into and the effect of cement based grout backfills upon the bentonite seal. The volume, location, and gradation of this final filter pack should be documented on the well completion diagram.

8.8 Grouting the Annular Space:

8.8.1 General -- Grouting procedures vary with the type of well design. The following procedures will apply to both single- and multi-cased monitoring wells. Sections 8.8.2 and 8.8.3 detail those procedures unique to single- and multi-cased installations, respectively.

8.8.1.1 Volume of Grout -- The volume and location of grout used to backfill the remaining annular space is recorded on the well completion diagram. The volume used should include a quantity to compensate for losses. The use of alternate grout materials, including grouts containing gravel, may be necessary to control zones of high grout loss.

8.8.1.2 Injection Procedures -- The grout should be injected under pressure to reduce the chance of leaving voids in the grout, and to displace any liquids and drill cuttings that may remain in the annulus. Depending upon the well design, grouting may be accomplished using a pressure grouting technique or by tremie pipe. With either method, grouting is introduced in one continuous operation until full strength grout flows out at the ground surface without evidence of drill cuttings or fluid. The grout should slope away from the riser or casing at the surface, but care should be taken not to create a grout mushroom that would be subject to frost heave.

8.8.1.3 Grout Setting and Curing -- The riser should not be disturbed until the grout sets and cures for the amount of time necessary to prevent a break in the seal between the grout and riser or grout and casing or both. The amount of time required will vary with grout content and climatic conditions and should be documented on the well completion diagram.

8.8.2 Specific Procedures for Single Cased Wells -- Grouting should begin at a level directly above the bentonite seal (see Fig. 1). Grout should be injected using a tremie pipe equipped with a side discharge. The tremie pipe should be kept full of grout from start to finish with the discharge end of the pipe completely submerged as it is slowly and continuously lifted. Approximately 5 ft to 10 ft of tremie pipe should remain submerged until grouting is complete. For deep installations or where the couplings of the selected riser cannot withstand the sheer or collapse stress exerted by a full column of grout as it sets, a staged grouting procedure may be considered. The temporary casing or hollow auger should be removed in increments immediately following each increment of grout installation and in advance of the time when the grout begins to set. If casing removal does not commence until grout injection is completed, then, after the casing is removed, additional grout may be periodically injected into the annular space to maintain a continuous column of grout up to the ground surface.

8.8.3 <u>Specific Procedures for Multi-Cased Wells</u> -- If the outer casing of a multi-cased well cannot be driven to form a tight seal between the surrounding formation(s) and the casing, it should be installed in a predrilled borehole. After the borehole has penetrated not less than 2 ft of the first targeted confining stratum, the outer casing is lowered to the bottom of the boring and the annular space is filled with grout. Grouting may be accomplished using a pressure grouting method or a tremie pipe. Pressure grouting will require the use of a grout shoe or packer installed at the end of the outer casing to prevent grout from moving up into the casing. If a tremie pipe is used to inject grout into the annular space, it should be equipped with a side discharge. With each alternative, the grout must be allowed to cure to form a seal between the casing and the grout prior to advancing the hole to the next hydrologic unit. This process is repeated for each hydrologic unit encountered. Upon reaching the final target depth, the riser and screen is set through the outer casing. Subsequent to the placement of the filter packs and bentonite seal, the remaining annular space is grouted as described in Section 8.8.2 (see Fig. 2).

NOTE 5 -- When using a packer, pressure may build up during grout injection and force grout up the sides of the packer and into the casing.

8.9 Well Protection -- Well protection refers specifically to installations made at the ground surface to deter unauthorized entry to the monitoring well and to prevent surface water from entering the annulus.

