FRAMATOME ANP FRAMATOME ANP DE&S	TECHNICAL DOCUMENT COVER SHEET *QA Record Type: N/A*	Form DPR-3.4A Page 1 of 1 Revision 3

DOCUMENT NO.: DESD-TD-YR-02-001 REV.: 1 Page: 1 of 26

DOCUMENT TITLE: Site Ground Water Data Collection for YNPS Decommissioning

PROJECT NAME: YNPS Environmental Engineering Field Support

PROJECT NO.: 01637.00.2002.03.00002

CLIENT: Yankee Atomic Electric Company – YNPS QA CONDITION: Non QA

*Non-QA

Pagination:

Cover Sheet & Text:	26
Figures 1-8	11 w/cover page
Tables 1-3	30 w/cover page
Attachment 1	3 w/cover pg
Attachment 2	34 w/cover pg
Attachment 3	30 w/cover pg
Attachment 4	33 w/cover pg
Attachment 5	2, w/cover page
DVC	1

Total 170

Revision 1 corrects the units/data used in Table 2 for gamma-emitting radionuclides and provides a few changes based on a general review of the document. Typographical errors were corrected in lab nos. 49101, 16466R, 47793, 341901 and 49113. Two verified analyses not previously reported were added to Table 2, lab nos 62623 and 62620. A general review of the report also prompted minor editorial changes, and a revision of the angle between true north and grid north on the Figures 2 and 4 through 8.

DESIGN VERIFICATION METHOD:

☒ Design Review

☐ Alternate Calculation

☐ Qualification Testing

	PRINTED/TYPED NAME	SIGNATURE	DATE
Prepared By: (First, MI, Last)	F. X. Bellini	F X Bellini	2/3/2003
Verified By: (First, MI, Last)	E. F. Maher	[signature]	2/3/2003
Approved By: (First, MI, Last)	G. A. Harper	George C. Harper	2/4/03

TABLE OF CONTENTS

		Page
1.0	**INTRODUCTION**	**4**
1.1	GENERAL SITE DESCRIPTION	4
1.1.1	*Plant Location and Local Topography*	*4*
1.1.2	*Plant Structures*	*5*
2.0	**SITE GEOLOGY**	**6**
2.1	DISTRIBUTION AND CHARACTER OF SOIL AND BEDROCK UNITS AT THE SITE	6
2.2	SITE CHARACTERISTICS AND MODIFICATIONS MADE BY CONSTRUCTION	8
3.0	**SITE GEOHYDROLOGY**	**8**
3.1	GROUND WATER TABLE ELEVATIONS	9
3.2	GROUND WATER IN BEDROCK	9
4.0	**GROUND WATER CHARACTERIZATION METHODS**	**11**
4.1	APPROACH FOR YNPS	11
4.2	PRIOR DETERMINATION OF ANALYTES OF CONCERN, SURROGATES	11
4.3	INVESTIGATION METHODS: PROCEDURES AND PLANS	12
4.4	BACKGROUND CONSIDERATIONS	13
5.0	**SUMMARY OF CHARACTERIZATION GROUND WATER INVESTIGATIONS**	**13**
5.1	WELL DESIGN AND LOCATIONS	15
5.2	REFERENCES AND DATA	15
5.3	ANALYTICAL DATA	16
6.0	**SITE CHARACTERIZATION RESULTS**	**17**
6.1	WATER LEVEL MEASUREMENTS	17
6.2	WELL DEVELOPMENT	17
6.3	SAMPLE ANALYSIS RESULTS	17
6.3.1	*Tritium*	*17*
6.3.2	*Gamma-Emitting Radionuclides in Ground Water Samples*	*19*
6.3.3	*Gross Alpha, Gross Beta and Sr-90 Analyses*	*20*
6.3.4	*Spent Fuel Pool (SFP) Leakage*	*20*
6.4	WELL CLOSURES	21
6.5	SITE GROUND WATER CONDITIONS SUMMARY	22
6.5.1	*Unit Thicknesses and Lateral Extent*	*22*
6.5.2	*Water-Transmitting Properties, Flow Velocity Estimates, and Inferred K_ds*	*22*
6.5.3	*Recharge and Discharge*	*23*
7.0	**REFERENCES**	**24**

LIST OF FIGURES

1. Regional Topographic Map
2. Site Structures and Areas
3A. Geologic Map
3B. Geologic Profile A-A'
3C. Geologic Profiles B-B' and C-C'
4. Ground Water Contour for Wells in Surficial Materials
5. Plan Map of Monitoring Wells
6. 1999 H-3 Concentration Map
7. 2001 H-3 Concentration Map
8. PAB Area: H-3 in Ground Water 1998-9

LIST OF TABLES

1. Monitoring Well Information Summary
2. YNPS Ground Water Database Analysis Information
3. Gross Alpha and Gross Beta data
4. Maximum 1999 H-3 Concentrations
5. Well Closure History
6. Properties of Geohydrologic Units at the Site

LIST OF ATTACHMENTS

1. Radiological Profiles of Soil
2. Graphs of H-3 Concentrations in Monitoring Well Samples
3. Monitoring Well Configuration Sketches
4. Monitoring Well Ground Water Levels
5. YNPS Spent Fuel Pool: Concentration of H-3, 1997-1999

1.0 INTRODUCTION

Environmental site characterization studies and surveys to support the Yankee Nuclear Power Station (YNPS) decommissioning began in late 1992 and have been carried out by Yankee Atomic Electric Co, (YAEC), Yankee Nuclear Services Division (YNSD), Duke Engineering & Services (DE&S) and Framatome ANP DE&S (FDE&S) personnel. This report summarizes the ground water studies performed to date for site characterization.

The goals of ground water monitoring at the site have been to evaluate the status of the site ground water following plant operation and to verify that on-site decommissioning activities are not having a negative impact on the ground water through the release of radionuclides. Ground water samples collected for site characterization have provided a very small number of results identifying elevated (compared to U. S. EPA Drinking Water Standards) levels of any radionuclide. Elevated concentrations have been principally limited to tritium in well samples from in or near the Primary Auxiliary Building (PAB) during the time period from 1998 to 2000.

Site radiological release criteria for unrestricted use are provided by 10CFR20, "Radiological Criteria for License Termination: Radiological Criteria for Unrestricted Use" (Reference 1). Dose equivalent from ground water is included in the 25 mrem/yr dose equivalent limit provided by this regulation. With one short-term exception, all sample analyses have met U. S. EPA primary drinking water standards, which are based on a 4 mrem/yr dose equivalent.

The investigation for non-radiological hazardous constituents in site ground water is based on guidance provided within Reference 2, the "Massachusetts Contingency Plan" (MCP) regulations under 310 CMR 40.00 for the release of oil or hazardous materials. Those investigations are not addressed in this report.

1.1 General Site Description

The YNPS was built in 1959-60, designed as a prototype to operate for 6 years, with a power level of 145 MW (later increased to 185 MW). In fact, YNPS operated for 32 years, safely and reliably producing low cost electric power. Descriptions of the site, related to ground water investigations, are provided in this section.

1.1.1 Plant Location and Local Topography

The YNPS plant site is located in northwestern Massachusetts in the town of Rowe, near the southern Vermont border (Figure 1). The developed area of the plant site encompasses approximately 12 acres at the northwest corner of a 2200-acre property owned by YAEC. Aside from electric transmission lines, the balance of the property area remains as undeveloped woodland.

The YNPS site is at the east side of Berkshire Mountains situated on a portion of a river terrace on the east side of the Deerfield River. The terrace is recessed into and largely surrounded by high slopes of the river valley. In the vicinity of the plant, the sides of the river valley rise to over 1000 feet above the river elevation, creating a valley about 2 miles wide.

The YNPS plant is adjacent to Sherman Dam, owned by USGen New England, Inc., one of several dams along the Deerfield River used for hydroelectric power generation. This upper (northern) portion of the Deerfield River Valley is unique in Massachusetts for its steep topography (a product of alpine-type glacial erosion) thus providing good locations for hydroelectric generating facilities. The local gradient for this portion of the Deerfield River is quite steep at 28.4 ft/mi, as measured from the Vermont border to the gauging station at West Deerfield, Massachusetts, a distance of about 33 miles.

Sherman Pond, impounded behind Sherman Dam, has been the source of cooling water throughout plant operation. This pond is about 2 miles long, a quarter mile wide, and up to 75 feet deep along its central channel. The pond and river are directly downgradient of the site. Figure 1 provides a topographic map of the site area, showing these general features.

This report along with plant drawings and many descriptive reports base reference elevations on this arbitrary Sherman Dam datum. The Sherman Dam datum is 105.66 ft higher than mean sea level (msl) datum.

Key elevations for the site are based on the datum used for construction of Sherman Dam. These are approximately as follows:

Typical water elevation of Sherman Pond	+999 ft
Deerfield River below Sherman Dam	+834 ft
Ground surface at the plant site	+1014 to +1054 ft

Unless otherwise noted, compass directions used to describe YNPS site locations in this report are based on a plant grid that has its north direction toward the Deerfield River, parallel to the sides of major plant structures. This grid-north direction is rotated 44.5 degrees counterclockwise from true north (Figure 2). This plant grid system is used on most original plant drawings and documents.

1.1.2 Plant Structures

The YNPS consisted of 26 permanent structures and a number of separate outdoor components, especially system tanks. Figure 2 shows the location of all of these original and added structures. Structures removed as part of decommissioning are denoted with dotted lines in Figure 2.

The plant's original Radiological Controlled Area (RCA) shown in Figure 2 represents a standard nuclear facility arrangement providing a restricted and controlled access and operations area where use and handling of radiological materials are permitted. "Summary of Excavation Volumes for YNPS Construction Projects Performed During the Time Period of Plant Operation" (Reference 3) provides a description of plant construction projects since the start of YNPS power generation. This is notable because construction included soil excavation inside the RCA for most projects. Excess soil from this work was generally placed elsewhere on the site. Radiological controls in effect at the time of these projects provided release criteria with lower thresholds than current requirements in effect for decommissioning

Currently all radiological components and materials, with the exception of the spent fuel and associated support structures, have been removed from the site as part of decommissioning work. The fuel will eventually be moved to an onsite dry cask storage facility and remaining structures decommissioned.

2.0 SITE GEOLOGY

Relevant site geologic data are described in detail in References 4 and 5. "YNPS Geology and Seismology" (Reference 4) is a licensing document prepared for the NRC's Systematic Evaluation Program to describe site and local geology and seismology in support of licensing of older nuclear power plants in 1979. Figures 3A, 3B, and 3C are a geologic map and two profiles taken from that document, respectively.

The document "Environmental Characterization Summary" (Reference 5) provides analysis of site characterization data collected through the year 1999. References 6, 7, 8, and 9 are the 1993-4, 1995, 1996, and 1997 "Annual Site Characterization Reports," respectively. These reports summarize YNPS site characterization information for those years and contain detailed data for specific characterization locations at the site where investigations were made, including soil boring information for many of the monitoring well locations.

2.1 Distribution and Character of Soil and Bedrock Units at the Site

Soils at the site consist of three basic types (Figures 3A, 3B and 3C):

- Fill outwash: silty sand and gravel outwash with some silt layers, generally 3 to 12 feet thick with original construction fill derived from sandy outwash and used for YNPS plant construction
- Till: dense, silty, sandy, gravelly bouldery glacial lodgment till, which includes some stiff clayey layers, with a total thickness of about 0 to 250 feet
- Ground moraine: thin till-like material present on valley slopes only

Reference 4 indicates soil thickness is over 100 feet beneath the center of the plant site (Figures 3B and 3C). The thickest soil deposits are located in the southwest portion of the site. Soil is absent or nearly so just above the base of the valley slopes from near the northeast around to the southeast side of the site. On the adjacent hillsides around the east, south, and west sides of the plant site, a thin layer of glacial till, essentially ground moraine, occurs intermittently over bedrock. Soil is absent and bedrock is exposed for a portion of the site just east of the RCA. A bedrock knob forms a topographic high between the site and Wheeler Brook (Figures 3A and 3C).

Close to the Deerfield River, soils include alluvial material consisting of sandy and gravelly sediment in and along the shorelines and silty sediment in the deeper sections of Sherman Pond. The contact between outwash and till or alluvium and till within the Deerfield River's south bank produces outflow of ground water as springs, as discussed in Section 3.0.

