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DRAFT

AREA RECOMMENDATION REPORT FOR THE CRYSTALLINE REPOSITORY PROJECT

VOLUME 1

JANUARY 1986

U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
CRYSTALLINE REPOSITORY PROJECT OFFICE

FOREWORD

The Nuclear Waste Policy Act of 1982 (NWPA) directs the U.S. Department of Energy (DOE) to, among other requirements, provide for the siting, construction and operation of deep, mined geologic repositories for the disposal of high-level radioactive waste (HLW) and spent nuclear fuel (SF). The NWPA establishes a schedule and a step-by-step process by which the President, the Congress, the affected States and Indian Tribes, DOE, and other Federal agencies are to work together in the siting and development of nuclear waste repositories, culminating in the operation of a safe, environmentally acceptable, licensed geologic repository by 1998.

To implement its provisions, the NWPA established DOE's Office of Civilian Radioactive Waste Management. The Civilian Radioactive Waste Management Program is currently considering bedded salt deposits, salt domes, basalt, tuff, and crystalline rock as host rocks for geologic repositories. These rock types are being analyzed at different locations within the conterminous United States under four coordinated projects: the Basalt Waste Isolation Project, the Salt Repository Project, the Nevada Nuclear Waste Storage Investigations, and the Crystalline Repository Project.

For the first repository, the NWPA requires that DOE recommend to the President, from at least five nominated sites, three candidate sites for characterization. The rock types being considered as potential hosts for this first repository are basalt, salt, and tuff.

The DOE is authorized to site a second repository because of the NWPA stipulation that no more than 70,000 metric tons of heavy metal be placed in the first repository until a second repository becomes operational. DOE is considering two sources of sites for the second repository.

Crystalline rock formations are the first source and are already the subject of a comprehensive screening program conducted by the Crystalline Repository Project. This draft report presents the results of current screening activities on crystalline rock formations. The second source is the sites which will have been characterized for the first repository but are not selected for the first repository site, and sites evaluated but not nominated for site characterization for the first repository.

Comments concerning this draft ARR will be considered in preparing the final ARR. Public briefings and hearings to receive oral comments are planned. Written comments should be directed to the address below during the public comment period indicated in the Federal Register notice announcing the availability of this document.

U.S. Department of Energy
Attention: Comments -- draft ARR
Crystalline Repository Project Office
Chicago Operations Office
9800 South Cass Avenue
Argonne, Illinois 60439

ABSTRACT

This Draft Area Recommendation Report for the Crystalline Repository Project identifies portions of crystalline rock bodies as proposed potentially acceptable sites for consideration in the second high-level radioactive waste repository program.

The U.S. Department of Energy (DOE) evaluated available geologic and environmental data for 235 crystalline rock bodies in the North Central, Northeastern, and Southeastern Regions to identify preliminary candidate areas. Further evaluation of these preliminary candidate areas resulted in the selection of 12 as proposed potentially acceptable sites. The process used for these evaluations and the narrowing of the number and size of crystalline rock bodies is in accordance with 10 CFR 960.3-2-1 of General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories and is described in the Region-to-Area Screening Methodology for the Crystalline Repository Project.

The 12 proposed potentially acceptable sites are located in the States of Georgia (1), Maine (2), Minnesota (3), New Hampshire (1), North Carolina (2), Virginia (2), and Wisconsin (1). Portions of the proposed potentially acceptable site in Wisconsin are located within the Menominee and Stockbridge-Munsee Indian Reservations and portions of one of the sites in Maine are located within the Penobscot and Passamaquoddy Reservations.

The data, analyses, and rationale with which the 12 proposed potentially acceptable sites were selected are presented in this draft report. The analyses presented demonstrate that the evidence available for each proposed potentially acceptable site supports (i) a finding that the site is not disqualified in accordance with the application requirements of Appendix III of the siting guidelines and (ii) a decision to proceed with the continued investigation of the site on the basis of the favorable and potentially adverse conditions identified to date.

Once this report is finalized, potentially acceptable sites in crystalline rock will be formally identified by the Secretary of Energy, in accordance with the DOE siting guidelines. These potentially acceptable sites will be investigated and evaluated in more detail during the area phase of the siting process. An additional eight areas, which meet the requirements for identification as potentially acceptable sites, will retain their designation as candidate areas; and the DOE may formally identify any or all as potentially acceptable sites during the area phase, if it is determined that additional areas are required to ensure an adequate number of sites for nomination and recommendation for site characterization.

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1.0 INTRODUCTION

This draft area recommendation report documents the selection of those areas of exposed and near-surface crystalline rock bodies which are proposed for area phase investigations and serves as the basis for the identification of these candidate areas as proposed potentially acceptable sites in accordance with 10 CFR 960.3-2-1.

1.1 PURPOSE AND SCOPE

The purpose of the area recommendation report is to (1) present the results of the region-to-area screening; (2) document the selection of candidate areas*; and (3) make the requisite findings for identification of potentially acceptable sites in accordance with Section 960.3-2-1 of DOE's siting guidelines (DOE, 1984a) which were developed pursuant to the requirement of Section 112 of the Nuclear Waste Policy Act of 1982 (NWPA). The report presents each step of the region-to-area screening process used to identify candidate areas as well as the analyses and findings required by the siting guidelines to support the identification of proposed potentially acceptable sites. This report thus serves as the decision-basis document specified in the DOE siting guidelines, 10 CFR 960.3-2-1. Computer-generated maps are provided to support the text; a set of computer-generated maps supporting the selection of candidate areas is provided as Volume 2. Any data utilized to support the selection of candidate areas and their subsequent identification as proposed potentially acceptable sites are also presented or referenced, as appropriate.

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* "Candidate area" is a land unit which generally has favorable characteristics and has no known characteristics which provide a sufficient basis for deferral. A candidate area covers a minimum of 100 km^2 (39 mi^2) within which a nominal circle 11.2 km (7 mi) in diameter can be inscribed. The 100 km^2 (39 mi^2) area is equivalent to the area requirement on crystalline rock bodies to be considered for regional phase evaluations (OCRD, 1983) and is consistent with the U.S. Environmental Protection Agency (EPA) requirement for the maximum size of a controlled area.

1.2 BACKGROUND OF THE CRYSTALLINE REPOSITORY PROJECT

Crystalline rocks* were considered as early as 1957 to be a viable host for a repository (NAS, 1957). As a result of the passage of the NWPA, DOE is proceeding with siting activities for two deep mined geologic repositories. Currently, bedded salt, salt domes, basalt, and tuff are being considered as host rocks for the first repository. However, in response to recommendations by the Interagency Review Group (IRG, 1979) to consider alternate host rocks for repositories, the DOE initiated and completed a national survey of crystalline rock (OCRD, 1983) and is presently considering crystalline rock as a potential host rock for a second repository. As described in the Mission Plan (DOE, 1985a), current DOE plans call for the President to recommend the second repository site to Congress by March 1998.

The major programmatic activities of the CRP are to conduct the technical studies (geologic, environmental, engineering, and socioeconomic) required to identify bodies of crystalline rock having the highest potential for qualifying as repository sites, and to develop the necessary technology to assure the long-term isolation of high-level radioactive waste (HLW) and spent nuclear fuel (SF) in a crystalline medium.

1.2.1 Siting Process

The purpose of a geologic repository is to provide long-term isolation of HLW and SF in a manner that gives reasonable assurance that the health and safety of the public, and the environment will be adequately protected. The DOE is implementing the siting process

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* "Crystalline rocks" are defined as intrusive igneous (e.g., granite) and high-grade metamorphic rocks rich in silicate minerals, with a grain size sufficiently coarse that individual minerals can be distinguished with the unaided eye.

established in the task of identifying, evaluating, and selecting sites which would be suitable for geologic repositories. The initial steps in the process for the second repository, developed in accordance with the NWPA, are set forth in 10 CFR 960.3-2-1 of the DOE siting guidelines. This section establishes the process for the identification of potentially acceptable sites. Next, in accordance with Section 112 of the NWPA, from the sites identified as potentially acceptable, the Secretary of Energy shall nominate five sites determined suitable for site characterization. After nomination, the Secretary of Energy shall recommend to the President three candidate sites from the five nominated sites for site characterization. Once the President has approved the sites, a detailed study program (site characterization) including construction of an exploratory shaft to repository depth will be undertaken at each site. After completion of site characterization, the Secretary of Energy shall recommend to the President a site for the development of a repository.

Site screening involves studies focusing on land units of successively decreasing size to determine whether or not they contain sites that might be suitable for development of a repository. In general, site screening may consist of up to four phases, each of which narrows to a land unit of smaller size: (1) a survey of the nation or geologic provinces, narrowing to regions; (2) a survey of regions, narrowing to areas; (3) a survey of areas, narrowing to locations; and (4) a survey of locations, narrowing to potentially acceptable sites. A site screening phase may be deleted if a preceding phase reveals smaller land units suitable for further study in the subsequent phase. In the case of the CRP, the location phase will be deleted because DOE has determined that it is appropriate to identify potentially acceptable sites based on the results of region-to-area screening. Therefore, area phase investigations will be conducted to identify the preferred site location within each potentially acceptable site. Accordingly, the screening process for the CRP to site nomination and recommendation for site characterization consists of: (1) a national survey, narrowing to regions; (2) a regional survey, narrowing to the identification of potentially acceptable sites; and (3) an area survey, narrowing to the identification of the preferred site location within each potentially acceptable site. The national and regional surveys are based on information available in the open literature. Area surveys will provide more detailed information, using field exploration and testing. It should be noted that field exploration and testing will be conducted in and outside of the potentially acceptable sites, as necessary.

1.2.1.1 National Survey

Section 960.3-2-1 of the DOE siting guidelines (DOE, 1984a) directs that the screening process for determining potentially acceptable sites for the second repository should begin with screening activities on large land masses that are likely to contain suitable rock with features favorable for waste containment and isolation. The national survey of crystalline rock bodies was conducted as a reconnaissance of available geologic literature on large regions of exposed and near-surface crystalline rocks in the conterminous United States. The requirement that only exposed or near-surface crystalline rocks would be considered was the initial criterion established by the DOE which determined where subsequent screening efforts would be concentrated (OCRD, 1983). The survey evaluated the suitability of rocks in those several regions as potential sites for repositories and recommended regions of exposed and near-surface crystalline rocks for further evaluation for possible repository sites (OCRD, 1983).