8.9.1 Protective Casing -- The protective casing should extend from below the frost line (3 ft to 5 ft below the grade depending on local conditions) to slightly above the well casing top. The protective casing should be sealed and immobilized in concrete placed around the outside of the protective casing. The casing should be positioned and stabilized in a position concentric with the riser (see Figs. 1 and 2). Sufficient clearance (usually 6 in.) should be maintained between the lid of the protective casing and the top of the riser to accommodate sampling equipment. A 1/4 in. diameter weep hole should be drilled in the casing 6 in. above the ground surface to permit water to drain out of the annular space. In cold climates, this hole will also prevent water freezing between the well protector and the well casing. Dry bentonite pellets, granules, or chips should then be placed in the annular space below ground level within the protective casing. Coarse sand or pea gravel or both is placed in the annular space above the dry bentonite pellets and above the weep hole to prevent entry of insects. All materials chosen should be documented on the well completion diagram. The monitoring well identification number should be clearly visible on the inside and outside of the lid of the protective casing.

8.9.2 Completion of Surface Installation -- The well protection installation may be completed in one of three ways:

8.9.2.1 In areas subject to frost heave, place a soil or bentonite/sand layer adjacent to the protective casing sloped to direct water drainage away from the well.

8.9.2.2 In regions not subject to frost heave, a 4 in. thick concrete pad sloped to provide water drainage away from the well may be placed around the installation. Care must be taken not to lock the concrete pad onto the protective casing if subsidence of the surface may occur in the future.

8.9.2.3 Where monitoring well protection must be flush with the ground, an internal cap should be fitted on top of the riser within the manhole or vault. This cap should be leak-proof so that if the vault or manhole should fill with water, the water will not enter the well casing. Ideally, the manhole cover cap should also be leak-proof.

8.9.3 Additional Protection -- In areas where there is a high probability of damaging the well (high traffic, heavy equipment, poor visibility), it may be necessary to enhance the normal protection of the monitoring well through the use of posts, markers, signs, etc. The level of protection should meet the damage threat posed by the location of the well.

9. Well Development

9.1 General -- Well development serves to remove the finer grained material from the well screen and filter pack that may otherwise interfere with water quality analyses, and to improve the hydraulic characteristics of the filter pack and hydrologic unit adjacent to the well screen. Methods of well development vary with the physical characteristics of hydrologic units in which the monitoring well is screened and with the drilling method used.

9.2 Development Methods -- Methods of development most often used include mechanical surging and bailing or pumping, over pumping, air lift pumping, and jetting. An important factor in any method is that the development work be started slowly and gently and increased in vigor as the well is developed. Most methods of well development require the application of sufficient energy to disturb the filter pack, thereby freeing the fines and allowing them to be drawn into the well. The coarser fractions would then settle around and stabilize the screen. The well development method chosen should be documented on the well completion diagram.

NOTE 6 -- Any time an air compressor is used, it should be equipped with an oil filter or oil trap to prevent the introduction of oil into the screen area. The presence of oil would alter the quality of the water samples.

NOTE 7 -- Development procedures for wells completed in fine sand and silt strata should involve methods that are relatively gentle so that the strata material will not be incorporated into the filter pack. Vigorous surging for development can produce mixing of the fine strata and filter pack and produce turbid samples from the installation.

9.2.1 Mechanical Surging -- In this method, water is forced to flow into and out of the well screen by operating a plunger (or surge block) or bailer up and down in the riser. A pump or bailer should then be used to remove the dislodged sediments following surging.

9.2.2 Over Pumping -- With this method, the monitoring well is pumped at a rate considerably higher than it would be during normal operation. The finer grain materials would be freed from the filter pack and surrounding formation that is influenced by the higher pumping rate. This method is usually conducted in conjunction with mechanical surging.

9.2.3 Air Lift Pumping -- In this method, an air lift pump is operated by turning the air pressure on and off for short periods of time. This operation will provide a surging action that will dislodge finer grained particles. Applying a steady low pressure will remove the fines that have been drawn into the well by the surging action. Efforts should be made to avoid pumping air into the filter pack and adjacent hydrologic unit because the air may lodge there and inhibit future sampling efforts and may alter ambient water chemistry by oxidation. Furthermore, application of large air pressure should be avoided to prevent damage to small diameter PVC risers and screens and filter packs.