Prior to plant construction a stream flowed through the south side of the site from the hills at the southwest corner of the site to the Deerfield River, downstream of the dam. This appears to have fed the so-called "unnamed tributary" that receives water from the plant's west storm drain system. This stream is shown on an original plant construction drawing for site clearing (Reference 10). Alluvial deposits, consisting of stream terrace sands and gravels with relatively higher permeability, appear to occur along the trace of this stream.

Sherman Dam is a large earth embankment that straddles the river at the north end of the YNPS site. It consists of various types of fill originally placed in 1927 and increased in height slightly in 1964.

Reference 4 also describes outwash as thinnest at the east margin of the site where bedrock crops out at the surface along the upper (south) portion of the site (Figure 3C). Near the center of the site where the bedrock surface is very deep, Reference 4 indicates that glacial till extends to depths of over 175 feet. Investigation for a new potable water well in 1999 showed glacial till up to 250 feet deep at the southwest corner of the plant site. Original plant construction included the placement of fill beneath and in the immediate vicinity of buildings and under the yard area of the plant.

Bedrock at the site is part of the lower Cambrian Hoosac formation. It consists of metamorphic rock described as quartz-albite-biotite gneiss and rusty gneiss in adjacent areas. Underlying these are garnet schist and a layered gneiss with some dolomitic marble belonging to the lower Cambrian or older Cavendish Formation (Reference 4). Bedrock structure consists of a south-plunging anticline, the axis of which occurs just west of the site (Figure 3B).

Reference 4 describes bedrock at the site as generally hard, fresh, internally welded metamorphic rock, without significant subaerial or other weathering features. Bedrock fracturing is not a prominent structural element. Bedrock outcrops exhibit either no joints or minor discontinuous joint surfaces. Analysis of fracture patterns for 74 joints or joint sets and 5 minor fault surfaces in the site vicinity showed no anomalously preferred orientation of fractures. These studies also suggest the absence of any through-going zones of post-metamorphic faulting or shear that is these faults are not found associated with contemporary seismicity (Reference 4).

2.2 Site Characteristics and Modifications Made by Construction

Plant structures with deep foundations that penetrate or impinge on the saturated zone include the Primary Auxiliary Building, Fuel Pool, and Ion Exchange Pit (PAB/FP/IXP). The Ash Dewatering Pit in the Waste Building is also very close to the water table level. The PAB/FP/IXP foundations are also built into a natural slope, providing a very steep local ground water gradient. The significance of this configuration is discussed in Section 3 of this Report. Underground storage tanks that held non-radiological liquids, were removed at the outset of decommissioning activities. One radiological liquid storage tank location remains as an underground concrete vault (storing drainage from a radiological lab and other radiological areas of the Service Building), while another subsurface vault, mostly filled with concrete due to internal radiological contamination also remains at the site. These are designated as nos. 35 and 36 on Figure 2.

The "Overview and Status: Environmental Characterization, Yankee Nuclear Power Plant Site" (Reference 11) describes residual contamination from water leakage to soil under the Fuel Pool, Ion Exchange Pit, PCA radiological decontamination-tub drain, and Waste Building Ash Pit. Subsurface soil at these locations is yet to be fully evaluated or remediated. However, no significant effect on ground water is apparent based on existing YNPS characterization data. A full description of soil at these locations is provided in Reference 5.

3.0 SITE GEOHYDROLOGY

Prior geologic studies and YNSD decommissioning site characterization data provide a fairly complete picture of shallow ground water conditions at the site. The major portion of the data comes from monitoring wells installed as part of site characterization (Figure 5). Shallow ground water at the site is contained in fill outwash and glacial till, soil types described in Section 2.1.

Shallow ground water occurs to some extent perched in shallow soils due to the relative impermeability of the underlying till. Along slopes where the contact between these soils is exposed, such as the banks of the Deerfield River, are small, perennial and intermittent natural springs. A perennial spring, called Sherman Spring has been formally monitored for radiological constituents over many years (see Section 4.1). A second spring emanates from the Deerfield River bank to the west of Sherman Spring above the roadway to the Sherman Dam powerhouse, downgradient of the old plant septic leaching field (Reference 7).

The shallow ground water depth at the south end of the RCA is about 3 to 7 feet, depending on local soil conditions, with surface ponding occurring in isolated areas. A wetland just south of the RCA fence line highlights this shallow ground water. At the north end of the site, toward the Deerfield River, ground water is 18 to 20 feet beneath the ground surface (Figure 4).

The site's ground water is recharged primarily by precipitation, which averages 47 inches/year at YNPS based on data in the "YNPS Environmental Report" (Reference 12). Surface runoff and shallow ground water flow from the surrounding hills are directed through the plant storm drain system, ultimately discharging to the Deerfield

River. Since the elevation of the Deerfield River below Sherman Dam is approximately 100 feet lower than average plant grade, a fairly steep average water table gradient of 0.10 ft/ft exists across of the site. This contrasts with a very steep localized ground water surface gradient of 0.15 ft/ft at the PAB/FP/IXP area. This steep gradient is due to construction of these structures along a slope and the damming effect of the deep foundations of these structures, which are extended into the glacial till.

Natural surface drainage in the YNPS site area is towards the Deerfield River and Sherman Pond. Like surface water flow, ground water flow was initially assumed to be directed toward the Deerfield River based on this practical assumption. These data can be compared to ground water elevations in wells as represented by Figure 4, described in Section 3.1. In Addition, leakage of tritium (H-3) from the plant's Fuel Pool and Ion Exchange Pit early in the plant's history in the "Yankee Nuclear Power Station Decommissioning Plan" (Appendix B of Reference 13) has provided a direct method (solubility of H-3 is not an issue) for tracing ground water movement, providing confirmation of the flow direction based on well known methods (References 14, p. 427, 15 and 16).

Ground water from surficial materials has not been used for drinking water at or nearby the site, nor is it a source of water for any purpose in the area of the plant (Reference 17, Section 3.4.2). The Deerfield River is not used for a source of drinking water downstream of the plant. The closest municipal water supply downstream of the plant is over 20 miles distant (Reference 17, Section 305). The site's potable water well, drilled into bedrock, serves as a source of drinking water for the plant. This state-licensed well is located approximately 450 feet southwest of the main plant buildings in the upgradient ground-water flow direction (Figure 2). Bedrock in the region is not a significant source of water supply, and no major ground water aquifers occur within the site area (Reference 17, Section 302).

3.1 Ground Water Table Elevations

Figure 4 is a ground water contour map based on average levels of water in site monitoring wells from data compiled over the years of plant decommissioning work. Also considered were:

- Topography (elevations rise sharply to the south, east and west) and toward the crest of Sherman Dam, and
- The shape of contour at elevation 1035 near the ISFSI structure is inferred based on the installation of a foundation drain and structural fill placed at that location per the "ISFSI Site Grading Plan" (Reference 18).

Ground water flow can be assumed to be directed perpendicular to these contour lines. Thus, in general, Figure 4 shows that ground water flow is directed towards the river, and for a small area at the northeast corner of the site, toward Sherman Pond.

3.2 Ground Water in Bedrock

Ground water in bedrock has provided potable water for the plant site from two wells over the course of plant operations and decommissioning. Locations of both wells are shown as features 41 and 42 on Figure 2. The first plant water well, drilled in 1958 to a depth of 437 feet and with a diameter of 8 inches, had a safe yield of 5.7 gpm as documented in a report to the MA DEP (Reference 19). Such a low yield is consistent with regional observations of yields from crystalline rock (Reference 20). That first well was decommissioned in December 1999 and grouted due to its proximity to the planned location for the YNPS ISFSI. Stratigraphy at that location was estimated to consist of:

Unit	Depths
Sand and gravel fill	0-5 ft
Silt and fine-grained sand outwash	5-12 ft
Glacial till	12-100 ft
Bedrock: Hoosac Gneiss	100-437 ft

A new well was drilled in 1999 at the southwest corner of the site to a depth of 280 feet. The well was determined to have the following stratigraphy during drilling:

Unit	Depths
Sand and gravel outwash	0-15 ft
Glacial till	15-250 ft
Bedrock: Hoosac Gneiss	250-280 ft

Yield estimated at the time of drilling was 60 gpm. This high yield is attributable to the well location, which was chosen based on standard geologic exploration principles:

- Bedrock is deep (and consequently glacial till cover thick) and
- A coincident topographic inflexion line for both ground surface and bedrock surface topography occurs, and
- Location is along the trend of a surface drainage feature, coincident with a recognizable fracture trend in the bedrock and surface topographic and drainage lineaments

Another 6-inch diameter bedrock well, 408 feet deep at the Plant's Visitor's Center, about ½ mile west of the site has a yield of about 8 gpm per its "1995 Annual Statistical Report" (Reference 21).

Two site monitoring wells, B-1 and CW-10 penetrate bedrock. The typical level of ground water in Well B-1, which has a screen that straddles the till and bedrock, is generally about 10 feet lower than that for CB-1, which is only 60 feet away and is screened in the fill-outwash. This condition demonstrates how the relative impermeability of the till perches ground water.

4.0 GROUND WATER CHARACTERIZATION METHODS

4.1 Approach for YNPS

With basic plant site geology fairly well documented in licensing plant studies and documents, the initial phase (scoping) location of monitoring wells was based on site history of spills and leaks (Reference 13, Appendix B). Some wells, installed subsequently, were located to help define a tritium (H-3) plume flow.

Based on many years of YNPS Radiological Environmental Monitoring Program (REMP) ground water analyses for radioactivity reported in the original YNPS D-Plan (Section 3 of Reference 13) it was clear that H-3 was present in the ground water at the site. Tritium acted as a tracer faithfully tracking ground water flow and provided an additional means to assess the suitability of monitoring well locations.

All pertinent descriptive information for each well and the basis for their locations are summarized in Table 1. Table 2 is a summary collection of all analyses done for characterization of ground water based on a database described in Section 5.3. A site plan showing all monitoring wells is in Figure 5.

Installed in 1993, monitoring wells, CB-1, -2, -3, -4 and CW-1, -2, -3, -4, -5, and -6 were located just downgradient of historic spill or leak locations. At locations where there was some possibility of subsurface soil contamination, soil samples were taken and analyzed as wells were installed (wells prefixed "CB").

Analyses for H-3 from wells installed in 1993, along with REMP results for Sherman Spring (Attachment 1), provide a reasonable definition for ground water flow direction. They also served as a basis to help locate monitoring wells, CB-6, -8, -9, CW-7, and -8, installed in 1994 to further defined general ground water flow and the H-3 plume at the site. Other monitoring wells installed upgradient or cross-gradient of the PAB/FS/IXP complex, CB-5, -7, -8, -10, -12, and CW-10 were located at places where warranted by soil conditions or site history.

4.2 Prior Determination of Analytes of Concern, Surrogates

Reference 5 addressed the historical analytes of concern for site environmental characterization based largely on soil sampling data. It describes the radiological analytes of concern and for all environmental media (soil, sediment, and ground water) at the site as follows, with analytical techniques noted:

Symbol	Radionuclide	Analytical Technique
• H-3	Tritium	Liquid Scintillation Counting
• Mn-54	Manganese 54	Gamma Spectroscopy
• Co-60	Cobalt 60	Gamma Spectroscopy
• Sr-90	Strontium 90	Radiochemical Separation
• Ag-108m	Silver 108 metastable	Gamma Spectroscopy
• Cs-134	Cesium 134	Gamma Spectroscopy
• Cs-137	Cesium 137	Gamma Spectroscopy

Other radionuclides that could have been released into the environment from YNPS are transuranics, alpha-emitting radionuclides with atomic numbers greater than 92 and with half-lives greater than 20 years. These include neptunium, plutonium, americium, and curium. No significant testing was performed for these analytes because:

- The lack of evidence for their presence in characterization soil samples at the site (Appendix 6 of Reference 7)
- Their very low transport rates in soils such as exist at YNPS
- Knowledge based on records/results of RP surveys, effluent sample analyses and radiological waste characterization analyses
- The use of gamma-emitting radionuclides Co-60 with Cs-137 as surrogates
- No detectable levels of these nuclides found in characterization soil samples containing the highest levels of gamma-emitting radioactivity (Appendix 6 of Reference 7)

Sr-90 was not originally considered to be a likely concern for ground water characterization. Recent interest in this radionuclide in ground water at other decommissioning plants has caused YNPS to consider a second look at the results for this analyte in YNPS ground water. Two rounds of analyses of well samples for Sr-90 are described in Section 6.3.3 of this report.