Other criteria used in the national survey were taken from draft regulations (proposed 10 CFR 60) of the U. S. Nuclear Regulatory Commission (NRC) (NRC, 1981). These criteria included consideration of the following factors on a national scale:

- rock mass size
- vertical movements
- faulting
- earthquakes
- seismically induced ground motion
- Quaternary volcanic rocks
- mineral deposits
- high-temperature convective ground-water systems
- hydraulic gradients incorporating regional topographic variations
- erosion.

The national survey resulted in the recommendation that further (i.e., regional) studies be conducted to investigate exposed and near-surface crystalline rocks in the Lake Superior region (i.e., the North Central Region), the northern Appalachians and Adirondacks (i.e., the Northeastern Region), and the southern Appalachians (i.e., the Southeastern Region) and provided the basis for selection of the three regions (Figure 1-1) in which region-to-area screening was conducted to select areas for continued studies.

Seventeen states with exposed and near-surface crystalline rock bodies are included in the three regions as stated below:

- North Central Region
  Michigan, Minnesota, Wisconsin
- Northeastern Region
  Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont
- Southeastern Region
  Georgia, Maryland, North Carolina, South Carolina, Virginia

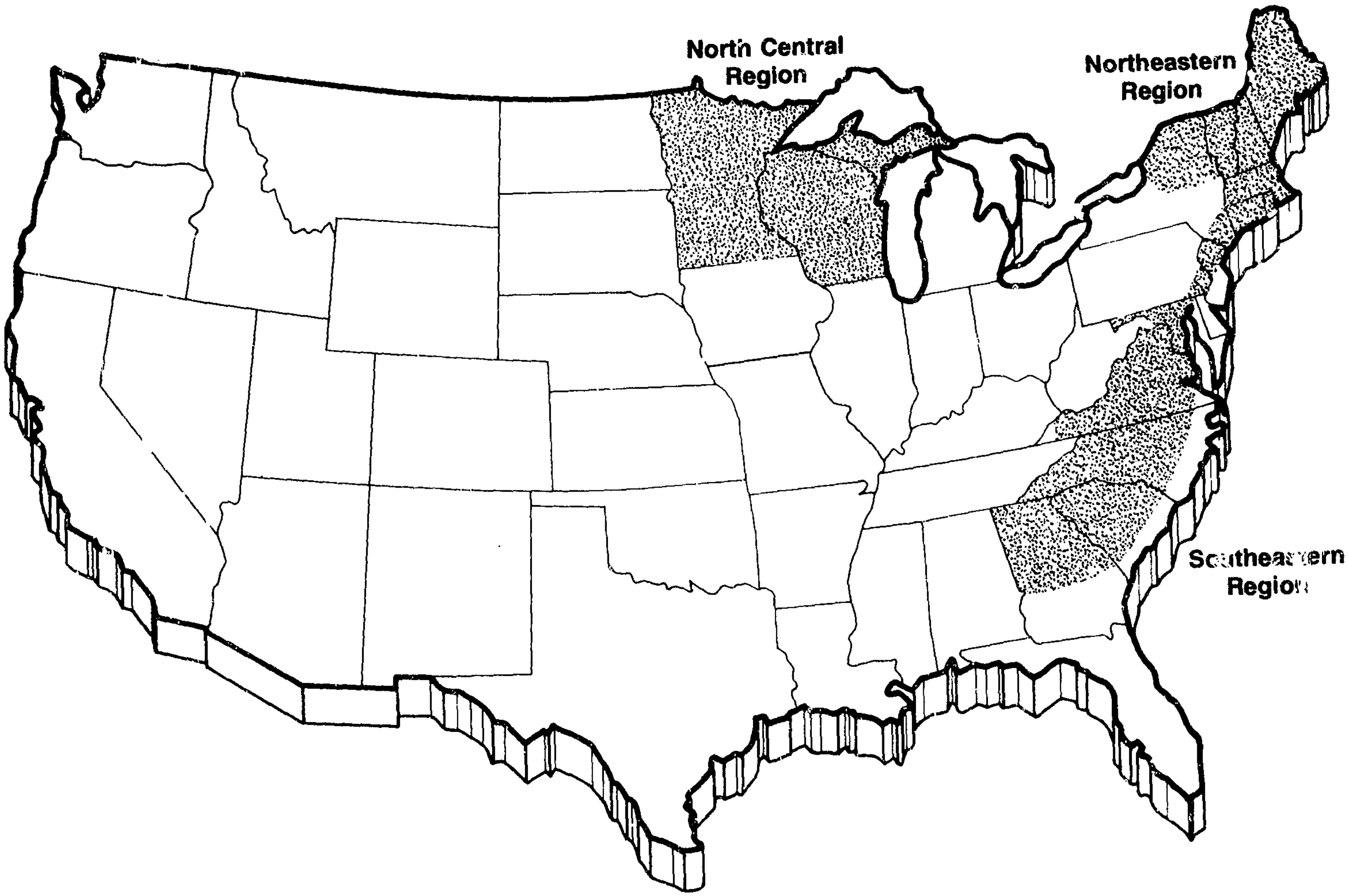

Figure 1-1. Crystalline Rock Regions Being Considered for the Second Repository

1.2.1.2 Regional Survey

To support region-to-area screening, information specific to regions identified by the national survey was collected and evaluated. The level of information obtained provided a general characterization of the region in order to allow DOE to disqualify or defer those large areas not likely to contain potentially acceptable sites. Areas which remain are likely to contain sites that will, upon further study, meet the requirements for nomination for site characterization.

Generally, this level of data is available in major public libraries and information available from State and Federal agencies operating within the regions being studied. These data include published scientific reports; geologic maps; drilling records generated in oil, gas, and mineral exploration programs; records of earthquake occurrences and intensities; records of oil, gas, and mineral production; and records from regional water well-drilling operations. Existing airborne geophysical survey results, where available, have been used to support the literature-based geologic and resource studies.

Geologic characteristics generally considered in these regional surveys include the structure, stratigraphy, depth, thickness, and continuity of rock formations; regional flow characteristics of the ground-water systems; gross physical characteristics of major formations (lithology and mineralogy); occurrence of natural resources and their current or future production potential; existence of folds or faults; general surface characteristics; and seismic history of the region.

Environmental and socioeconomic characteristics of the region considered at this stage include dedicated land use areas, threatened and endangered species, population centers, and transportation systems.

A series of six regional characterization reports covers different characteristics of each of the three regions (DOE, 1985c through h).

These reports prov[illegible] data base for application of the region-to-area screening methodology (DOE, 1985b), the results of which are used as input to this draft area recommendation report.

1.3 STATUS OF CRYSTALLINE REPOSITORY PROJECT

The DOE has completed the national and regional surveys in 1983 and 1985, respectively. The 235 crystalline rock bodies identified in the regional survey were evaluated using the region-to-area screening methodology described in the SMD (DOE, 1985b). This draft area recommendation report summarizes the results of that evaluation and proposes the identification of 12 potentially acceptable sites for further evaluation in the area phase.

This draft area recommendation report has been sent to each of the 17 involved states and potentially affected Indian Tribes and has been made publicly available for review and comment. The DOE will finalize this report after consideration of all comments received during the public comment period. Once the report is finalized the Secretary of Energy will formally identify potentially acceptable sites in crystalline rock. The governors and legislators of those states which contain potentially acceptable sites and the tribal representatives of any potentially affected Indian Tribe will be notified.

Area surveys including field sampling and testing will be conducted to investigate potentially acceptable sites identified in the final area recommendation report to identify the preferred site location within each potentially acceptable site.

1.4 AREA SCREENING AND SITE NOMINATION AND RECOMMENDATION

The focus of area phase efforts will be the acquisition of new and more detailed geologic, engineering, environmental, and socioeconomic data on the potentially acceptable sites identified as a result of region-to-area screening. The area screening process will use the DOE siting guidelines as the basic criteria for identifying the preferred site location in each potentially acceptable site, although the approach will not be the same as that used in the region-to-area screening as described in the SMD (DOE, 1985b) because of the availability of field data. Before the initiation of area phase field work, an area characterization plan will be developed. The major objective of the area characterization plan will be to describe the plans for the acquisition of data necessary to support the nomination and recommendation of sites for site characterization. The approach for area phase activities will be developed in consultation with the affected States and Indian Tribes, and a draft area characterization plan will be issued for their review and comment. The final area characterization plan will be issued prior to the initiation of area-phase field investigations. Figure 1-2 summarizes the CRP report schedule up to the beginning of area-phase field work. The schedule allows for approximately 3 years of field work in the area phase.