9.2.4 Well Jetting -- Another method of development involves jetting the well screen area with water while simultaneously air lift pumping the well. However, the water added during this development procedure will alter the natural, ambient water quality and may be difficult to remove. Therefore, the water added should be deionized or be obtained from the approved water source. Water from the monitoring well being developed may also be used if the suspended sediments are first removed.

9.3 Duration of Well Development -- Well development should begin after the monitoring well is completely installed and prior to water sampling. Development should be continued until representative water, practically free of the effects of well construction, is obtained. Representative water is assumed to have been obtained when pH, temperature, and specific conductivity readings stabilize and the water is visually clear of suspended solids. The minimum duration of well development should vary in accordance with the method used to develop the well. For example, surging and pumping the well may provide a stable, sediment free sample in a matter of minutes; whereas, bailing the well may require several hours of continuous effort to obtain a clear sample. The duration of well development and the pH, temperature, and specific conductivity readings should be recorded on the well completion diagram.

9.4 Well Recovery Test -- A well recovery test should be performed immediately after development. The well recovery test not only provides an indication of well performance but also provides data for determining the transmissivity of the screened hydrologic unit. Estimates of the transmissivity, the permeability and hydraulic conductivity of the unit can also be determined. Readings should be taken at intervals suggested in the table below until the well has recovered to 90% of its static water level.

Table 2. Suggested Recording Intervals for Well Recovery Tests

Time Since Starting Test	Time Intervals
0-15 min	1 min
15-50 min	5 min
50-100 min	10 min
100 min - 5 h	30 min
5 h - 24 h	60 min

NOTE 8 -- If a monitoring well does not recover sufficiently for sampling within a 24 h period, the installation should not generally be used as a monitoring well for detecting or assessing low level organic constituents. The installation may, however, be used for long-term water level monitoring.

10. Installation Survey

10.1 General -- The vertical and horizontal position of each monitoring well should be surveyed and subsequently mapped by a registered surveyor. The well location map should include the location of all monitoring wells in the system and their respective identification numbers, elevations of the top of riser position to be used as the reference point for water level measurements, and the elevations of the ground surface protective installations. The locations and elevations of all permanent benchmark(s) and corner monument marker(s) located on site or used in the survey should also be noted on the map.

10.2 Water Level Measurement Reference -- The water level measurement reference point should be permanently marked by cutting a V-notch into the top edge of the riser pipe. This reference point should be surveyed in reference to the nearest NGVD reference point.

10.3 Location Coordinates -- The horizontal location of all monitoring wells (active or decommissioned) should be surveyed by metes and bounds or by reference to a standardized survey grid.

11. Monitoring Well Installation Report

11.1 To demonstrate that the goals as set forth in Section 1 have been met, a monitoring well installation report should be prepared. This report should:

11.1.1 Locate the area investigated in terms pertinent to the project. This may include sketch maps or aerial photos on which the exploratory borings, piezometers, sample areas, and monitoring wells are located, as well as topographic items relevant to the determination of the various soil and rock types, such as contours, stream beds, pot holes, cliffs, etc. Where feasible, include a geologic map and geologic cross-sections of the area being investigated.

11.1.2 Include copies of all well boring and exploratory borehole logs, all laboratory test results, and all well completion diagrams.

11.1.3 Include the well installation survey.

11.1.4 Describe and relate the findings obtained in the initial reconnaissance and field investigation (Section 5) to the design and installation procedures selected (Sections 7-9) and the surveyed locations (Section 10).

11.1.5 Should include a recommended decommission procedure that is consistent with the well construction and local regulatory requirements.