4.3 Investigation Methods: Procedures and Plans

The YNPS Site Characterization process was planned and constructed based on the YNPS Plant Procedure "Administrative Program for Radiological Characterization Surveys to Support YNPS Decommissioning Planning," (Reference 22). Monitoring well installation was done using YNPS Plant Procedure, "Subsurface Soil Sampling and Monitoring Well Installation" (Reference 23). That procedure provided installation direction and documentation and allowed for soil samples to be taken during well installation, where needed. Wells were designed consistent with Massachusetts Department of Environmental Protection (MA DEP) guidelines for monitoring wells as recommended in MA DEP "Standard References for Monitoring Wells" (Reference 24).

Sketches showing the configuration of each well are included in Attachment 2. Well development (preparation for initial sampling) was accomplished by pumping multiple well volumes (screen as well as filter pack volume) from each with pumping continued until satisfactory water clarity was obtained.

Ground water samples are obtained using YNPS Plant Procedure "Ground Water Level Measurement and Sample Collection in Observation Wells" (Reference 25) with transport to offsite labs performed in accordance with the YNPS Plant Procedure "Sample Chain of Custody" (Reference 26). Ground water samples were initially obtained from wells using bailers or a peristaltic sump. Where dedicated equipment was not used, care was taken to insure decontamination of samplers between wells. Sample acidification and filtration as needed were initially done in the laboratory but eventually these steps were provided in the field.

The Framatome ANP DE&S Environmental Laboratory (FDESEL) typically performed analyses but the YNPS plant laboratory also performed some analyses. Analyses were done using standard environmental Minimum Detectable Concentrations (MDCs) based on the YNPS Offsite Dose Calculation Manual as guidance. For H-3, the analysis method was distillation with the distillate subject to liquid scintillation counting (Reference 27). Gamma spectroscopy analyses were performed using a shielded high purity germanium detector (Reference 28). Strontium analyses were performed using the Cerenkov method (Reference 29).

As a minimum initial survey for each well, samples were typically obtained at least quarterly for a year. Analyses included H-3 liquid scintillation counting and gamma spectroscopy.

CB-11A was installed in the PAB following detection of H-3 in samples from standing water exposed during concrete floor removal in that building. Subsequent samples from that well revealed elevated H-3 concentrations in a highly localized zone. Several new monitoring wells were placed in the vicinity of that well to assure that any significant related information was uncovered. Results of these investigations are discussed in section 6.3.1.

Soil permeability conditions were evaluated using YNPS Plant Procedure, "Field Permeability Data Collection in Observation Wells" (Reference 30). "YR Ground Water Model–Permeability and K-Summary" (Reference 31) an informal, unverified calculation, provided permeability estimates based on the field data.

The YNPS Plant "Procedure for Permanent Closure of Monitoring Wells" (Reference 32) was used to insure the safe and complete decommissioning of wells when monitoring is no longer needed. To date, five wells (shaded entries in Table 1) have been grouted for various reasons, using this procedure.

All pertinent radiological data collected for environmental characterization are documented in a database provided by YNPS Plant Procedure, "Site Characterization Environmental Radiological Database" (Reference 33).

4.4 Background Considerations

Background levels of plant-related radionuclides in ground water are generally very low, well below any drinking water standards for ground water (Reference 34 p. 137-9 and Reference 35 p. 6.40). For example naturally occurring H-3 typically occurs in ground water at levels less than 10 pCi/L; slightly higher levels may occur where atmospheric weapons testing has impacted ground water (Reference 36). However, this level is not only well below drinking water standards (20,000 pCi/L), but is also below typical environmental level MDCs for H-3, which ranges from about 350 to 2000 pCi/L. Other radiological analytes of concern are expected to have even lower presence in background.

5.0 SUMMARY OF CHARACTERIZATION GROUND WATER INVESTIGATIONS

References 5 and 11 provide summaries of all radiological and non-radiological site characterization data collected through 1999. Ground water data collected since that time is compiled in a site characterization database per requirements of Reference 33. A summary of H-3 plume data was presented in a recent memo entitled, "H-3 Concentrations in YNPS Site Ground Water" (Reference 37). General radiological sampling activities for ground water were last assessed in mid-1998 (Reference 38). Reference 5, Environmental Characterization Summary describes the radiological analytes of concern for all environmental media at the site as described in Section 4.2.

With the exception of H-3, the analytes of concern listed in Section 4.4 generally have relatively low solubility in water. It is possible for them to migrate through soil when driven by water flow, but such migration is greatly inhibited by their physical state, atomic sizes, as well as the ionically charged nature of the soil column and radionuclide. Consequently, movement of these radionuclides through soil occurs very slowly or not at all when water sources (regular rainfall, or continuous leakage, e.g.) to carry them are not available. This is supported by the relatively high soil-liquid partition coefficients estimated for them by Reference 39. Thus with the exception of H-3, radionuclides inadvertently released to soils tend to remain very close to the source. This anticipated condition has been found to be the case for every instance of radioactivity investigated in YNPS site soils.

An example of this is provided in Appendix 10 of Reference 6 (Included as Attachment 3). *Investigations were performed at three YNPS locations where* soil radioactivity was found to be the highest in surface soils:

- Beside the Waste Holdup Tank Moat,
- In the radiological storage area north of the Old PCA, and
- Under the Vapor Container

Hand excavation of surface soil beneath asphalt revealed very consistent profiles of diminishing radioactivity within a depth of less than 18 inches. The soil sampled is representative of the fill-outwash at the site. Pavement was added in the latter two areas in the mid-1980s. H-3 behaves very differently compared to gamma-emitting radionuclides. H-3 moves through soils with ground water.

Historic water leakage from the Ion Exchange Pit (repaired in 1966) and the Spent Fuel Pool (prior to its lining in 1979) has introduced H-3 to the ground water at the site. The extent of this leakage is discussed and summarized in Reference 13, and the "YNPS Site Radiological Environmental History Supplement" (Reference 40). Table 2 contains a summary of H-3 values from all samples taken from wells since initiation of monitoring.

Gamma-emitting radionuclides were detected in a very few well samples, generally in samples that were not filtered. Retesting of those samples after filtration, a standard field/lab practice for ground water samples, confirmed that radioactivity was in sediment in the samples and not dissolved in the water. This implies that while there is some radioactivity at depth in soils, these components resist dissolving in water. This is consistent with behavior the expected due to high permeability coefficients (K_d) values. Table 2 contains a summary of all detected gamma-emitting radionuclide values from all samples taken from wells since initiation of monitoring. A description of that data is provided in Section 6.3.2.

5.1 Well Design and Locations

Figure 5 shows all site well locations and Attachment 2 contains construction sketches of all monitoring well installations. These sketches show well ground elevations, well and screen diameters, depths, materials, stratigraphic summaries, sand filter packs and bentonite seals, installation dates, drilling contractors, design engineers, and initial ground water depths.

Table 1 summarizes all information relevant to the monitoring wells including:

- Date installed/grouted
- Surface elevation
- Well depth
- Typical ground water depth
- Responsible engineer
- Well location
- Basis for the location of the well
- Characterization results summary
- Grid location

5.2 References and Data

A number of documents were produced to address ground water monitoring results for YNPS site characterization. Key references include formally issued reports and documents in several categories as well as outside references:

- The original Decommissioning Plan submitted in 1993
- Annual Site Characterization data reports
- YNPS Plant Procedures used for characterization work
- Topical reports and technical memoranda by DE&S and others
- Licensing documents: YNPS Final Safety Analysis Report, YNPS Environmental Report, the original License Termination Plan draft, and the SEP submittal on site geology
- External references on geology and geohydrology of the area

There also exists a quantity of characterization data collected but for which assessment is not documented. This information is addressed in this report, as follows:

- YNPS Site Characterization Database. A periodically updated, verified and validated (V&V) database of all radiological analyses done for site characterization, plant procedure DP-8600 provides for this data catalog. Copies of the database have been provided to YNPS as new data are entered. Data are V&V through 1999. Outstanding data packages (6/01 and 12/01) have been provided to YAEC for validation check per Reference 33.

- A round of 1994 gross alpha and gross beta results from 12 monitoring wells.
- Two rounds (1997 and 1998: 20 and 23 wells) of Sr-90 results and one round (1997: 20 wells) of Sr-89 results from monitoring wells.
- Graphs of ground water depths/elevation data collected during monitoring of wells. Presented in the annual Site Characterization Annual Reports, References 6, 7, 8, and 9, these graphs have not been updated since 1998. More recent data are included in this report in Attachment 4.
- Graphs of H-3 data from the time of initiation of site monitoring in 1993. Presented in the annual Site Characterization Annual Reports, References 6, 7, 8, and 9, these graphs have not been updated since 1999. Newer data are included in this report in Attachment 1.
- YNPS REMP data for ground water samples from Sherman Spring and the site potable water well. Collected and compiled from FDESEL results, these data provide baseline information starting in 1978 to support site characterization ground water studies. Data for H-3 in Sherman Spring samples are represented in the graph in Attachment 1. No other significant detectable levels of radionuclides have been found in either Sherman Spring or in samples from the site potable water wells.
- A single round of Sr-89 and Sr-90 analyses was done for 20 monitoring well samples in late 1997 and a single round of Sr-90 analyses were done for 23 YNPS monitoring well samples in early 1998. The data were not formally presented in a report. Results show no detectable Sr-90 or Sr-89 in ground water samples. MDCs for the samples were less than 20% of the U.S. EPA drinking water limits.
- A single round of gross alpha and gross beta analyses was done for the 12 existing monitoring wells at YNPS in 1993. Gross beta data were presented in the original D-Plan (Reference 13, Section 3) but gross alpha data were not formally presented. Samples were unfiltered and results show no detectable gross alpha levels for samples from 12 wells. Gross beta levels were within typical background levels for environmental samples.

5.3 Analytical Data

Reference 33 provides a means to formally compile, store and provide data excerpts for evaluation or analysis. The database consists of a catalog that includes all the pertinent data from sample analyses, recorded in a way that provides V&V information and ready access. Attachment 6 contains a list of the data provided in the database for each sample. Input of information has been handled both electronically and manually from lab data sheets. Currently the ground water data has 2 sets of data ready for inclusion, pending V&V completion. The V&V status of data is noted in the last column of Table 2 where, per Reference 33, a single V identifies data that is verified; VV identifies verified and validated data; X represents invalid data; and no designation represents data not yet V&Vd.

6.0 SITE CHARACTERIZATION RESULTS

6.1 Water Level Measurements

Graphs representing ground water depths for all monitoring wells are included in Attachment 5. Most wells show minor seasonal fluctuations in ground water levels, as demonstrated by the data plots in Attachment 4.

Figure 4 is a ground water table hand-drawn contour based on average levels of water in site monitoring wells from data compiled over the years of plant decommissioning work. The contours show the general flow direction of ground water toward the river and Sherman Pond.

6.2 Well Development

Well development was provided based on a procedure that included the initial use of driller's equipment when wells were constructed, and pumping prior to initial sampling. Well development (preparation for initial sampling) was accomplished by pumping 2 to 3 well volumes (volume of the casing as well as filter pack) from each with pumping continued until optimal water clarity was obtained.

6.3 Sample Analysis Results

Radiological analytical results for site characterization ground water samples are presented in Table 2.

6.3.1 Tritium

Tritium (H-3) has had a constant, though generally decreasing low-level presence in wells. These data are represented in graphical form in Attachment 2. The graphs show filled and open symbols to denote detectable and non-detectable (<MDC) levels, respectively. Results for wells with persistent H-3 levels are:

B-1, CB-1, -2, -6, -9, -10, -11A, CW-11, MW-1, 2, MW-3 and its replacement, MW-5.

A few wells have had H-3 detectable intermittently in samples:

CW-7, -8

Most wells had no detectable H-3 in their samples:

CB-3, -4, -5, -7, -8, -12, CW-1, -2, -4, -5, -6, -7, -8, -9, -10, MW-6, OSR-1, NSR-1, CFW-1, -2, -3, -4, -5, -6

With the possible exception of CB-10, H-3 concentrations have trended down due partly to natural dilution and attenuation. Decreasing H-3 levels in the Fuel Pool since the start of decommissioning are also a likely contributor to this trend (see Section 6.3.4).