Acquisition and evaluation of these data will make it possible to evaluate potentially acceptable sites in crystalline rock and to nominate candidate sites which are suitable to be included in the Secretary of Energy's recommendation to the President of sites to undergo site characterization for the second repository. In accordance with Section 112(b)(1)(E) of the NWPA, each nomination will be accompanied by an environmental assessment. These environmental assessments will be issued in draft form for review and comment in March 1991. The recommendation to the President is currently scheduled to be made in October 1991. Presidential approval of the candidate sites for characterization for the second repository would result in site characterization work at the approved sites for approximately 4 to 6 years. Prior to the initiation of site characterization at any site, DOE will issue a site characterization plan in accordance with Section 113(b) of the NWPA, which will include, among other requirements, a description of the

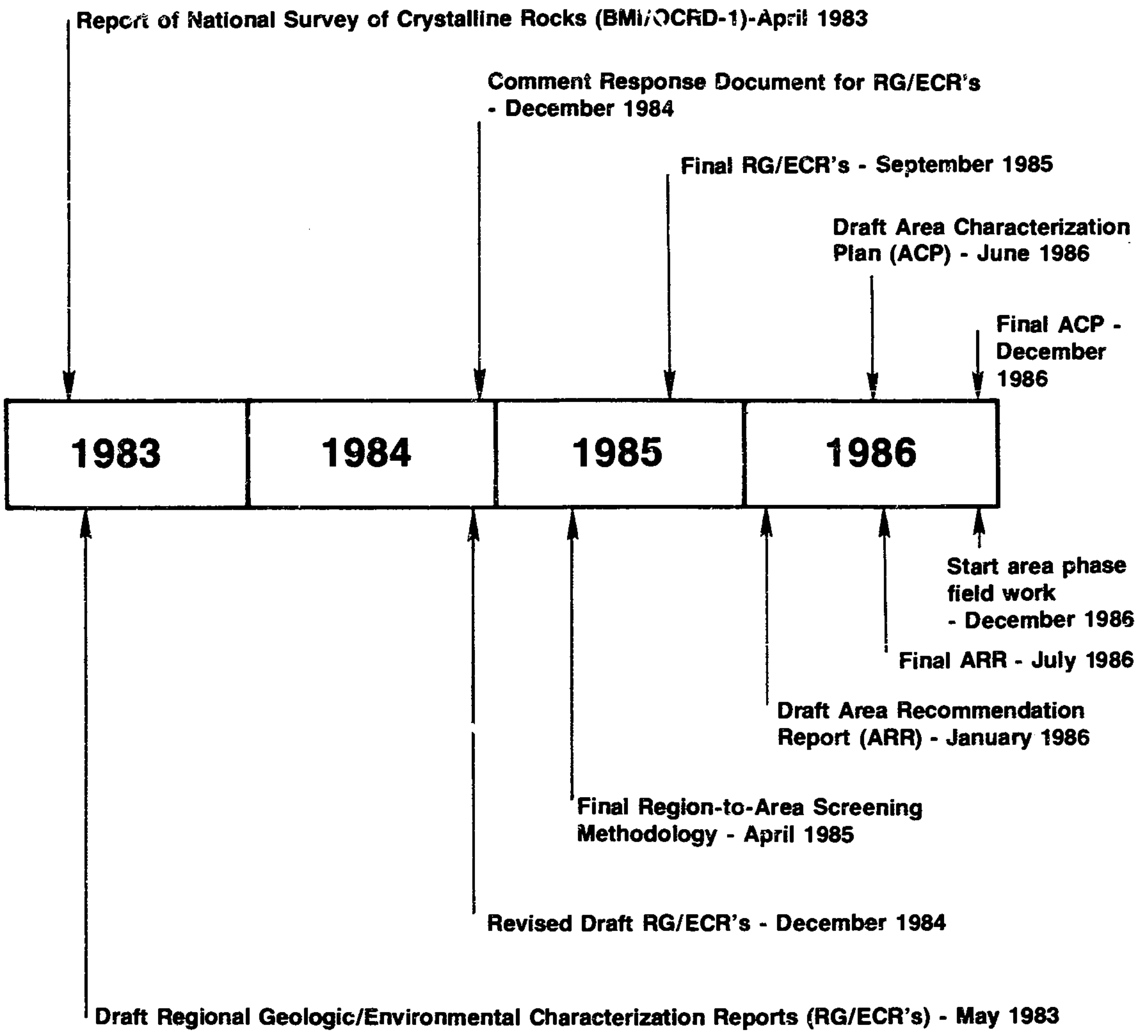

Figure 1-2. Crystalline Repository Project Report Schedule Leading to Initiation of Area Phase Field Work

candidate site, the site characterization activities to be conducted, plans for decontamination and decommissioning, and any other information that may be required by the NRC. After completion of site characterization, DOE will recommend one site, from among all characterized sites, to the President for approval as the second repository site. This recommendation will be accompanied by an environmental impact statement in accordance with Section 114(a) of the NWPA. The environmental impact statement will be prepared pursuant to Section 114(f) of the NWPA and the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.). This is to be followed by the President's recommendation to Congress of a single site for location of the second repository in March 1998. A license application will be made to the NRC after the site designation becomes effective. The review period of 27 months for issuance of a construction authorization by NRC is considered to be minimal but achievable for the second repository. The present estimate for the time required to construct a repository ready for receipt and emplacement of waste is approximately 6 years. Before construction of a second repository, the DOE must receive Congressional authorization.

The long-term CRP schedule is contained on Figure 1-3.

Major CRP milestones are:

Milestone	Date
– Issue Region-to-Area Screening Methodology	April 1985
– Issue Final Regional Characterization Reports	September 1985
– Issue Final Area Recommendation Report	July 1986
– Identify Potentially Acceptable Sites	July 1986
– Issue Final Area Characterization Plan	December 1986

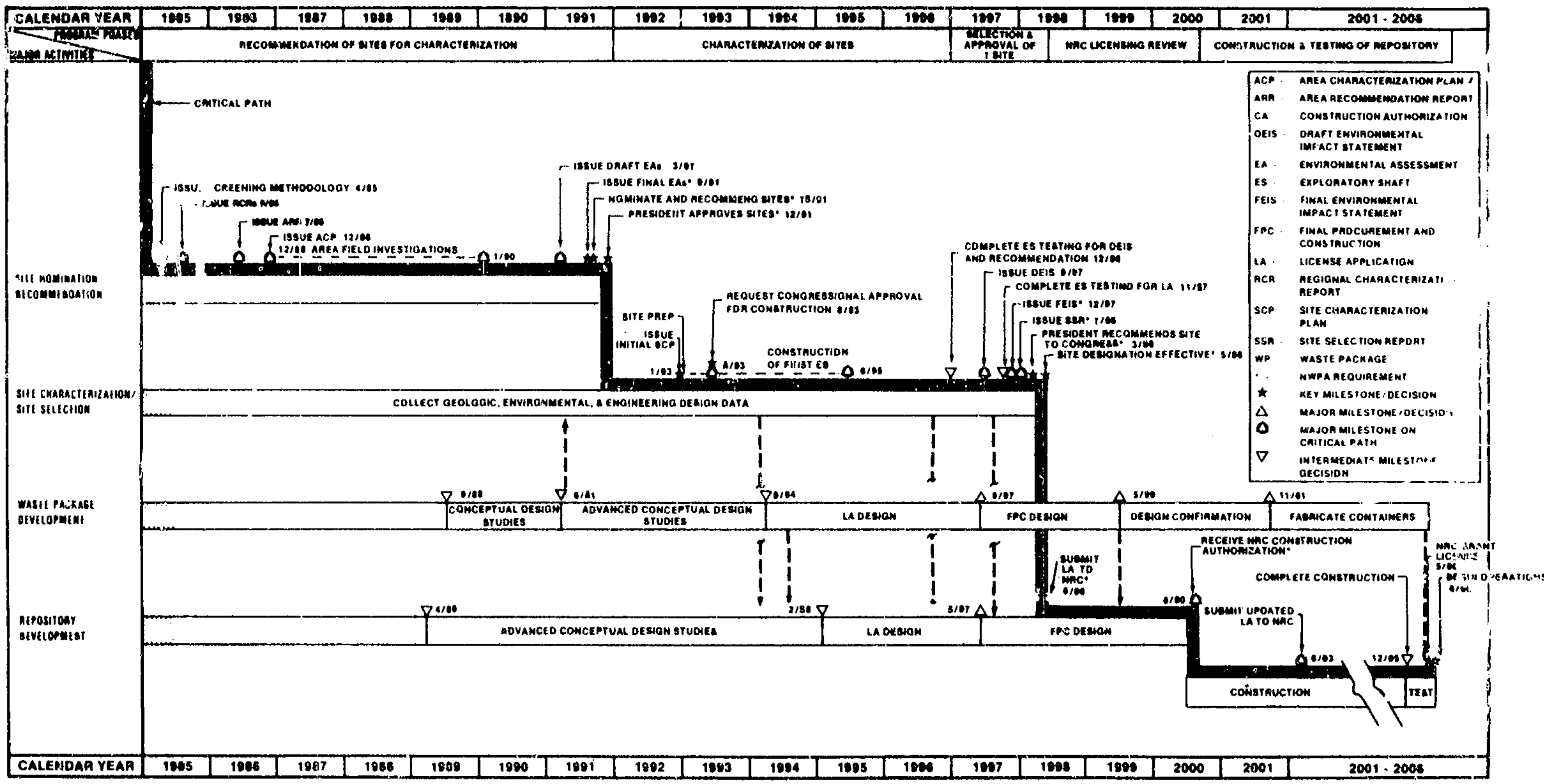

Figure 1-3. Schedule for Second Geologic Repository

- Begin Area Phase Field Investigations — December 1986
- Complete Area Phase Field Investigations — January 1990
- Issue Final Environmental Assessments — September 1991
- Nominate and Recommend Sites for Characterization — October 1991
- President Approves Sites — December 1991
- Issue Initial Site Characterization Plan — January 1993
- Request Congressional Approval for Construction — March 1993
- President Recommends Second Repository Site to Congress — March 1998
- Submit License Application to NRC — May 1998
- Receive Construction Authorization from NRC and Begin Construction — August 2000
- Begin Waste Emplacement — June 2006

1.5 GENERAL DESCRIPTION OF A REPOSITORY

The purpose of the deep, mined geologic repository is to provide for the long-term containment and isolation of HLW and SF. During postclosure, geologic and hydrologic characteristics of the site provides the primary barriers in preventing radionuclides from reaching the accessible environment in excess of permissible concentrations. Additional protection is provided during postclosure by the waste package and backfill placed in excavations and the sealing of all entries. During the operation period, protection to the environment is ensured by the design, construction, and operation of facilities for waste receipt, handling, and emplacement. Design of a repository in crystalline rock will proceed from conceptual designs to preliminary and final designs. The designs will meet requirements of applicable regulations and engineering constraints to ensure safe construction and operation. The depth and general layout of the repository facilities are dependent on the geologic and hydrologic characteristics of the site. The conceptual design will be based on existing data on crystalline rock properties and field data obtained in the area phase; the preliminary and final designs will make full use of subsequent data obtained from site characterization phase activities including repository horizon in situ testing.