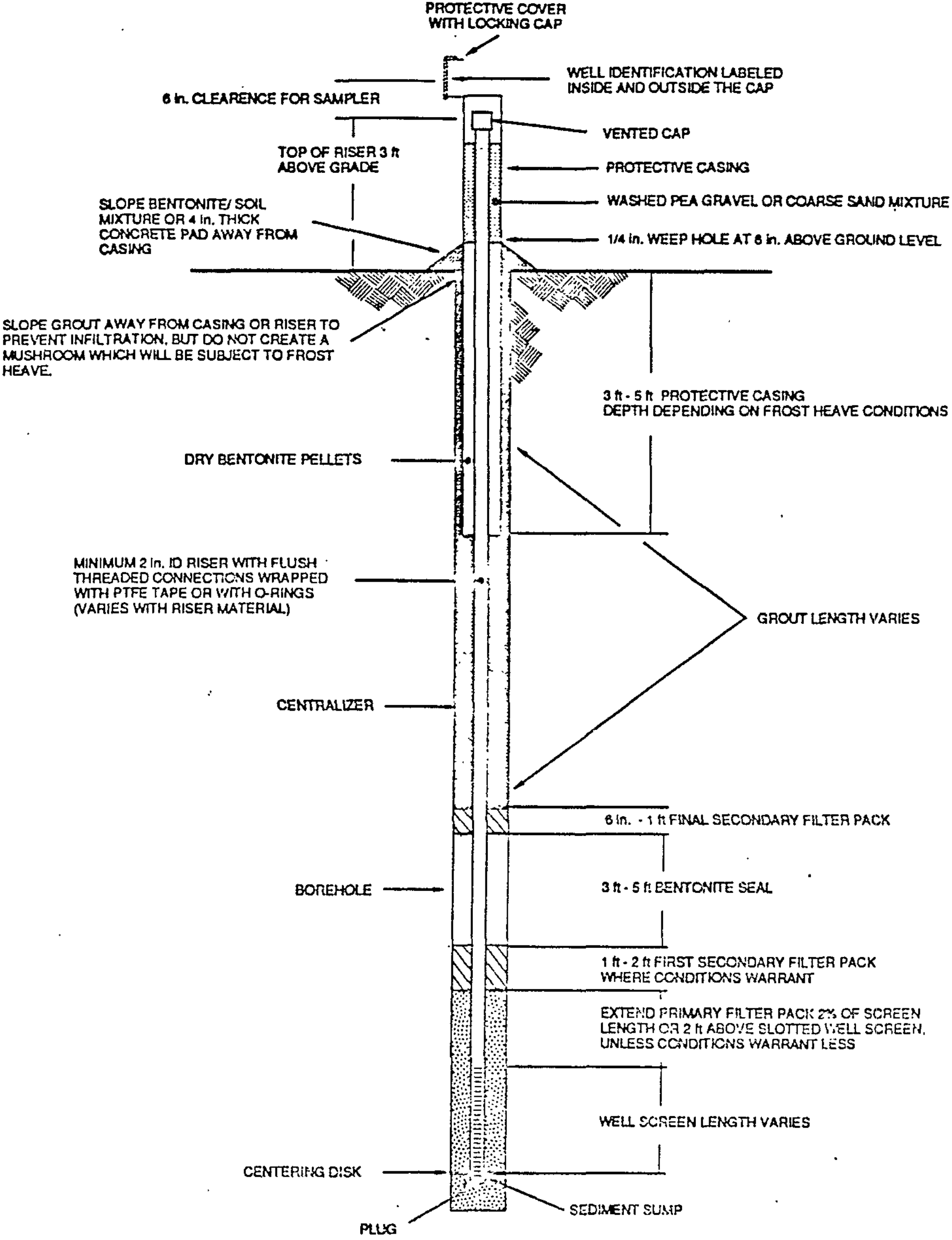


FIG. 1 Typical