The results from monitoring wells define a plume for the site as illustrated in Figures 6 and 7. These show:

- The relatively low concentrations of H-3 in site ground water (almost all below the U. S. EPA drinking water standard of 20,000 pCi/L)
- The rapid dilution of H-3 concentrations with movement toward the river, and
- The significant decrease of H-3 concentration with time

The single exception to these conditions is the presence of elevated concentrations of H-3 in wells CB-11A, CW-11, MW-2 and MW-3 between early 1998 and late 1999. This appears to be a consequence of leakage from beneath the PAB, which occurred in the course of decommissioning work. Reference 41 is a memo that addressed the situation at the time.

Initial samples from well CB-11A, installed (12/18/97) inside the PAB through its concrete foundation mat, contained H-3 at levels near 80,000 pCi/L. In addition, this well exhibited an artesian condition with water flowing from the hole at a rate of ½ to ¾ gpm. The initial water level was about 2 to 3 inches above the top of the concrete foundation slab of the PAB cubicle corridor pipe trench. This condition supports the belief that the foundation of the PAB along with those of the Ion Exchange Pit and the Fuel Pool, all deep structures extending beneath the ground water table and into the top of glacial till, are providing a "dam" impeding flow of ground water from beneath the PAB. Dewatering of the PAB to facilitate building cleanup effectively removed a very large percentage of the trapped ground water. The result was an effective remediation of the tritium. Water produced by this process was collected and processed through the plant evaporator and released to surface drainage in keeping with regulatory release permits. The consequences of residual concentrations of H-3 in the ground water beneath the PAB were investigated by installation of several new and existing wells, as described below.

Soil samples taken during installation of CB-11A contained very low levels of gamma-emitting radioactivity. Ground water samples from CB-11A have contained no detectable gamma-emitting radionuclides. Additional monitoring wells were installed downgradient (MW-2 and MW-3) and upgradient (MW-1) of this location in early April 1998. These new wells supplemented existing downgradient wells CB-1, -2, -6, and CB-9.

During the period between early 1998 and early 2000, samples from downgradient wells showed some increase in H-3 levels compared with prior results. These data is illustrated for the two closest wells, CW-11 and MW-2 in Figure 8 and in graphs for wells in Attachment 2. After early 2000 the trend of decreasing H-3 resumed for downgradient wells.

The H-3 plume maps in Figures 6 and 7 provide a comparison of H-3 concentrations in the vicinity of the PAB for years1999 and 2000. These show that H-3 concentrations decrease rapidly downgradient of the PAB. In Figure 6, for example, maximum H-3 1999 concentrations were as listed in Table 4.

Table 4. Maximum 1999 H-3 Concentrations

Well	Downgradient Distance from CW-11	Maximum 1999 H-3 Concentration, pCi/L
MW-5	30	5610
CB-9	75	4010
CB-2	350	1280
CB-6	500	666

Figure 7 shows that by the year 2001 the highest H-3 concentration in any of the wells was just over 4000 pCi/L in MW-5.

6.3.2 Gamma-Emitting Radionuclides in Ground Water Samples

Routine tests for gamma-emitting radionuclides have been done for all site monitoring wells. Samples that were found to have detectable levels are highlighted in Table 2. This includes eight samples from CB-1 (and two reanalyses of those samples), and one sample each from wells CB-6, CW-5 and MW-3. Almost all of these have been in unfiltered samples. Detected levels in all samples are all well below U. S. EPA Drinking Water Standards levels (based on a 4 mrem/yr dose equivalent).

Follow-up samples or results from filtering of samples have shown that the radioactivity in CB-1 samples appears to have been in suspended particulate matter in samples, and not dissolved in the water itself. Since field filtration of samples was initiated in 1996, no samples from that well have contained detectable levels of gamma-emitting radionuclides.

Single samples from wells CW-5 (unfiltered) and MW-3 (filtered) contain detectable Co-60 and Cs-134, respectively. In both cases concentrations were very low and no subsequent samples from those wells contained gamma-emitting radionuclides above MDC levels. During the sampling episode for the CW-5 sample demineralized water used for decontamination of sampling equipment was found to contain gamma-emitting radioactivity and that is the suspected source for that sample. The sample from well CB-6, filtered in the lab, retested with no detectable gamma activity.

Fifteen samples from seven wells taken in early March 1999 were found to be contaminated by Co-60 due to field and/or laboratory error. Subsequent resampling of these wells provided Co-60 results below detectable levels (Reference 42).

6.3.3 Gross Alpha, Gross Beta and Sr-90 Analyses

As discussed in Section 4.2 testing of ground water for gross alpha, gross beta, strontium and transuranics has not been a major component of YNPS site characterization. Data were collected at the outset of the project in 1993 for gross alpha and gross beta (Table 3). Strontium analyses were done for two sets of samples (Table 2).

Samples from 12 wells were analyzed for gross beta as both unfiltered and filtered through a 40-micron screen (Table 3). Results for both filtered and unfiltered samples showed detectable gross beta in all samples with levels consistent with those found in ground water for samples in YNPS REMP analyses, that is detectable but low (based on U. S. EPA criteria discussed below) levels of gross beta. The U.S. EPA defines a gross beta screening level for "vulnerable" locations (such as near a nuclear facility) at 50 pCi/L. All results for filtered samples and all but two results from filtered samples were well below that threshold. The two unfiltered samples that exceeded that guideline, from CB-3 and CW-4, had values of 74 and 79 pCi/L, respectively. Subsequent filtering and reanalysis of these samples resulted in concentrations of 5.20 and 1.70 pCi/L for CB-3 and CW-4, respectively. Thus the high values for the unfiltered samples are attributable to radioactivity in the suspended fraction of the sample and thus not contributing to internal dose. Most if not all gross beta in these samples is likely to be attributable to naturally-occurring radioactivity.

Samples from 12 wells were analyzed for gross alpha with all samples filtered prior to analysis. All sample results were less than detectable levels (<MDC). The MDC for those analyses was generally between 1 and 4 pCi/L, sufficient to analyze against the U. S. EPA drinking water standard of 15 pCi/L.

Sr-90 analyses were done for 20 wells in 1997 and 24 wells in 1998. The 1997 work included analyses for Sr-89 as well. None of the samples showed detectable levels of either nuclide. MDC values were all below the U. S. EPA drinking water standards of 8 and 20 pCi/L for Sr-90 and Sr-89, respectively (based on a 4 mrem/yr dose equivalent).

6.3.4 Spent Fuel Pool (SFP) Leakage

"YNPS Condition Report CR 1999-036" was issued on 5/17/99 (Reference 43) and addressed leakage from the upgradient Spent Fuel Pool (SFP) wall into the Ion Exchange Pit (IXP). The CR was prompted by analysis of standing water in the Ion Exchange Pit, which contained H-3 at a concentration of 50,000 pCi/L. Subsequent inspections and analyses of standing water from IXP provided information confirming that the leak to the IXP was less than 10 gallons per year. H-3 concentrations in water on the IXP floor, sump and in upgradient well CB-10 showed decreasing concentrations based on data reported in YNPS memoranda (References 44 through 48).

A chart showing the average concentration of H-3 in SFP water was included with these references and is included in this report as Attachment 7. This graph shows a significant decrease in H-3 concentration from 1/97 to 12/98 due mostly to evaporation (approximately 90% of the decrease) and the balance to H-3 decay (approximately 10% of the decrease). The significance of this condition to ground water monitoring is high. First, if there is leakage from the SFP to the IXP, there appears to be a reasonable likelihood that leakage occurs through the floor, the other walls and/or the joints between them. Thus, it seems likely that leakage from the SFP is the source of H-3 found in ground water monitoring wells. The general decreasing levels of H-3 in wells like CB-1, -9, -2, and -6, and B-1 would appear to be consistent with a decreasing source term like the SFP water.

A "blister" (water penetration) in the New Fuel Vault was noted as a leakage location. A water sample taken at the blister contained low levels of Co-60, Cs-134 and Cs-137. It was indicated that the Cs-134/Cs-137 ratio, compared to that of the SFP water, suggested a 4-year migration-rate through the SFP wall (Reference 48).

Removal of the fuel from the SFP in the near future will allow it to be drained. Levels of H-3 in ground water should then reflect the extent to which the SFP is the source of H-3 in site ground water.

6.4 Well Closures

Five YNPS monitoring wells have been closed since the start of monitoring. These are noted with shading in Table 1. Closure was accomplished in keeping with Reference 32. The procedure is based on Reference 24. The wells closed are as shown in Table 5.

Table 5. Well Closure History

Well No.	Date Closed	Reason for Closure
B-3	2-Jan-97	Well used for prior geotechnical investigation was small diameter and difficult to sample, replaced with CB-3
CW-1	7-Jul-00	Replaced by CW-9 to confirm isolated contamination with paint chips
CW-9	7-Jul-00	Replaced with MW-6 to confirm isolated contamination with paint chips
MW-3	7-Jul-00	Bent casing made sampling difficult, results from adjacent well, MW-2, appeared more conservative
NSR-1	7-Jul-00	Offsite location: non-radiological investigation completed

6.5 Site Ground Water Conditions Summary

This section presents a review and evaluation of conditions at the YNPS site relevant to ground water. It addresses the three potentially water-bearing units: fill outwash, glacial till and bedrock and their measured or inferred water transmitting and water bearing properties, and their potential for radionuclide transport. Key properties of the geohydrologic units at the site are estimated as shown in Table 6 based on study done for site characterization (Reference 31) and estimated done using site geotechnical data.

6.5.1 Unit Thicknesses and Lateral Extent

The thicknesses of key geologic units related to ground water at the YNPS site are as follows:

- Fill-Outwash 3-12 feet
- Glacial Till 0-250 feet

The limits of the fill-outwash and the till are generally defined by site topography as shown in Figures 3A and 3B.

6.5.2 Water-Transmitting Properties: Estimated Coefficients of Permeability

Values for coefficients of permeability for site soils were obtained in two ways: 1) estimates based on soil description using a standard chart and 2) based on computations using field testing results. Table 6 shows these data.

Table 6. Properties of Geohydrologic Units at the Site

Unit	Description	Silt and Clay	Estimated Permeability	Computed Permeability
Fill outwash (sandy portion, excludes silt layer)	Silty sand and gravel with some silt layers, 3 to 12 feet thick. Original plant construction fill was derived from sandy outwash	5-25% silt; 5% or less clay	5.0×10^{-1} to 1.0×10^{1} g/d/ft^2 (Equivalent to 2.0×10^{-2} to 4.0×10^{-1} m/d)	2.5×10^{1} to 4.6×10^{1} g/d/ft^2 (Equivalent to 1.0×10^{0} to 1.8×10^{0} m/d)
Glacial till	Dense, silty, sandy, gravelly bouldery glacial lodgment till, which includes some stiff clayey layers (till), from 0 to about 250 feet	30% to 40% silt, 8% to 20% clay	1.0×10^{-3} to 1.0×10^{-1} g/d/ft^2 (Equivalent to 4.0×10^{-5} to 4.0×10^{-3} m/d)	5.0×10^{-2} to 4.0×10^{0} g/d/ft^2 (Equivalent 2.0×10^{-3} to 1.6×10^{-1} m/d)

Table 6. Properties of Geohydrologic Units at the Site, continued

Bedrock	Quartz-albite-biotite gneiss and a rusty gneiss, generally hard, fresh, low fracture frequency metamorphic rock, and without significant weathering	Estimates based on low yields for drilled wells	1.0×10^{-7} to 1.0×10^{-5} g/d/ft^2 (Equivalent 4.0×10^{-9} to 4.0×10^{-7} m/d)	No measurements made

Estimated permeabilities were based on grain size distribution data from References 49 and 50, geotechnical studies done for the YNPS site and site characterization data. Key properties of the various units are noted in Table 6, in particular the abundance of fines (silt and clay) in soils and fracture frequency in the bedrock. Permeability of the fill-outwash soil is estimated to be moderate. Till and bedrock permeabilities are both estimated to be low. These data were used to make estimates based on a standard chart describing permeabilities for the range soil and rock deposits in Reference 14 p. 29.

Specific ground water inputs to RESRAD (Reference 51) were presented for the YNPS site in Reference 52 with some revisions provided in Reference 53. These are the results of site-specific judgments made by personnel familiar with characterization data and these dose codes. Those data represent one of the principal products of site characterization work.

6.5.3 Recharge and Discharge

Ground water recharge for the YNPS site is described in Section 3.0. It is provided by rainfall as well as by ground water flow from the steep hills adjacent to the site.

Ground water discharge from the site is to the Deerfield River surface water via springs or to underlying river deposits via ground water flow. Minimal ground water discharge occurs from the site soils to the underlying bedrock.