The waste types to be considered in the design process for receipt at the second repository are more fully described in the report Generic Requirements for a Mined Geologic Disposal System (DOE, 1984b). Wastes to be received are spent fuel from commercial reactors and defense high-level waste. If reprocessing of commercial spent fuel occurs in the future, commercial high-level waste and possibly transuranic waste, will require isolation in a geologic repository. However, the extent and layout of the repository underground area required to accommodate commercial high-level waste is not expected to be substantially different from that required for spent fuel. For early conceptual design purposes, the wastes are assumed to be brought directly to the facility by rail or truck in licensed, shielded, shipping casks. This assumption does not include the consideration of the operation of a monitored retrievable storage facility that supports the prepackaging of wastes prior to shipment to the second repository. Therefore, it is assumed for the second repository that the wastes will be received, consolidated (in the case of spent fuel assemblies), and packaged in the surface facilities. Once the wastes have been packaged for emplacement, they will be placed in transfer casks and transported underground for final disposal. First repository emplacement will be limited to 70,000 metric tons of heavy metal until a second repository becomes operational. The joint capacity of the two repositories will be such that all of the waste generated through the year 2020 can be accommodated. The repository is to be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after emplacement operations are initiated, unless a different time period is approved or specified by the NRC. Following a decision to close the repository, backfilling of the underground workings with some relatively impermeable material will be completed, and all shafts and boreholes will be sealed. During this process, all surface facilities will be decontaminated, dismantled, and decommissioned.

Figure 1-4 shows a schematic layout of areas at a repository site. Figure 1-5 shows a schematic of surface and underground facilities.

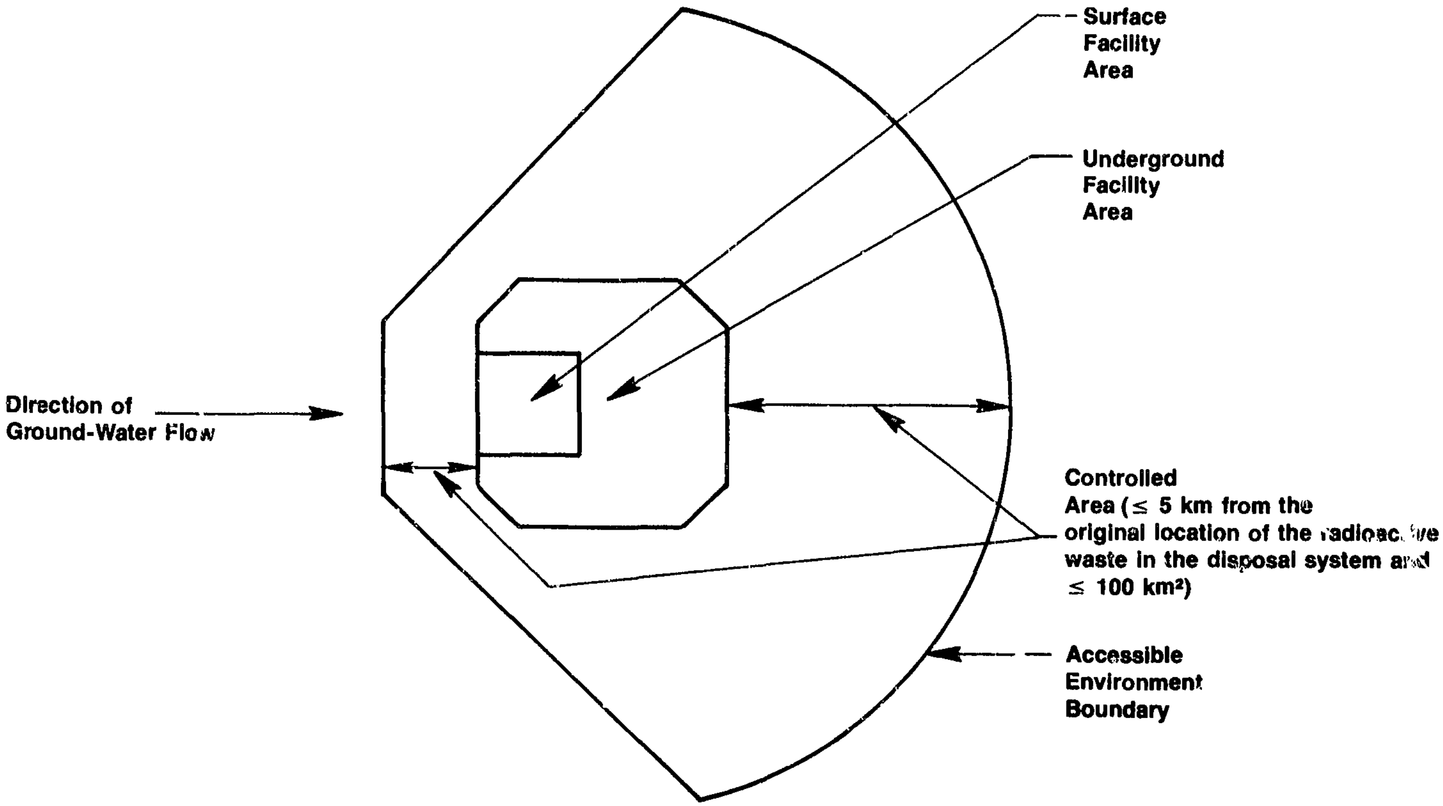

Figure 1-4. Schematic Layout of Areas at a Repository Site

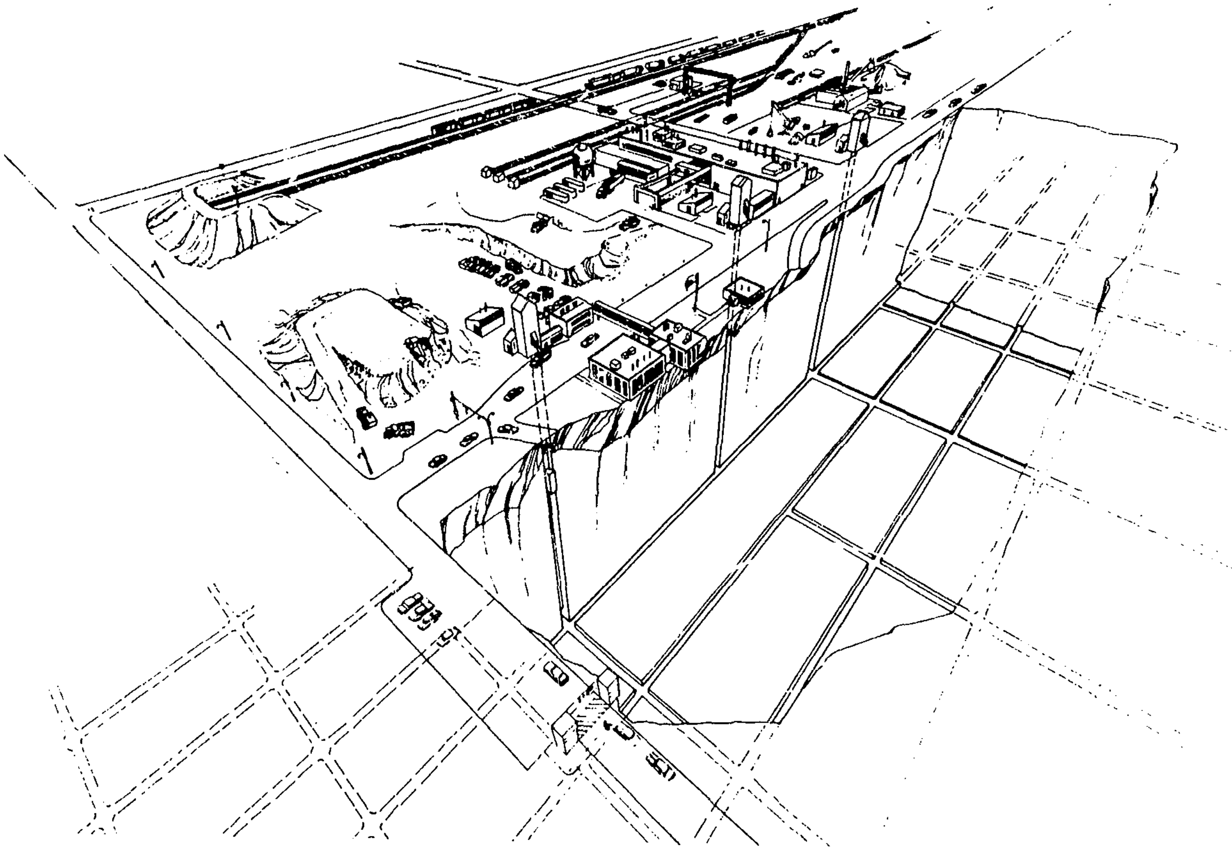

Figure 1-5. Schematic of Surface and Underground Facilities

Conceptual designs for nuclear waste repositories in tuff, salt, and basalt have shown that [illegible] facilities will occupy approximately 160 ha (400 ac). Depending [illegible] the mode of underground emplacement of waste packages, the underground facility may occupy about 880 ha (2,200 ac). The crystalline rock mass at the recommended site must have sufficient thickness and lateral extent to provide adequate isolation as defined by 10 CFR 60 (NRC, 1983) and 40 CFR 191 (EPA, 1985). Conditions that permit the emplacement of waste at a depth of at least 300 m (1,000 ft) from the ground surface are considered favorable siting conditions by both the NRC [10 CFR 60.122(b)(5)], and DOE [10 CFR 960.4-2-5(b)(1)]. It is expected that favorable rock mass depth conditions can readily be met for the crystalline rocks being considered by the CRP because they are deep-seated masses that generally extend downward for thousands of meters. The assumed repository horizon in crystalline rock is to be located at a depth between 350 and 800 m (1,150 to 2,620 ft) below the ground surface. The minimum depth is based on the NRC favorability criterion of a 300-m (1,000-ft) depth cited from ground surface to the disturbed zone around the repository [10 CFR 60.122(b)(5)]. A disturbed zone, which is the zone around the waste emplacement area where the physical or chemical properties are predicted to change as a result of underground construction activities and the heat generated by the waste, will not exceed 50 m (164 ft). Based on current mining experience, in situ stress conditions could cause excavation problems at depths greater than 800 m (2,620 ft). Therefore an 800 m (2,620 ft) depth below ground surface is considered as a maximum depth for the repository horizon in crystalline rock.