Monitoring Well Design Single Cased Well

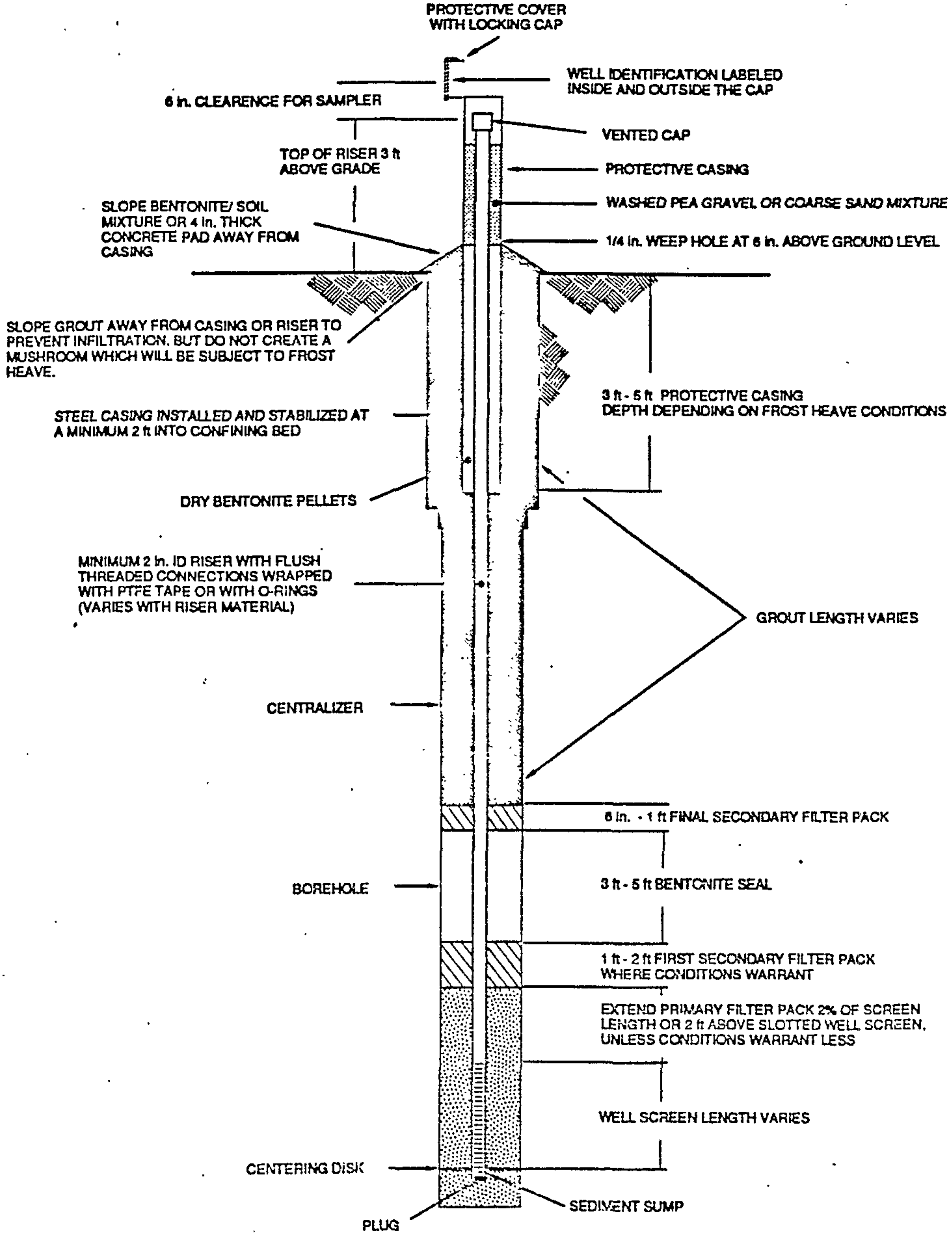