7.0 REFERENCES

1. "Radiological Criteria for License Termination: Radiological Criteria for Unrestricted Use," 10CFR20.1402, 1/1/01.
2. "The Massachusetts Contingency Plan" (MCP), 310 CMR 40.0000, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup, October 29, 1999.
3. "Summary of Excavation Volumes for YNPS Construction Projects Performed During the Time Period of Plant Operation," Memo to: E. Cumming from F. Bellini ESG 97-082, 2/27/98.
4. "Geology and Seismology Yankee Rowe Nuclear Power Plant," Prepared for Yankee Atomic Electric Company, Weston Geophysical, 1979, Docket No. 50-29, 67p.
5. "Environmental Characterization Summary," Yankee Nuclear Power Plant Site, DE&S, June 2000.
6. "Summary Report of Site Characterization Activities (1993-4)," Environmental Engineering Department, September 1995, YAEC-1924.
7. "Summary Report of Site Characterization Activities (1995)", Environmental Engineering Department May, 1996, YAEC-1934.
8. "Summary Report of 1996 Site Characterization Activities," Environmental Engineering Department, October 1997, YAEC-1945.
9. "Summary Report of 1997 Site Characterization Activities," Environmental Engineering Department, August 1999.
10. "Site Clearing," YNPS Plant Drawing 9699-FY-1C, 8/22/57.
11. "Overview and Status: Environmental Characterization," Yankee Nuclear Power Plant Site, DE&S, Feb. 2000.
12. "YNPS Decommissioning Environmental Report," December 1993.
13. "Yankee Nuclear Power Station Decommissioning Plan," Revision: 0.0, Yankee Atomic Electric Co., 1993.
14. "Groundwater," R.A. Freeze and J. A. Cherry. Prentice-Hall, 1979.
15. "Isotope Tracers in Catchment Hydrology," Chapter 2, Fundamentals of Isotope Geochemistry, Carol Kendall and Eric A. Caldwell, 1998, Elsevier Science B.V., Amsterdam, 839 p.
16. "Introduction to Ground Water Tracers," Dept of Hydrology and Water Resources, University of Arizona for the U. S. EPA, EPA/600/2-05/022 March 1985.
17. "YNPS Final Safety Analysis Report," 1999.
18. "ISFSI Rough Site Grading and Earthwork, Plan," Sheet 1, YNPS Drawing ISFSI-FY-010, 3/23/00.
19. "Comprehensive Compliance Evaluation: Sanitary Survey Stage 1," Letter to Yankee Atomic Electric Co. from MA DEP, NYR 96-047, 4/24/96.

20. Ground Water Atlas Of The United States: Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont, Crystalline-rock aquifers," HA 730-M, 1995.

21. Submittal of 1995 Annual Statistical Report," Letter to Massachusetts DEP Division of Water Supplies from W. J. Meyers, YNPS, BYR 96-055, 11/25/96.

22. "Administrative Program for Radiological Characterization Surveys to Support YNPS Decommissioning Planning," YNPS Procedure, AP-0831, Rev. No. 1.

23. "Subsurface Soil Sampling and Monitoring Well Installation," YNPS Procedure, OP-8122, Rev. No. 0, Issue Date, 4/93.

24. "Standard Reference for Monitoring Wells," Section 4.6, "Decommissioning of Monitoring Wells," Massachusetts Department of Environmental Protection, Publication WSC-310-91, November 1993.

25. "Ground Water Level Measurement and Sample Collection in Observation Wells," YNPS Procedure, DP-9745, Rev. No. 1, 9/96.

26. "Sample Chain of Custody," YNPS Procedure, DP-8123, Rev No. 8, 5/02.

27. "Determination of Tritium in Environmental and Bioassay Matrices," FDESEL Procedure No. 371, Rev 19, 1/25/02.

28. "The Determination of Gamma-Ray Emitting Radionuclides In Environmental/Bioassay and Effluent/Waste Media," FDESEL Procedure No. 450, Rev. 15, 2/21/00.

29. "The Determination of Sr-89, 90 in Environmental Media via Cerenkov Counting," FDESEL Procedure No.368, Rev. 10, 3/1/02.

30. "Field Permeability Data Collection in Observation Wells," YNPS Procedure, DP-9747 10/94.

31. "YR Ground Water Model–Permeability and K Summary," informal unverified calculation: F. X. Bellini and G. A. Harper, YNDS, February 1996.

32. "Procedure for Permanent Closure of Monitoring Wells at YNPS," YNPS Procedure, OP-8125.

33. "Site Characterization Environmental Radiological Database," YNPS Procedure, DP-8600, Rev 0, 5/00.

34. "Hydrogeology," S. N. Davis and R. J. M. DeWeist, John Wiley & Sons, Inc., 1966

35. "Handbook of Hydrology," D. R. Maidment (editor), McGraw-Hill, Inc., 1993.

36. "Determining Background Radiation Levels In Support of Decommissioning Nuclear Power Facilities": Contributing author: soil and ground water sampling plan designs and river sediment case studies, EPRI Report No. TR-1003030, December 2001.

37. "H-3 Concentrations in YNPS Site Ground Water," Letter to K. W. Dow from Daniel L Magnarelli, DSF 2002-034, 2/19/02.

38. "Assessment of Ground Water Sampling Activities," Memo to E. M. Heath from F. X. Bellini/D. R. Orlowski, ESG 98-061, 6/2/98.

39. "Default Soil Solid/Liquid Partition Coefficients, K_ds, for Four Major Soil Types: A Compendium," M.I. Sheppard and D.H. Thibault, Health Physics. Oct 1990, v.59 (4), p.471-482.

40. "YNPS Site Radiological Environmental History: Supplemental Information," Memo to E. M. Heath from F. X. Bellini, ESG 98-100, 12/22/98.

41. "Evaluation of Tritium in Ground Water at YNPS PAB," Memo to E. M. Heath from F. X. Bellini, ESG 98-045, 3/25/98.

42. "Co-60 results from 7 Ground Water Observation Wells for 3/99 and 5/99," Memo to E. M. Heath from F. X. Bellini, ESG 99-11, 6/10/99.

43. "Possible Spent Fuel Pool in-leakage to the Ion Exchange Pit," YNPS Condition Report CR-1999-036, Issued: 5/24/99, Closed 2/7/00.

44. "CR-1999-036 – Possible Spent Fuel Water In-Leakage to the Ion Exchange Pit (5/18/99)," Memo to Management Review Team from J. Gedutis, CHM 99-012, 11/22/99.

45. "Reference CR-1999-036'" CHM 99-015," Memo to Rick Williams from J. Gedutis, 12/1/99.

46. "Ion Exchange Pit Inspection Report," Memo to Rick Williams from J. Gedutis, CHM 00-005, 5/17/00.

47. "Surveillance for Spent Fuel Pit Wall Leakage," Memo to Rick Williams from J. Gedutis, CHM 01-008, 6/14/01.

48. "Surveillance for Spent Fuel Pit Wall Leakage," Memo to Greg Babineau/Rick Williams from J. Gedutis, CHM 02-009, 5/12/02.

49. "Project Plan: Preliminary Geotechnical Studies for the Proposed Expansion of Spent Fuel Facility (Draft)," Dames & Moore, 1978. YAEC Microfilm # 1000010.

50. "Report on Foundation Investigation, Fire Water Tank, Rowe Atomic Plant, Rowe, MA," Geotechnical Engineers, Inc, 1980, Prepared for Yankee Atomic Electric Company, Docket No. 50-29.

51. "Manual for Implementing Residual Radioactivity Materials Guidelines Using RESRAD, Version 5.0," Yu, C., Zielen, A.J., Cheng, J.-J., Yuan, Y.C., Jones, L.C., LePoire, D.J., Wang, Y.Y., Loueiro, C.O., Gnanapragasam, E., Faillace, E., Wallo III A., Williams, W.A., and Peterson, H., September 1993, Environmental Assessment Division, Argonne National Laboratory.

52. "YNPS Soil and Ground Water Inputs for Dose Models," Memo to J. W. Bisson from F. X. Bellini, ESG 98-025, Rev. 1, 3/24/98.

53. "YNPS Soil and Ground Water Inputs for Dose Models," Memo to J. W. Bisson from F. X. Bellini, ESG 00-001, 1/20/00.