The lateral extent of the crystalline rock body must be sufficient to contain the repository underground workings as well as a controlled area of undisturbed rock capable of isolating the waste. Proposed criteria for establishing the extent of the controlled area include the distance ground water can travel prior to emplacement of waste in 1,000 years (10 CFR 60.113) and distance at which permissible releases to the accessible environment can be met in a 10,000-year period (40 CFR 191.13).

There will be restrictions on surface and subsurface activities in the facility to protect individuals from exposure to radiation and radioactive materials. A controlled area, marked by suitable monuments, will extend horizontally no more than 5 km (3.1 mi) in any direction from the outer boundary of the original location of the radioactive wastes in a disposal system, and the total area encompassed by the controlled area may not exceed 100 km^2 (39 mi^2). However, the DOE siting guidelines and the NRC regulations allow for the designation of a smaller controlled area if the EPA standards for radioactive releases to the accessible environment can be met in a shorter distance. The size of the controlled area at a given site will ultimately depend on the rate of ground-water flow and other site characteristics and will be finalized on a site-specific basis after completion of site characterization to ensure that releases to the accessible environment will not exceed those permitted by the EPA. Estimates of the size of the controlled area will be made as part of area-phase investigations. Incompatible activities (e.g., deep mining and borehole drilling) will be prohibited in the controlled area both before and after permanent closure of the repository.

2.0 REGION-TO-AREA SCREENING PROCESS

The purpose of region-to-area screening is to select candidate areas and identify potentially acceptable sites from the 235 exposed or near-surface crystalline rock bodies within the 17 involved States of the North Central, Northeastern, and Southeastern Regions. These 235 rock bodies are shown and identified on the geologic index maps (Plates 1A and 1B) in three regional geologic characterization reports (DOE, 1985c;e;f). During the area phase, potentially acceptable sites will be investigated and evaluated in more detail. The region-to-area screening process was designed to use applicable regional data from the available literature to identify areas with a high likelihood of containing licensable sites. While subsequent field investigations will determine whether these areas actually contain sites which are suitable for nomination, recommendation, and site characterization, application of the region-to-area screening process has identified the areas which warrant further examination in the area phase.

The region-to-area screening process was also designed to allow the results to be utilized as the basis for the identification of candidate areas as potentially acceptable sites in accordance with the requirements of 10 CFR 960.3-2-1. A copy of the DOE Siting Guidelines (10 CFR Part 960) can be obtained from: U.S. Department of Energy-Office of Civilian Radioactive Waste Management, Office of Policy and Outreach, Mail Stop RW-43, 1000 Independence Avenue SW, Washington, D.C. 20585.

2.1 REGIONAL PHASE DATA BASE

Regional geologic and environmental characterization reports were prepared for the North Central, Northeastern, and Southeastern Regions (DOE, 1985c through h). The purposes of these reports were to (1) summarize available information on disqualifying factors and regional screening variables identified in the Region-to-Area Screening Methodology for the Crystalline Repository Project (SMD) (DOE, 1985b) for use in screening the 235 exposed or near-surface crystalline rock bodies within the 17 involved States to identify the most suitable areas for continued investigation in the area phase, (2) present supplementary descriptive information which provides a general characterization of the region; and (3) include summary information on other parameters, e.g., identify threatened and endangered species, socioeconomics, etc., that will be considered at a later phase of repository siting. It should be noted that data collection was not limited to the area within the boundaries of crystalline rock bodies, primarily because proximity to off-rock features was a consideration of many of the region-to-area screening variables. The regional characterization reports are a compilation of publicly available information from sources such as State agencies, university libraries, and Federal agencies. The regional data base has been stored in a series of computer files for use with Steps 1 through 3 of the region-to-area screening methodology and computer access has been made available to the 17 involved States.

2.2 SCREENING PROCESS DESCRIPTION

The region-to-area screening process is a four-step process.* These four steps are consistent with the site screening sequence prescribed in 10 CFR 960.3-2-1.

Step 1 - The Disqualifying Factors Screen uses those disqualifying conditions from the DOE siting guidelines determined to be appropriate for consideration at the regional scale to eliminate certain rock bodies or portions of rock bodies from further consideration. The application of this step is made by using a computerized data base to generate maps which indicate disqualified land areas.

Five of the 10 disqualifying conditions in Appendix III of the DOE siting guidelines applicable to screening for potentially acceptable

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* For purposes of this document, the selection of candidate areas is described as Step 4.

sites were determined to have sufficient regional data in a form which permitted their incorporation into Step 1 without further interpretation/ evaluation. These were:

- Deep Mines and Quarries, 10 CFR 960.4-2-8-1(d)(1)
- Federal-Protected Lands, 10 CFR 960.5-2-5(d)(2)
- Components of National Forest Lands, 10 CFR 960.5-2-5(d)(3)
- State-Protected Lands, 10 CFR 960.5-2-5(d)(3)
- Population Density and Distribution, 10 CFR 960.5-2-1(d)(1),(d)(2).

Each of the five Step 1 factors is discussed in Appendix A. A detailed discussion as to why the remaining five disqualifying conditions were not utilized in Step 1 (i.e., Erosion, 10 CFR 960.4-2-5(d); Dissolution, 10 CFR 960.4-2-6(d); Tectonics, 10 CFR 960.4-2-7(d); Offsite Installations and Operations, 10 CFR 960.5-2-4(d); and Tectonics, 10 CFR 960.5-2-11(d) can be found in the Region-to-Area Screening Methodology for the Crystalline Repository Project (DOE, 1985b, pp. 61-64).

Step 2 - The Scaled* Regional Variables Screen uses the applicable potentially adverse and favorable conditions from the DOE siting guidelines as scaled regional screening variables (developed in three workshops with the involved States) to identify the more favorable land areas. The application of this step is made by using a computerized data base. Weight sets (see Section 2.3) which provide a spectrum of viewpoints regarding relative importance of variables are used in this step to generate maps indicating the relative

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* Scaling was the process by which the Crystalline Repository Project (CRP) translated physical conditions for each screening variable (potentially adverse or favorable) into a numerical value that could be used to estimate the aggregate favorability of crystalline rock bodies or portions thereof (DOE, 1985b).

favorability of land areas remaining after application of Step 1. The 16 variables used in this step are listed in Table 2-1.

Step 3 - The Sensitivity Analysis accomplishes four major objectives. The first is to explore the implications of modifying variable scales on the selection of preliminary candidate areas.* The second is to evaluate the effects of using the geometric mean as an alternate index of aggregate favorability on the selection of preliminary candidate areas. The third is to evaluate the effects of using different sets of weights for the variables by preparing and comparing summary composite maps and to evaluate the effects of the sets of weights on the selection of preliminary candidate areas. The fourth is to allow further differentiation, if any, in selecting preliminary candidate areas by incorporating other geologic variables based on available rock body-specific data. This was accomplished by developing geologic variables for which limited data exist across the three regions. The application of Step 3 also uses the computerized data base and the weight sets to generate maps indicating the relative favorability of the land areas remaining after application of Step 1.

Not all of the DOE siting guidelines are utilized in region-to-area screening, either because the data to support the use of some disqualifying, potentially adverse, and favorable conditions will not be

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* The land units derived by application of Steps 1 through 3 are termed "preliminary candidate areas" until a further examination of the results is conducted in Step 4 to determine if they warrant further investigation in the area phase.

Table 2-1. [illegible] Conditions from 10 CFR 960

Disqualifying Conditions Included in Step 1

Screening Factors	Applicable Siting Guideline
Deep Mines and Quarries	4-2-8-1(d)(1)
Population Density and Distribution	5-2-1(d)(1) 5-2-1(d)(2)
Federal-Protected Lands	5-2-5(d)(2)
Components of National Forest Lands	5-2-5(d)(3)
State-Protected Lands	5-2-5(d)(3)

Favorable and Potentially Adverse Conditions Included in Steps 2 and 3

Screening Variables	Applicable Siting Guideline
Rock Mass Extent	4-2-3(b)(1) 5-2-9(b)(1) 5-2-9(c)(1)
Major Ground-Water Discharge Zones	4-2-1(b)(4)(ii)
Rock and Mineral Resources	4-2-8-1(b)(1) 4-2-8-1(c)(1) 4-2-8-1(c)(2) 4-2-8-1(c)(3) 4-2-8-1(c)(4)
Seismicity	4-2-7(b) 4-2-7(c)
Suspected Quaternary Faulting	4-2-7(b) 4-2-7(c) 5-2-11(c)(1)
Postemplacement Faulting	4-2-7(b) 4-2-7(c) 5-2-9(c)(5)
Proposed Federal-Protected Lands	5-2-5(c)(3)
Population Density	5-2-1(b)(1) 5-2-1(c)(2)
Proximity to Federal-Protected Lands	5-2-5(c)(3)

Table 2-1. Steps 1, 2, and 3 Conditions from 10 CFR 960
Sheet 2 of 2

Favorable and Potentially Adverse Conditions Included in Steps 2 and 3

Screening Variables	Applicable Siting Guideline
Proximity to State-Protected Lands	5-2-5(c)(4)
National Forest Lands	5-2-5(c)(3)
State Forest Lands	5-2-5(c)(4)
Designated Critical Habitat for Threatened and Endangered Species	5-2-5(c)(6)
Wetlands	5-2-5(c)(1)
	5-2-5(c)(2)
Surface Water Bodies	5-2-5(c)(2)
	5-2-8(c)
	5-2-10(b)(2)
Proximity to Highly Populated Areas or 1 Square-Mile Areas of 1,000 or More Persons	5-2-1(b)(2)
	5-2-1(c)(2)
	5-2-6(b)(1)
	5-2-6(b)(2)
	5-2-6(b)(3)
	5-2-6(b)(4)
	5-2-6(c)(1)
	5-2-6(c)(2)
	5-2-6(c)(4)
Thickness of Rock Mass	4-2-3(b)(1)
	4-2-5(b)(1)
	5-2-9(b)(1)
	5-2-9(c)(1)
Thickness of Overburden	5-2-9(c)(2)
	5-2-10(b)(1)
	5-2-10(c)
State-of-Stress	5-2-9(b)(2)
	5-2-9(c)(2)
	5-2-9(c)(3)
Ground-Water Resources	4-2-1(c)(2)
	5-2-10(b)(1)

available until field [illegible] conducted in the area phase or during site characterization or because [illegible] data in the literature are not appropriate for use on a regional scale to identify preliminary candidate areas. Table 2-1 lists the disqualifying, favorable, and potentially adverse conditions used in Steps 1 through 3 of the region-to-area screening methodology.