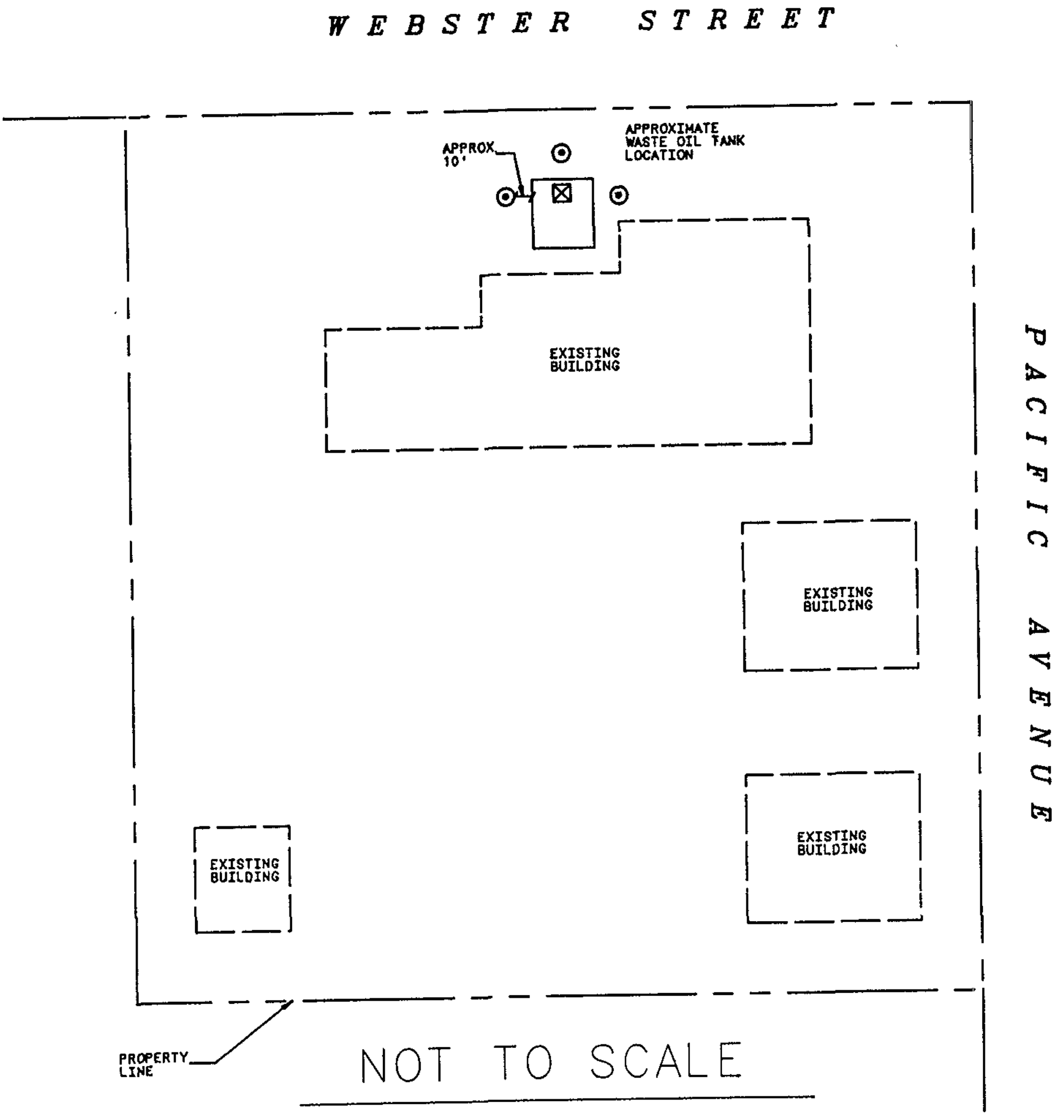