Figures

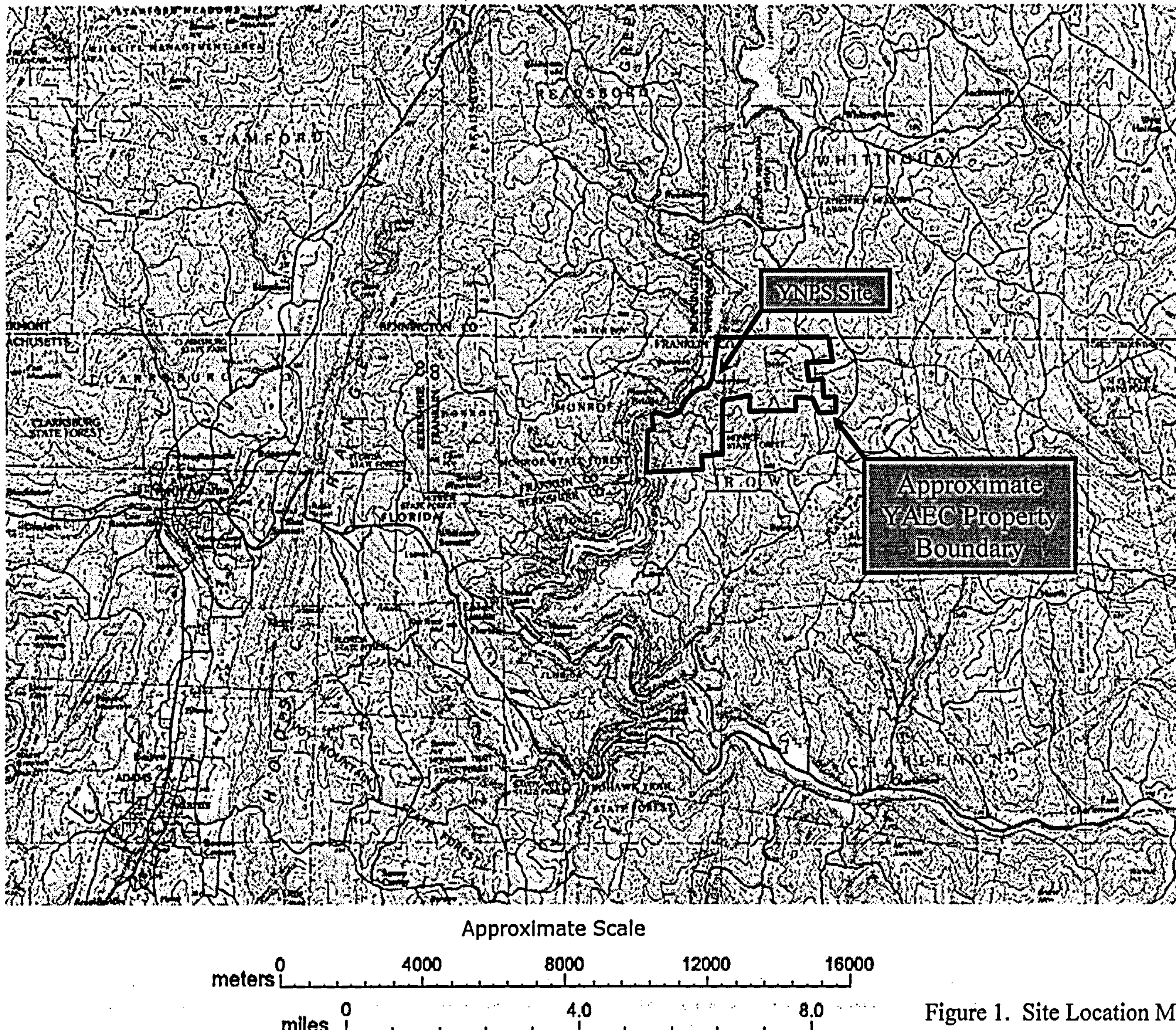


Figure 1. Site Location Map

Site Structures and Area Designations
Yankee Nuclear Power Station

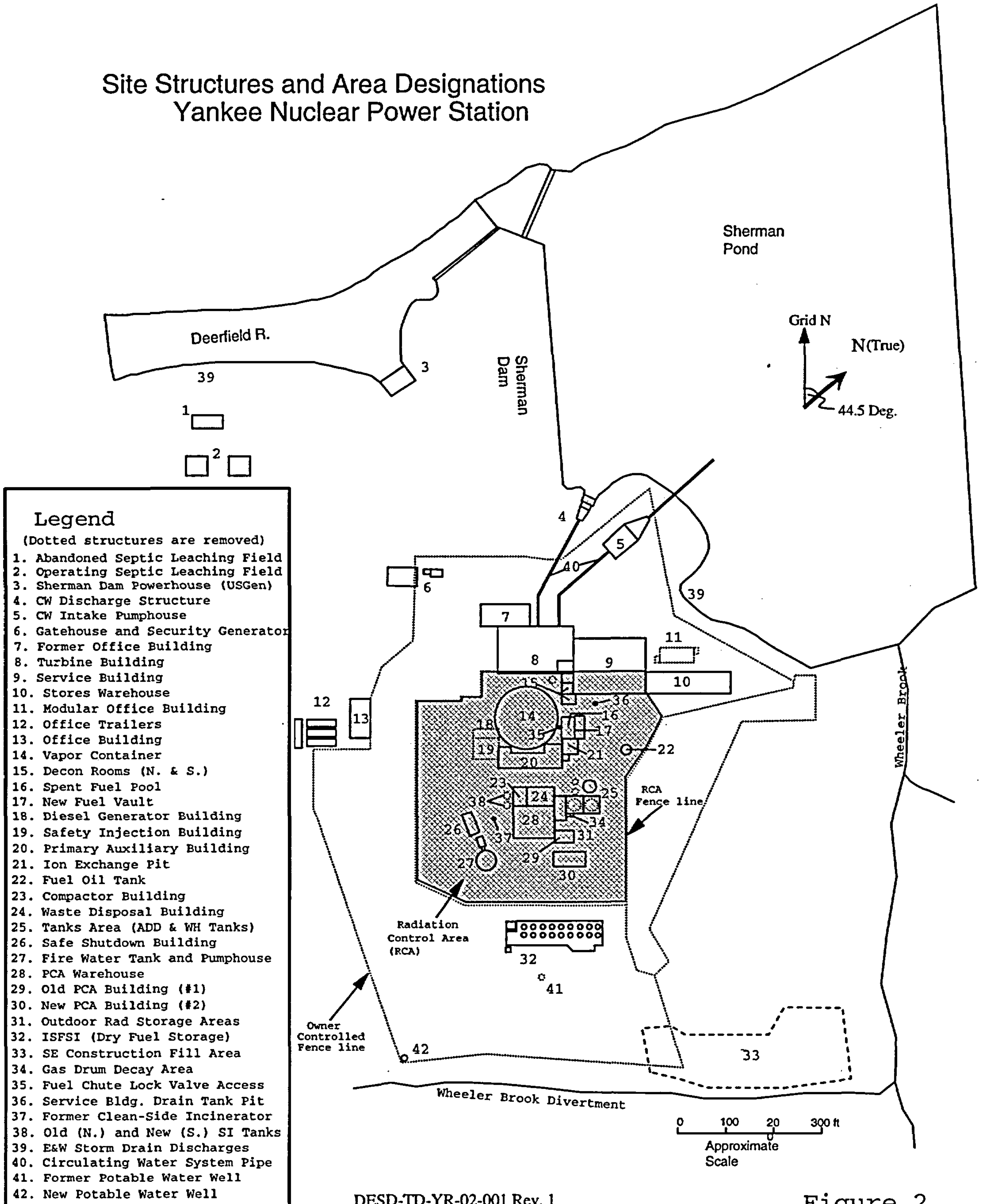


Figure 2

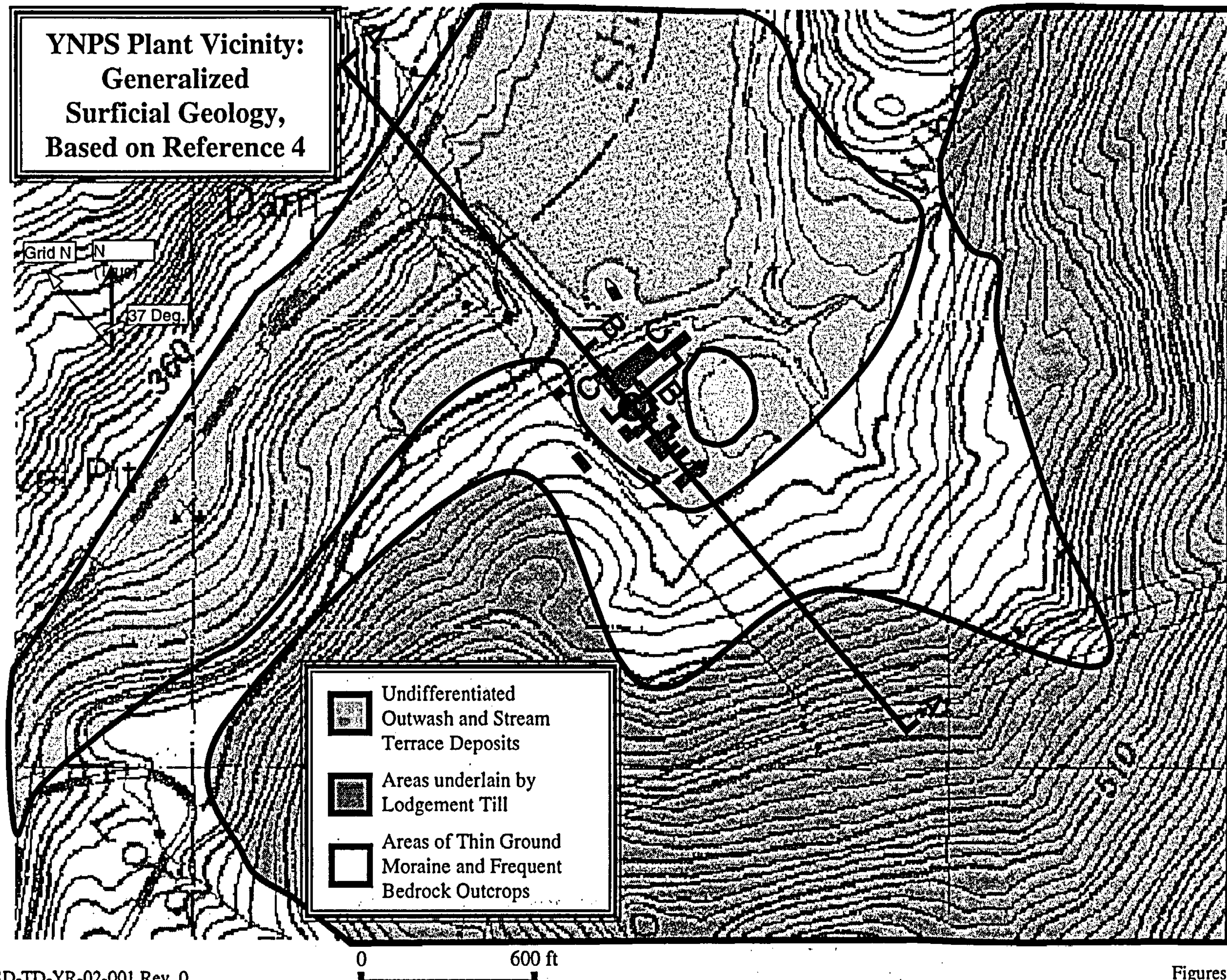


Figure 3A. Geologic Map
See Figs 3B and 3C for profiles

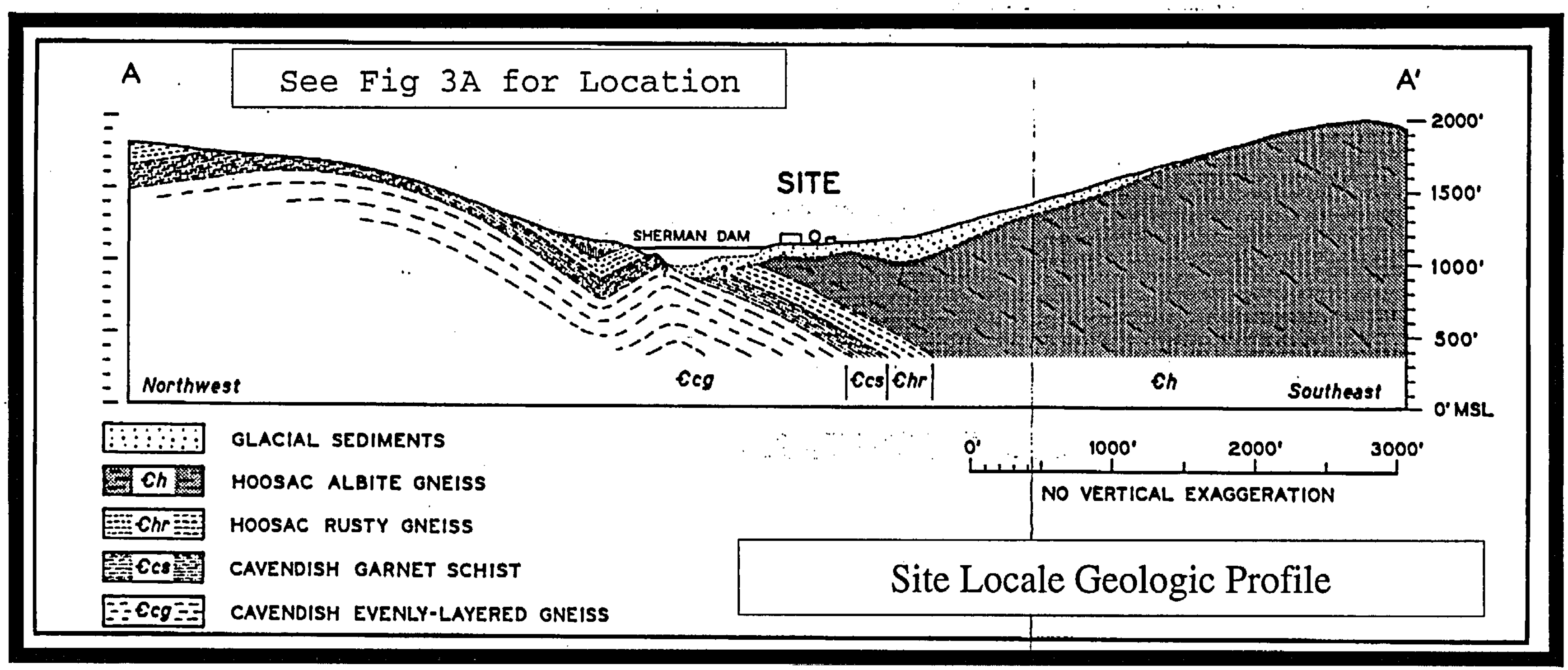


Figure 3B. Geologic
Profile
From Reference 4

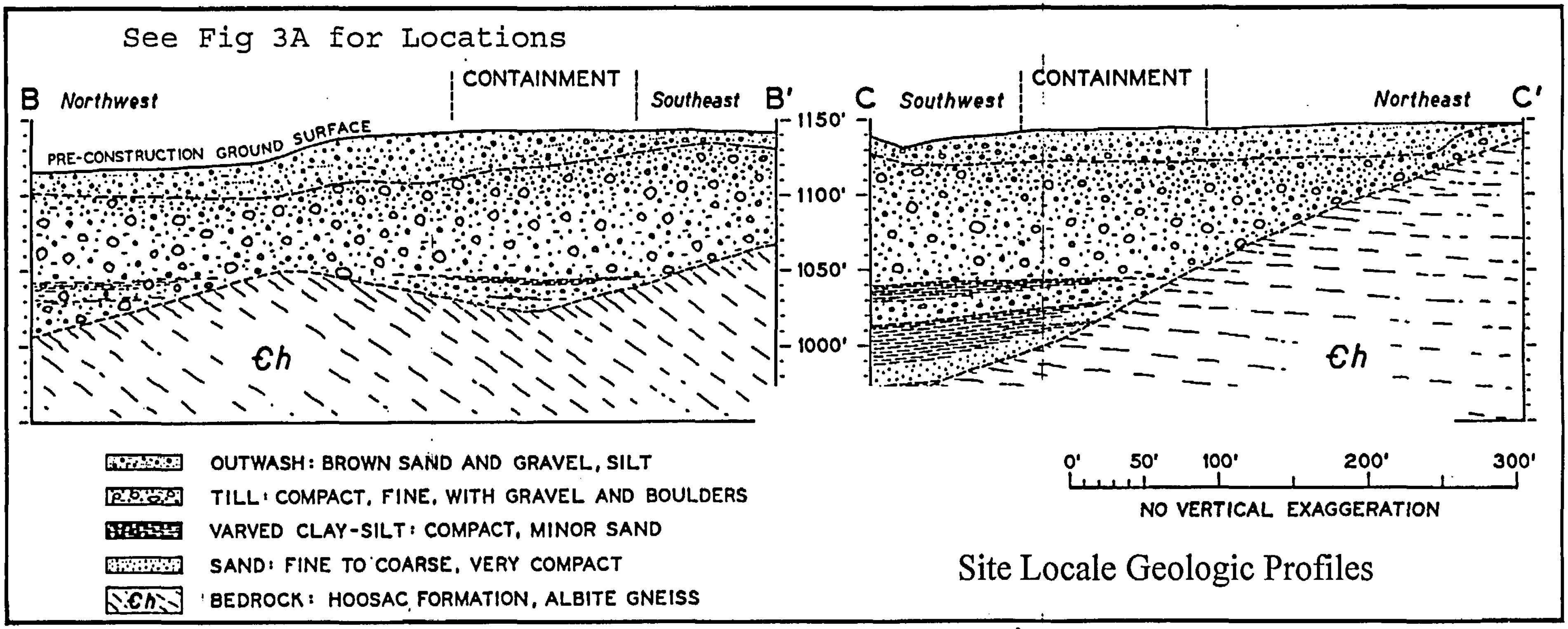
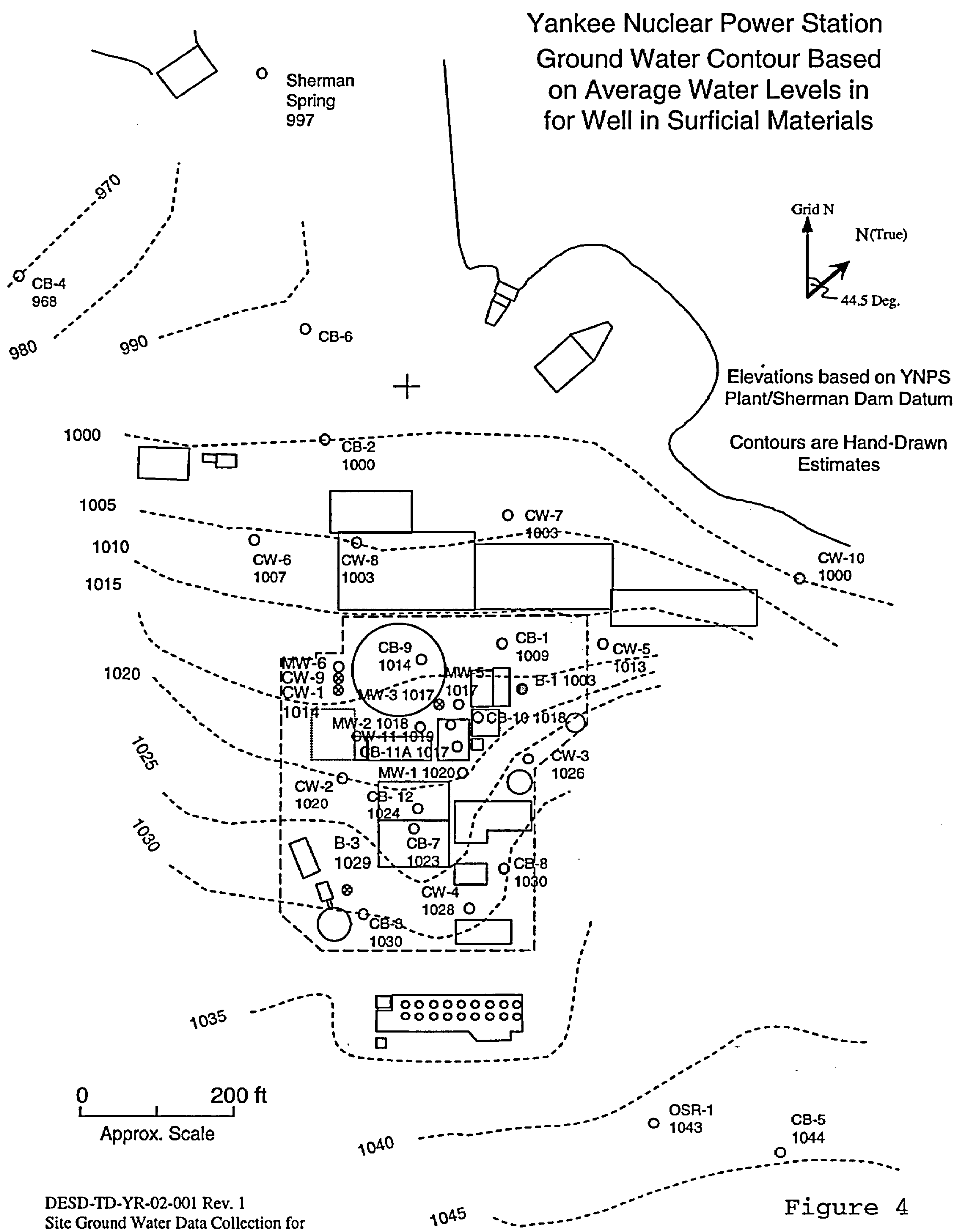


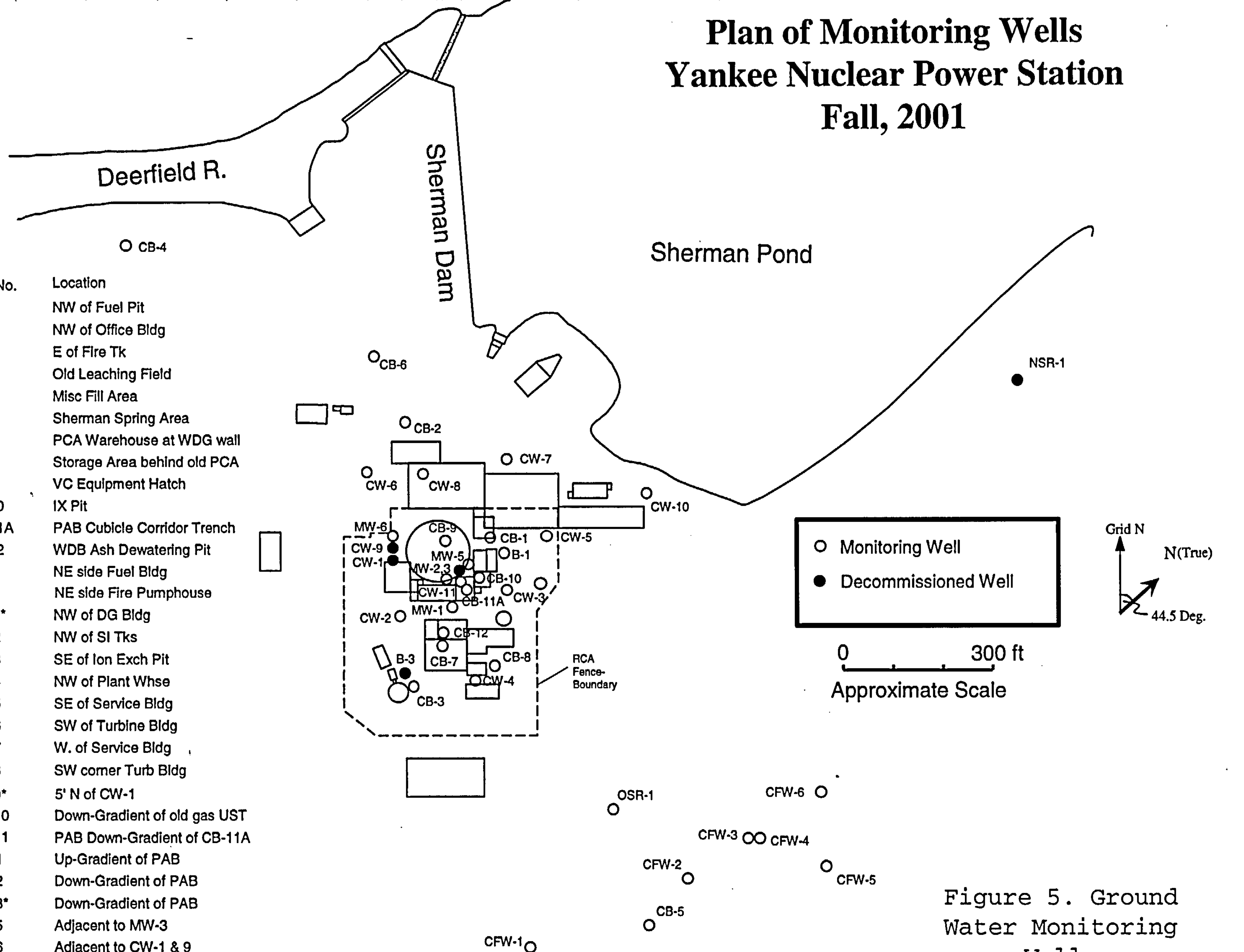
Figure 3C.
Geologic Profiles
from Reference 4



Yankee Nuclear Power Station
Ground Water Contour Based
on Average Water Levels in
for Well in Surficial Materials
Sherman Spring 997
Grid N
N(True)
44.5 Deg.
Elevations based on YNPS Plant/Sherman Dam Datum
Contours are Hand-Drawn Estimates
970
980
990
1000
1005
1010
1015
1020
1025
1030
1035
1040
1045
CB-4 968
CB-6
CB-2 1000
CW-7 1003
CW-6 1007
CW-8 1003
CW-10 1000
CB-1 1009
CW-5 1013
CB-9 1014
MW-6
CW-9
CW-1 1014
MW-3 1017
MW-5 1017
B-1 1003
CB-10 1018
MW-2 1018
CW-11 1019
CB-11A 1017
CW-3 1026
MW-1 1020
CW-2 1020
CB-12 1024
B-3 1029
CB-7 1023
CB-8 1030
CW-4 1028
CB-3 1030
OSR-1 1043
CB-5 1044
0 200 ft
Approx. Scale