Step 4 - Selecting Candidate Areas involves a complete review of the previous steps as well as a review of any additional qualitative/descriptive literature not directly incorporated in Steps 1 through 3, and review and application, as appropriate, of the implementation guidelines (Subpart B of 10 CFR 950) to help ensure, within the limitations of a regional study, that the preliminary candidate areas identified warrant further examination in the area phase.

The objective of this review was to ensure that there are no data in the CRP data base, as reflected in the regional characterization reports, or in other information available to the CRP, that indicates an anomaly in the results of the application of Steps 1 through 3 which identified the preliminary candidate areas. Accordingly, DOE considered all significant information not directly incorporated in Steps 1 through 3, which could affect the continued consideration of an area. The Implementation Guidelines that were considered as part of this review were: Diversity of Geohydrologic Settings (10 CFR 960.3-1-1), Diversity of Rock Types (10 CFR 960.3-1-2), and Regionality (10 CFR 960.3-1-3).

A detailed discussion of the disqualifying factors and regional screening variables, including definitions, significance, measures, data sources, comments, and scales, as well as a description of the region-to-area screening process is contained in the screening methodology document (SMD) (DOE, 1985b). An abbreviated version of the information in the SMD regarding Steps 1 through 3 is contained in Appendix A.

2.3 WEIGHTING

Weighting played an important role in region-to-area screening. While scaling assessed the range of conditions for a single variable, weighting evaluated the relative importance of each variable in relation to every other variable in region-to-area screening. Nine different sets of weights were used to evaluate the implications of a broad range of views of the relative importance of individual regional screening variables for the selection of preliminary candidate areas for further study. Of the nine sets used, five were derived from a CRP weighting workshop and four were derived from a similar State workshop which included only crystalline State representatives of the 17 involved States. Both workshops were structured to include a cross-section of representation, including individuals with expertise in geologic, engineering, waste isolation, environmental, and socioeconomic disciplines. This was done to help ensure that the products of each workshop captured a broad spectrum of views of the relative importance of the regional screening variables.

2.3.1 Weighting Workshop Process

As discussed above, the nine weight sets were derived from two workshops conducted to determine the relative importance of the screening variables through the assignment of weights. For a more detailed description of the weighting process, including a description of the selection of participants, consult Section 3.2.3 of the SMD (DOE, 1985b). Weights were assigned in each of four phases:

Phase A - 16 Step 2 variables,* per SMD

Phase B - 16 Step 2 variables, some scale modification

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* Following the first workshop and in accordance with the SMD, State wildlife lands was deleted as a variable and State-Owned Wildlife Lands was added as a disqualifying factor. Accordingly, the weights derived at the CRP workshop were normalized, i.e., the points assigned to the State Wildlife Lands variable were proportionally redistributed to the other 16 variables.

Phase C - 2? [illegible] variables, per SMD

Phase D - 20 Step [illegible] variables, some scale modification.

The process of assigning weight sets was described fully in the SMD (DOE, 1985b) and is outlined briefly below.

1. Background materials were sent to the participants which contained a description of the regional screening variables, the process of subgroup formation, and discussion of the phases for which weights would be assigned. The package mailed to the participants also described a possible way of allocating weights.

2. Review and group discussion of the SMD took place during the early periods of the workshops. Questions raised by the participants were answered.

3. Individual participants distributed 1,000 points among the regional variables to indicate their relative importance. The mechanism of allocating the points and forming subgroups was as follows:

   - If desirable, participants would group the variables in a manner selected by the individual participants prior to allocation of the weighting points. This was suggested to the participants because it would make the process more systematic.
   - Participants would then distribute 1,000 points to the Step 2 variables (Phase A) in accordance with their relative importance using, if desired, the groupings developed.

   - Using a cluster analysis model, the CRP would perform a cluster analysis of the weights assigned by the individual participants to identify homogeneous subgroups (i.e. those individuals with similar views. The cluster analysis was implemented by using the Statistical Package for the Social Sciences computer model.

- The result was the formation of five subgroups in the CRP workshop and four in the States workshop.
- Group discussions were conducted among the individuals of each subgroup led by an independent facilitator. The objective was to refine the individual views to a point where the views would change no further. The weights derived from this process and subsequently used in screening represent the mean of each group.

2.3.2 Results of Weighting Workshops

The CRP weighting workshop was held in Chicago, Illinois, in November 1984, and involved personnel from DOE, Office of Crystalline Repository Development of Battelle, subcontractors, and the U.S. Geological Survey. Forty-six individuals participated in this workshop. The participants were divided into five subgroups according to the relative similarity of their views on the relative importance of the variables. Tables 2-2 through 2-5 represent the mean weights assigned to each variable by each subgroup for each of the four phases, respectively.

The second weighting workshop was conducted for States' representatives in Columbus, Ohio, in May 1985. Thirty-seven participants from 14 of the 17 involved states* attended the workshop. The participants in this workshop were divided into four subgroups according to the relative similarity of their views on the relative importance of the variables.

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* North Central Region - Michigan, Minnesota, Wisconsin
Northeastern Region - Maine, Massachusetts, New Hampshire, New York Rhode Island, Vermont
Southeastern Region - Georgia, Maryland, North Carolina, South Carolina, Virginia

It should be noted that one of the subgroups at the States' workshop was comprised of individuals with rather disparate individual views of variable weights. While this was contrary to the stated intent to have subgroups with similar views, it was necessitated by the need to avoid very small group sizes (less than 8 to 10 people). Thus, a few people with statis- tically unique points of view were combined to constitute a fourth subgroup (State Subgroup 1). Tables 2-6 through 2-9 represent the mean weights assigned to each variable by each subgroup for each of the four phases, respectively. In no way do these mean weights directly reflect either individual participant or crystalline state points of view on the relative importance of the region-to-area screening variables. This was ensured by the way the workshops were structured and by the manner the results were reported.

2.4 SELECTING CANDIDATE AREAS ("STEP 4")

Prior to the selection of candidate areas, the following activities were undertaken:

- A complete review of the results of Steps 1 through 3 of the region-to-area screening methodology to ensure their accuracy and technical defensibility.
- A review of qualitative/descriptive literature not directly incorporated in Steps 1 through 3, to help ensure that there is reasonable expectation, within the constraints of a regional study, that each preliminary candidate area warrants further examination in the area phase from a technical point of view. This review was to ensure that there are no data in the CRP's data base, as presented in the regional characterization reports or additional data in the existing literature, that indicate an anomaly in the results of screening Steps 1 through 3, and to evaluate the preliminary candidate areas to determine whether there was sufficient reason to defer them from designation as candidate areas.

Table 2-2. Phase A Summary of Mean Responses by CRP Subgroup per Screening Variable Out of a total score of 1000 for 16 variables

SUBGROUP 1		SUBGROUP 2		SUBGROUP 3		SUBGROUP 4		SUBGROUP 5	
2	399.5	2	201.1	2	154.3	2	101.3	8	144.9
1	242.8	1	178.4	5	141.0	8	86.4	1	113.0
6	106.2	6	118.4	4	126.0	15	79.1	2	99.1
5	52.0	5	78.8	6	97.7	1	78.7	16	86.8
3	38.2	4	76.1	3	94.3	5	75.6	6	80.0
8	35.1	8	69.3	1	91.0	6	74.8	13	74.8
4	27.0	3	50.6	8	68.5	7	60.8	4	64.1
7	16.3	15	49.3	15	53.3	14	60.1	9	64.0
16	13.5	16	39.3	9	27.7	9	60.0	5	52.0
13	13.3	9	26.1	13	25.8	16	57.0	10	46.2
12	11.5	10	22.5	16	24.2	10	55.5	15	37.3
11	10.8	13	21.6	7	21.8	4	54.6	7	36.4
15	10.2	14	21.6	10	21.8	13	51.1	14	30.7
9	9.5	7	19.3	11	19.3	3	36.5	11	26.2
10	8.3	11	14.3	12	19.2	11	35.8	3	24.3
14	6.5	12	13.8	14	14.3	12	33.0	12	20.9

LEGEND - SCREENING VARIABLES

1 ROCK MASS EXTENT
2 MAJOR GROUND-WATER DISCHARGE ZONES
3 ROCK AND MINERAL RESOURCES
4 SEISMICITY
5 SUSPECTED QUATERNARY FAULTING
6 POSTEMPLACEMENT FAULTING
7 PROPOSED FEDERAL-PROTECTED LANDS
8 POPULATION DENSITY
9 PROXIMITY TO FEDERAL-PROTECTED LANDS
10 PROXIMITY TO STATE-PROTECTED LANDS
11 NATIONAL FOREST LANDS
12 STATE FOREST LANDS
13 DESIGNATED CRITICAL HABITAT FOR THREATENED AND ENDANGERED SPECIES
14 WETLANDS
15 SURFACE WATER BODIES
16 PROXIMITY TO HIGHLY POPULATED AREAS

Table 2-[illegible] [illegible] Summary of Mean Responses by CRP
Subgroup per Screening Variable
Out of a total score of 1000 for 16 variables