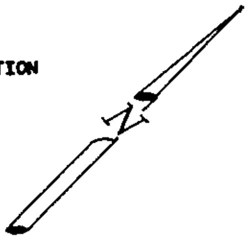
FIG. 2 Typical Monitoring Well Design Multi Cased Well



LEGEND

⊙ PROPOSED SOIL BORING LOCATION

☒ PROPOSED MONITORING WELL LOCATION



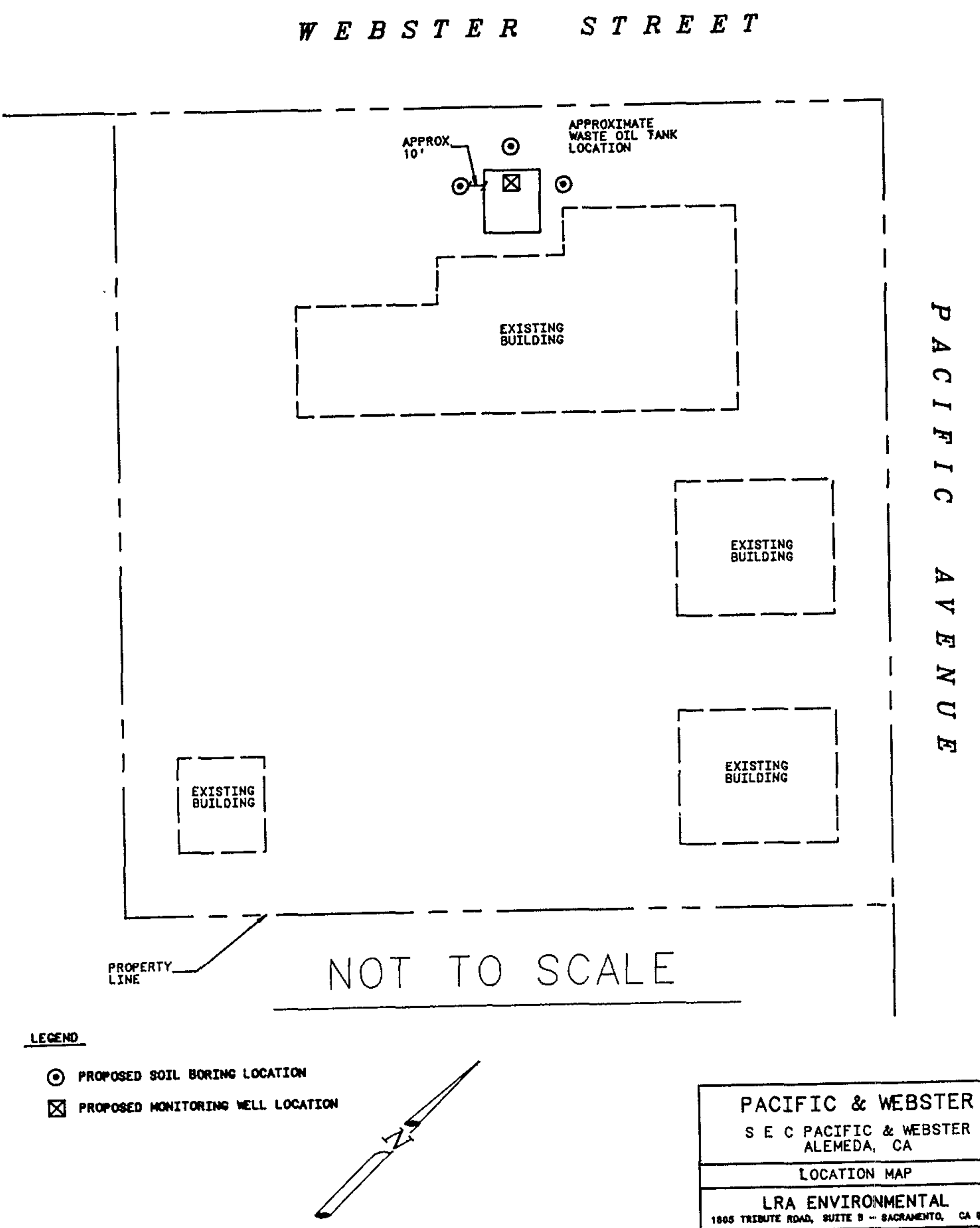
PACIFIC & WEBSTER
S E C PACIFIC & WEBSTER
ALEMEDA, CA

LOCATION MAP

LRA ENVIRONMENTAL
1805 TRIBUTE ROAD, SUITE 8 - SACRAMENTO, CA 95815

DATE 25-JULY-89
DRWG. NO. E8934-1

PLATE NUMBER 1



PACIFIC & WEBSTER

S E C PACIFIC & WEBSTER
ALEMEDA, CA

LOCATION MAP

LRA ENVIRONMENTAL
1805 TRIBUTE ROAD, SUITE B — SACRAMENTO, CA 95815

DATE 25-JULY-89
DRWG. NO. E8934-1
PLATE NUMBER 1