Figure 4

Plan of Monitoring Wells
Yankee Nuclear Power Station
Fall, 2001

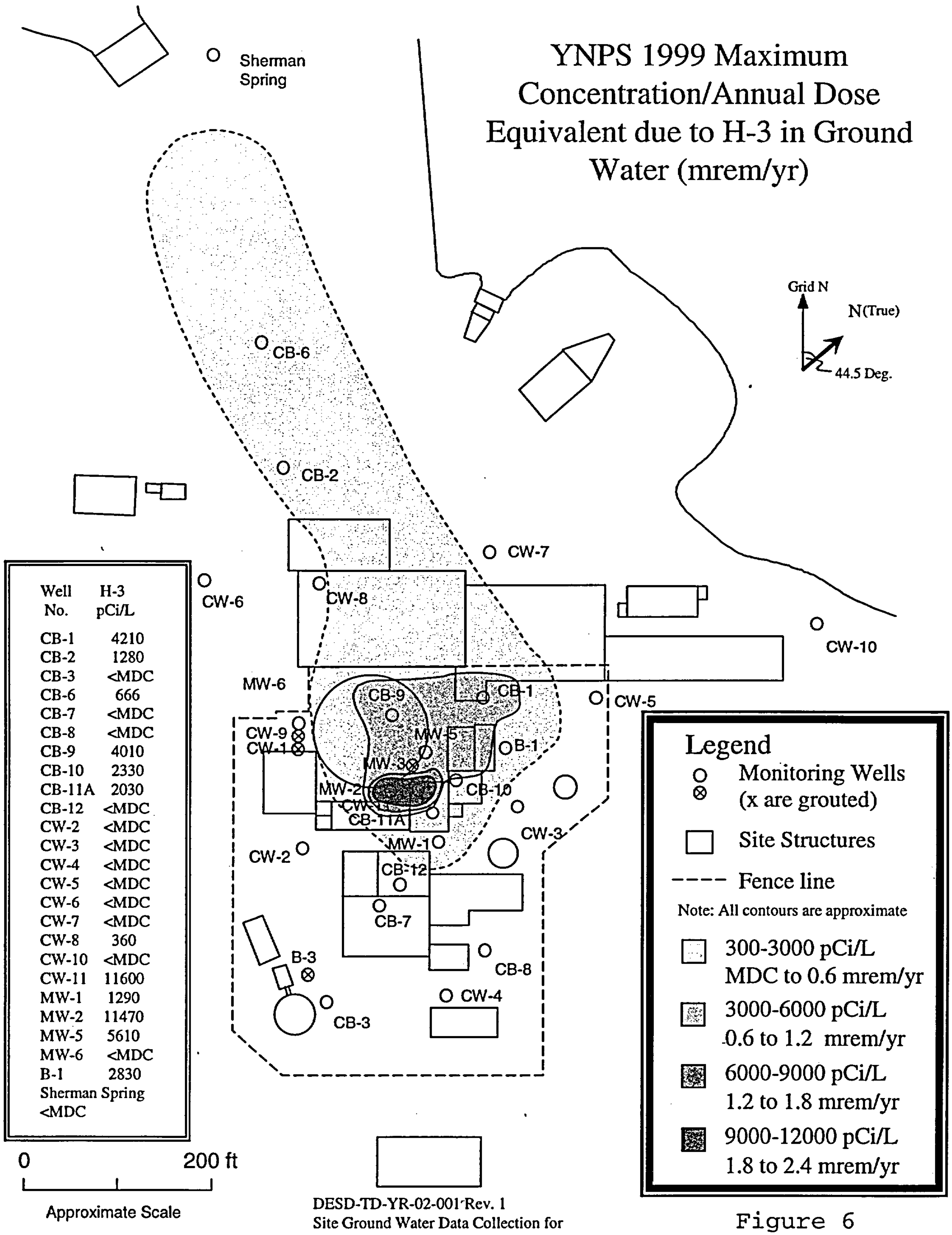


Well No.	Location
CB-1	NW of Fuel Pit
CB-2	NW of Office Bldg
CB-3	E of Fire Tk
CB-4	Old Leaching Field
CB-5	Misc Fill Area
CB-6	Sherman Spring Area
CB-7	PCA Warehouse at WDG wall
CB-8	Storage Area behind old PCA
CB-9	VC Equipment Hatch
CB-10	IX Pit
CB-11A	PAB Cubicle Corridor Trench
CB-12	WDB Ash Dewatering Pit
B-1	NE side Fuel Bldg
B-3*	NE side Fire Pumphouse
CW-1*	NW of DG Bldg
CW-2	NW of SI Tks
CW-3	SE of Ion Exch Pit
CW-4	NW of Plant Whse
CW-5	SE of Service Bldg
CW-6	SW of Turbine Bldg
CW-7	W. of Service Bldg
CW-8	SW corner Turb Bldg
CW-9*	5' N of CW-1
CW-10	Down-Gradient of old gas UST
CW-11	PAB Down-Gradient of CB-11A
MW-1	Up-Gradient of PAB
MW-2	Down-Gradient of PAB
MW-3*	Down-Gradient of PAB
MW-5	Adjacent to MW-3
MW-6	Adjacent to CW-1 & 9
NSR-1*	New Shooting Range
OSR-1	Old Shooting Range

* Well Decommissioned, Grouted

Figure 5. Ground Water Monitoring Wells

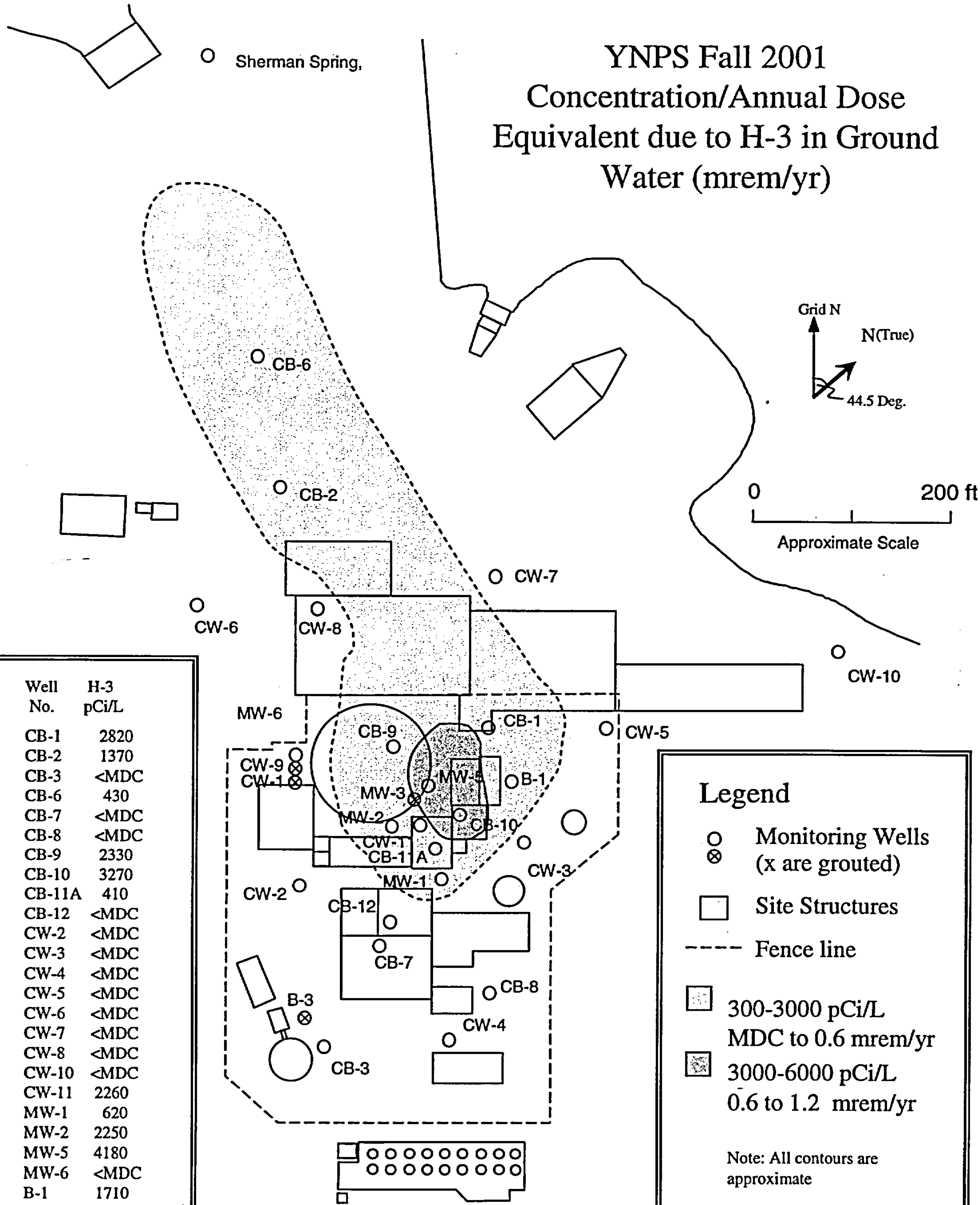
YNPS 1999 Maximum Concentration/Annual Dose Equivalent due to H-3 in Ground Water (mrem/yr)



Well No.	H-3 pCi/L
CB-1	4210
CB-2	1280
CB-3	<MDC
CB-6	666
CB-7	<MDC
CB-8	<MDC
CB-9	4010
CB-10	2330
CB-11A	2030
CB-12	<MDC
CW-2	<MDC
CW-3	<MDC
CW-4	<MDC
CW-5	<MDC
CW-6	<MDC
CW-7	<MDC
CW-8	360
CW-10	<MDC
CW-11	11600
MW-1	1290
MW-2	11470
MW-5	5610
MW-6	<MDC
B-1	2830
Sherman Spring	<MDC

Figure 6

YNPS Fall 2001 Concentration/Annual Dose Equivalent due to H-3 in Ground Water (mrem/yr)



Well No.	H-3 pCi/L
CB-1	2820
CB-2	1370
CB-3	<MDC
CB-6	430
CB-7	<MDC
CB-8	<MDC
CB-9	2330
CB-10	3270
CB-11A	410
CB-12	<MDC
CW-2	<MDC
CW-3	<MDC
CW-4	<MDC
CW-5	<MDC
CW-6	<MDC
CW-7	<MDC
CW-8	<MDC
CW-10	<MDC
CW-11	2260
MW-1	620
MW-2	2250
MW-5	4180
MW-6	<MDC
B-1	1710
Sherman Spring	<MDC

Figure 7

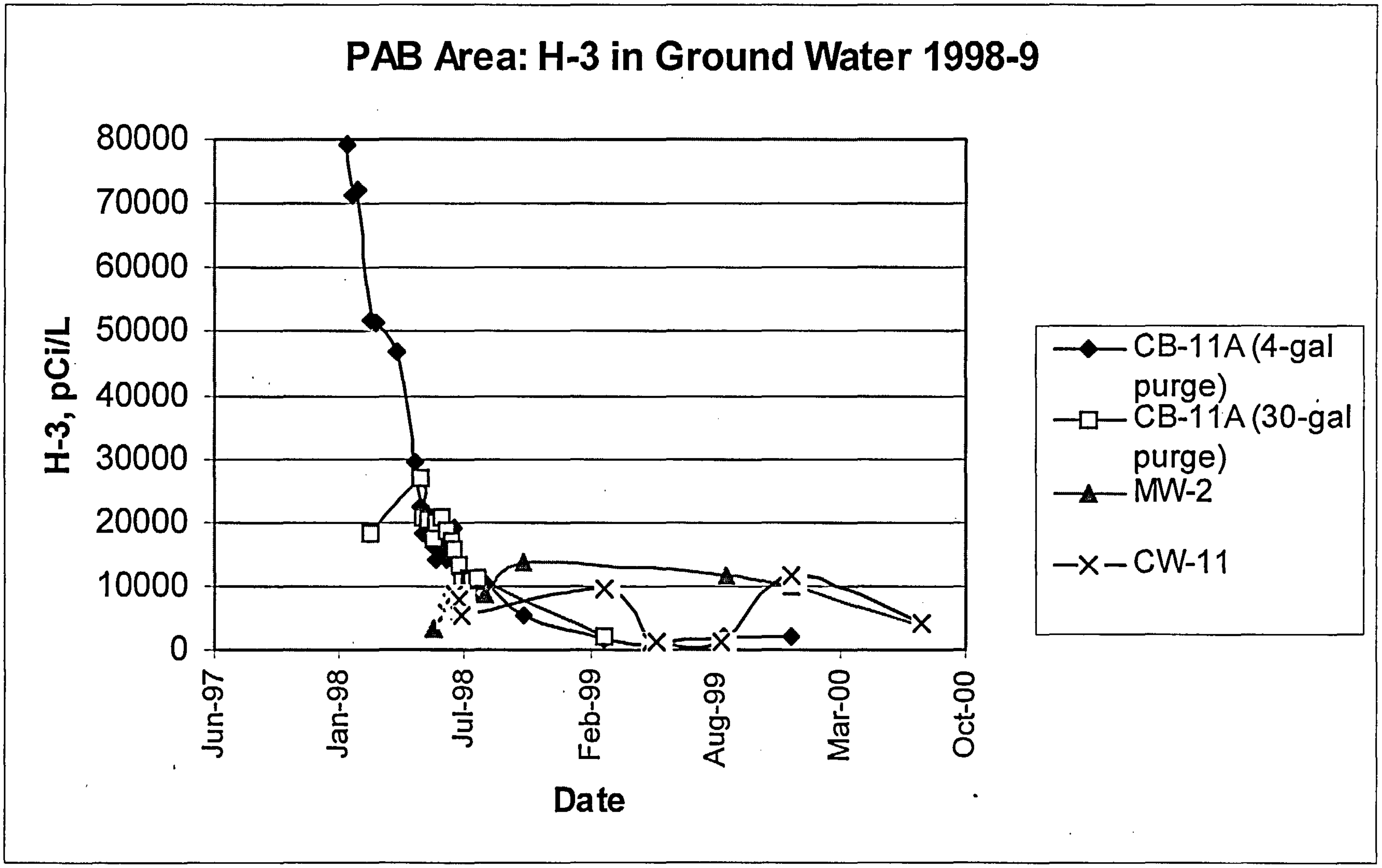

PAB Area: H-3 in Ground Water 1998-9
80000
70000
60000
50000
40000
30000
20000
10000
0
H-3, pCi/L
Jun-97
Jan-98
Jul-98
Feb-99
Aug-99
Mar-00
Oct-00
Date
CB-11A (4-gal purge)
CB-11A (30-gal purge)
MW-2
CW-11

Figure 8