SUBGROUP 1		SUBGROUP 2		SUBGROUP 3		SUBGROUP 4		SUBGROUP 5	
2	397.8	1	205.4	2	152.6	2	102.4	8	144.0
1	263.6	2	201.5	5	140.9	8	85.9	1	113.0
6	107.8	6	115.4	4	129.2	15	79.1	2	99.1
5	43.2	4	78.1	6	97.6	5	75.8	16	94.3
3	38.2	5	74.2	3	94.2	1	74.4	6	80.0
16	27.1	8	69.4	1	89.2	6	74.1	13	74.8
8	27.0	3	48.9	8	68.4	16	67.4	9	63.6
7	16.3	15	46.2	15	53.4	7	61.0	4	61.6
13	13.1	16	43.1	16	31.7	14	60.2	5	51.2
4	12.0	9	22.0	9	26.7	9	60.1	10	45.8
12	11.3	10	21.1	13	23.4	10	55.5	15	36.9
11	10.7	13	19.8	7	20.9	4	51.9	7	36.4
15	10.0	14	18.0	10	20.9	13	41.1	14	30.3
9	8.8	7	14.5	11	18.4	3	36.6	11	26.2
10	7.7	11	11.7	12	18.4	11	34.1	3	22.6
14	6.2	12	10.8	14	13.4	12	31.1	12	20.9

LEGEND - SCREENING VARIABLES

1 ROCK MASS EXTENT
2 MAJOR GROUND-WATER DISCHARGE ZONES
3 ROCK AND MINERAL RESOURCES
4 SEISMICITY
5 SUSPECTED QUATERNARY FAULTING
6 POSTEMPLACEMENT FAULTING
7 PROPOSED FEDERAL-PROTECTED LANDS
8 POPULATION DENSITY
9 PROXIMITY TO FEDERAL-PROTECTED LANDS
10 PROXIMITY TO STATE-PROTECTED LANDS
11 NATIONAL FOREST LANDS
12 STATE FOREST LANDS
13 DESIGNATED CRITICAL HABITAT FOR THREATENED AND ENDANGERED SPECIES
14 WETLANDS
15 SURFACE WATER BODIES
16 PROXIMITY TO HIGHLY POPULATED AREAS

Table 2-4. Phase 2 Summary of Mean Responses by CRP Subgroup per Screening Variable
Out of a total score of 1000 for 20 variables

SUBGROUP 1		SUBGROUP 2		SUBGROUP 3		SUBGROUP 4		SUBGROUP 5	
2	372.0	2	172.8	2	141.0	2	85.0	8	136.0
1	226.4	1	162.9	5	127.7	8	72.0	1	98.1
6	99.0	6	98.2	4	114.4	1	66.2	2	82.5
5	48.6	5	65.9	6	88.0	15	65.5	16	75.9
20	38.4	4	64.0	3	85.0	5	63.5	6	71.5
3	36.0	8	56.4	1	81.5	6	63.1	13	65.8
8	32.9	17	46.0	8	61.4	19	58.1	9	57.2
4	25.5	20	42.5	15	47.4	20	57.8	4	54.8
18	17.5	18	40.8	20	40.9	7	51.3	20	45.9
7	15.5	15	39.9	9	25.2	9	50.5	17	45.2
17	13.3	3	38.8	18	24.5	14	49.5	5	44.6
16	12.1	19	33.7	19	24.2	16	46.8	10	39.9
13	12.0	16	31.7	13	21.7	10	46.3	15	31.8
12	10.1	9	20.6	16	21.2	4	46.0	7	31.7
11	9.6	10	18.3	7	19.5	13	42.1	14	26.9
15	9.0	13	16.2	10	19.5	3	30.9	11	22.7
9	8.8	14	15.9	11	16.9	17	30.5	3	19.7
10	7.6	7	14.2	12	16.9	11	29.4	12	18.4
14	5.6	11	10.5	14	12.4	12	27.1	19	16.2
19	0.5	12	10.2	17	10.7	18	18.1	18	14.7

LEGEND - SCREENING VARIABLES

1 ROCK MASS EXTENT
2 MAJOR GROUND-WATER DISCHARGE ZONES
3 ROCK AND MINERAL RESOURCES
4 SEISMICITY
5 SUSPECTED QUATERNARY FAULTING
6 POSTEMPLACEMENT FAULTING
7 PROPOSED FEDERAL-PROTECTED LANDS
8 POPULATION DENSITY
9 PROXIMITY TO FEDERAL-PROTECTED LANDS
10 PROXIMITY TO STATE-PROTECTED LANDS
11 NATIONAL FOREST LANDS
12 STATE FOREST LANDS
13 DESIGNATED CRITICAL HABITAT FOR THREATENED AND ENDANGERED SPECIES
14 WETLANDS
15 SURFACE WATER BODIES
16 PROXIMITY TO HIGHLY POPULATED AREAS
17 THICKNESS OF ROCK MASS
18 THICKNESS OF OVERBURDEN
19 STATE OF STRESS
20 GROUND-WATER RESOURCES

Table 2-[illegible] [illegible] Summary of Mean Responses by CRP Subgroup per Screening Variable
out of a total score of 1000 for 20 variables

SUBGROUP 1		SUBGROUP 2		SUBGROUP 3		SUBGROUP 4		SUBGROUP 5	
2	370.6	1	174.1	2	142.0	2	85.9	8	134.3
1	245.8	2	170.1	5	128.7	8	71.9	1	98.1
6	100.5	6	97.7	4	115.2	15	65.3	16	82.6
5	40.3	4	65.1	6	88.9	5	63.5	2	82.5
20	38.3	5	63.2	3	85.7	6	63.0	6	71.5
3	36.0	8	57.1	1	82.4	1	62.4	13	65.4
8	25.3	17	45.9	8	62.0	19	57.0	9	56.8
16	24.9	20	42.3	15	48.0	20	56.7	4	53.2
18	17.5	18	40.7	20	32.0	16	56.3	20	45.9
7	15.5	15	38.2	16	28.2	7	51.3	17	44.8
18	13.3	3	37.0	9	24.7	9	50.4	5	44.6
13	11.9	16	36.2	18	24.7	14	49.3	10	39.5
4	11.5	19	35.5	19	24.4	10	46.2	15	31.8
12	10.0	9	18.4	13	20.4	4	45.8	7	31.3
11	9.5	10	17.7	7	19.0	13	41.9	14	26.9
15	8.9	13	15.8	10	19.0	3	30.9	11	22.3
9	8.1	14	13.8	11	16.4	17	30.3	3	19.7
10	6.9	7	12.1	12	16.2	11	27.9	12	18.4
14	5.5	11	10.2	14	11.9	12	25.5	19	16.2
19	0.5	12	9.8	17	10.9	18	17.9	18	14.3

LEGEND - SCREENING VARIABLES

1 ROCK MASS EXTENT
2 MAJOR GROUND-WATER DISCHARGE ZONES
3 ROCK AND MINERAL RESOURCES
4 SEISMICITY
5 SUSPECTED QUATERNARY FAULTING
6 POSTEMPLACEMENT FAULTING
7 PROPOSED FEDERAL-PROTECTED LANDS
8 POPULATION DENSITY
9 PROXIMITY TO FEDERAL-PROTECTED LANDS
10 PROXIMITY TO STATE-PROTECTED LANDS
11 NATIONAL FOREST LANDS
12 STATE FOREST LANDS
13 DESIGNATED CRITICAL HABITAT FOR THREATENED AND ENDANGERED SPECIES
14 WETLANDS
15 SURFACE WATER BODIES
16 PROXIMITY TO HIGHLY POPULATED AREAS
17 THICKNESS OF ROCK MASS
18 THICKNESS OF OVERBURDEN
19 STATE OF STRESS
20 GROUND-WATER RESOURCES

Table 2 [illegible] Summary of Mean Responses by State
Subgroup for Screening Variable
Out of a total score of 1000 for 16 variables

SUBGROUP 1		SUBGROUP 2		SUBGROUP 3		SUBGROUP 4	
16	265.1	6	221.8	8	182.5	14	109.1
1	258.2	1	176.9	16	166.3	15	97.7
15	173.9	4	164.3	2	119.5	11	84.5
6	166.8	8	65.9	1	98.3	16	80.5
3	42.0	2	62.5	14	93.8	8	75.9
11	35.0	3	62.1	15	84.6	10	74.5
8	24.0	10	52.1	4	75.8	12	71.4
9	20.0	16	42.0	11	57.1	1	71.0
10	15.0	12	39.6	6	40.3	9	69.1
2	0.0	15	26.0	12	39.4	2	68.7
4	0.0	14	22.3	10	34.0	13	56.4
5	0.0	5	20.8	5	6.0	6	46.4
7	0.0	11	17.5	9	2.5	3	44.6
12	0.0	9	15.0	3	0.1	4	28.3
13	0.0	13	8.8	7	0.0	5	20.1
14	0.0	7	2.6	13	0.0	7	1.8

LEGEND - SCREENING VARIABLES

1 ROCK MASS EXTENT
2 MAJOR GROUND-WATER DISCHARGE ZONES
3 ROCK AND MINERAL RESOURCES
4 SEISMICITY
5 SUSPECTED QUATERNARY FAULTING
6 POSTEMPLACEMENT FAULTING
7 PROPOSED FEDERAL-PROTECTED LANDS
8 POPULATION DENSITY
9 PROXIMITY TO FEDERAL-PROTECTED LANDS
10 PROXIMITY TO STATE-PROTECTED LANDS
11 NATIONAL FOREST LANDS
12 STATE FOREST LANDS
13 DESIGNATED CRITICAL HABITAT FOR THREATENED AND ENDANGERED SPECIES
14 WETLANDS
15 SURFACE WATER BODIES
16 PROXIMITY TO HIGHLY POPULATED AREAS

Table 2-7. Phase B Summary of Mean Responses by States Subgroup per Screening Variable Out of a total score of 1000 for 16 variables

SUBGROUP 1		SUBGROUP 2		SUBGROUP 3		SUBGROUP 4	
16	251.4	6	221.8	8	183.8	14	113.2
1	243.8	4	169.3	16	167.5	15	99.5
15	166.4	1	167.5	2	120.0	11	84.5
6	154.9	8	65.9	1	98.8	10	74.5
4	52.3	3	63.4	14	94.4	16	74.1
3	37.0	2	62.5	15	78.8	8	71.4
11	31.0	10	52.1	4	76.3	12	71.4
8	24.0	16	45.1	11	57.5	1	69.1
9	24.0	12	39.6	6	40.6	9	69.1
10	15.0	15	26.0	12	39.4	2	68.6
2	0.0	14	22.3	10	34.4	13	56.4
5	0.0	5	20.8	5	6.3	6	47.7
7	0.0	11	17.5	9	2.5	3	46.8
12	0.0	9	15.0	3	0.0	4	31.8
13	0.0	13	8.8	7	0.0	5	20.0
14	0.0	7	2.6	13	0.0	7	1.8

LEGEND - SCREENING VARIABLE

1 ROCK MASS EXTENT
2 MAJOR GROUND-WATER DISCHARGE ZONES
3 ROCK AND MINERAL RESOURCES
4 SEISMICITY
5 SUSPECTED QUATERNARY FAULTING
6 POSTEMPLACEMENT FAULTING
7 PROPOSED FEDERAL-PROTECTED LANDS
8 POPULATION DENSITY
9 PROXIMITY TO FEDERAL-PROTECTED LANDS
10 PROXIMITY TO STATE-PROTECTED LANDS
11 NATIONAL FOREST LANDS
12 STATE FOREST LANDS
13 DESIGNATED CRITICAL HABITAT FOR THREATENED AND ENDANGERED SPECIES
14 WETLANDS
15 SURFACE WATER BODIES
16 PROXIMITY TO HIGHLY POPULATED AREAS

Table [illegible] Summary of Mean Responses by States
Subgroup [illegible] Screening Variable
out of a total score of 1000 for 20 variables

SUBGROUP 1		SUBGROUP 2		SUBGROUP 3		SUBGROUP 4	
16	265.1	6	178.1	8	160.4	14	106.3
1	258.2	1	151.4	16	145.1	15	93.0
15	173.9	17	135.1	2	104.8	11	83.1
6	166.8	4	132.9	1	88.0	8	78.0
3	42.0	20	61.3	20	85.1	16	75.6
11	33.0	8	50.8	14	77.1	10	71.7
8	24.0	2	45.4	15	76.4	12	69.9
9	20.0	3	42.1	4	61.4	1	68.5
10	15.0	10	42.0	18	44.8	9	66.4
2	0.0	12	34.1	11	43.3	2	59.1
4	0.0	16	29.8	12	37.1	13	53.5
5	0.0	15	21.8	6	36.6	6	46.4
7	0.0	14	14.8	10	25.4	3	44.5
12	0.0	5	14.4	5	6.0	4	28.2
13	0.0	19	13.8	9	5.5	5	20.0
14	0.0	9	12.8	7	2.5	18	18.2
17	0.0	11	8.4	3	0.6	20	13.5
18	0.0	18	6.3	13	0.0	17	2.3
19	0.0	13	3.9	17	0.0	7	1.8
20	0.0	7	1.3	19	0.0	19	0.0

LEGEND - SCREENING VARIABLES

1 ROCK MASS EXTENT
2 MAJOR GROUND-WATER DISCHARGE ZONES
3 ROCK AND MINERAL RESOURCES
4 SEISMICITY
5 SUSPECTED QUATERNARY FAULTING
6 POSTEMPLACEMENT FAULTING
7 PROPOSED FEDERAL-PROTECTED LANDS
8 POPULATION DENSITY
9 PROXIMITY TO FEDERAL-PROTECTED LANDS
10 PROXIMITY TO STATE-PROTECTED LANDS
11 NATIONAL FOREST LANDS
12 STATE FOREST LANDS
13 DESIGNATED CRITICAL HABITAT FOR THREATENED AND ENDANGERED SPECIES
14 WETLANDS
15 SURFACE WATER BODIES
16 PROXIMITY TO HIGHLY POPULATED AREAS
17 THICKNESS OF ROCK MASS
18 THICKNESS OF OVERBURDEN
19 STATE OF STRESS
20 GROUND-WATER RESOURCES

Table 2-[illegible]. Pha[illegible] Summary of Mean Responses by States
Subgroup per Scre[illegible]ing Variable
Out of a total score of 1000 for 20 variables

SUBGROUP 1		SUBGROUP 2		SUBGROUP 3		SUBGROUP 4	
16	253.9	6	178.1	8	160.4	14	105.9
1	246.4	1	149.0	16	145.1	15	93.2
15	161.5	17	135.1	2	104.8	11	83.2
6	154.9	4	132.9	1	88.0	16	74.1
4	52.6	20	61.3	20	85.1	8	73.6
3	37.1	8	50.8	14	77.1	10	71.8
11	31.0	2	45.4	15	76.4	12	70.0
9	24.0	3	42.1	4	61.4	1	66.8
8	23.5	10	42.0	18	44.8	9	66.4
10	15.0	12	34.1	11	43.3	2	61.8
2	0.1	16	32.1	12	37.1	13	53.6
5	0.0	15	21.8	6	36.6	6	47.7
7	0.0	14	14.8	10	25.4	3	46.8
12	0.0	5	14.4	5	6.0	4	29.1
13	0.0	19	13.8	9	5.5	5	20.0
14	0.0	9	12.8	7	2.5	18	18.2
17	0.0	11	8.4	3	0.6	20	13.6
18	0.0	18	6.3	13	0.0	17	2.3
19	0.0	13	3.9	17	0.0	7	1.8
20	0.0	7	1.3	19	0.0	19	0.0

LEGEND - SCREENING VARIABLES

1 ROCK MASS EXTENT
2 MAJOR GROUND-WATER DISCHARGE ZONES
3 ROCK AND MINERAL RESOURCES
4 SEISMICITY
5 SUSPECTED QUATERNARY FAULTING
6 POSTEMPLACEMENT FAULTING
7 PROPOSED FEDERAL-PROTECTED LANDS
8 POPULATION DENSITY
9 PROXIMITY TO FEDERAL-PROTECTED LANDS
10 PROXIMITY TO STATE-PROTECTED LANDS
11 NATIONAL FOREST LANDS
12 STATE FOREST LANDS
13 DESIGNATED CRITICAL HABITAT FOR THREATENED AND ENDANGERED SPECIES
14 WETLANDS
15 SURFACE WATER BODIES
16 PROXIMITY TO HIGHLY POPULATED AREAS
17 THICKNESS OF ROCK MASS
18 THICKNESS OF OVERBURDEN
19 STATE OF STRESS
20 GROUND-WATER RESOURCES

In addition, CRP was investigated to determine if there is any evidence that a disqualifying condition applicable to the identification of potentially acceptable sites exists within the preliminary candidate area. Where evidence supported a finding that a disqualifying condition was present within a preliminary candidate area, (e.g. Step 1 disqualifying features smaller than 130 ha (320 ac) in size) an assessment was made to determine if the area should continue to be considered a preliminary candidate area. Any data relied on but not included in the regional characterization reports that were used in making these evaluations have been documented.

- A review and application, as appropriate, of the Implementation Guidelines (Subpart B of 10 CFR 960) were reviewed and applied as appropriate (see Section 3.3). The Implementation Guidelines considered were:

  - Diversity of Geohydrologic Settings (10 CFR 960.3-1-1)
  - Diversity of Rock Types (10 CFR 960.3-1-2)
  - Regionality (10 CFR 960.3-1-3)

Candidate areas were finally selected from among the preliminary candidate areas after due consideration of the several aspects of Step 4. The objective of Step 4 was to obtain a thorough understanding of the actual strengths and weaknesses of each preliminary candidate area. The selection of candidate areas from the preliminary candidate areas was made after full consideration of the available information not directly incorporated in Steps 1 through 3.

2.5 IDENTIFYING POTENTIALLY ACCEPTABLE SITES

Each candidate area selected was further analyzed to determine if DOE could identify each such area as a potentially acceptable site in accordance with 10 CFR 960.3-2-1. For DOE to identify a potentially acceptable site, 10 CFR 960.[illegible]1 requires that the "evidence shall support a finding that the site is not disqualified in accordance with the application requirements set forth in Appendix III of this Part [10 CFR 960] and shall support the decision by DOE to proceed with the continued investigation of the site on the basis of the favorable and potentially adverse conditions identified to date". Accordingly, for the identification of a potentially acceptable site, DOE had to apply the 10 disqualifying conditions specified in Appendix III and assess whether the available evidence did or did not support a finding that a site is disqualified.

Five of the 10 disqualifying conditions were directly applied in Step 1 of the screening methodology [i.e., 10 CFR 960.4-2-8-1(d)(1), 10 CFR 960.5-2-1(d)(1) and (d)(2), 10 CFR 960.5-2-5(d)(2) and (d)(3)]. The presence of Federal-protected and State-protected lands smaller than 130 ha (320 ac), the presence of ground-water resources, and the other five disqualifying conditions, were evaluated as part of the review of qualitative/descriptive literature which was undertaken following Step 3 of the region-to-area screening methodology.

The DOE siting guidelines also require as a precondition to the identification of a candidate area as a potentially acceptable site that the evidence support the decision to proceed with the continued investigation of the potentially acceptable site on the basis of the favorable and potentially adverse conditions identified to date. According to 10 CFR 960.3-1-4-1 of the DOE siting guidelines, the evidence for the identification of potentially acceptable sites is the type of information specified in Appendix IV of the DOE siting guidelines, although more general and less detailed than that required for the nomination of a site as suitable for characterization. This evaluation was primarily based on the results obtained from the application of the region-to-area screening methodology (Steps 1 through 3) and was supplemented by the review of the qualitative/descriptive literature prior to the selection of candidate areas.

3.0 REGION-TO-AREA SCREENING

The purpose of this chapter is to document the selection of preliminary candidate areas and identification of candidate areas. The chapter describes the results of: (1) the application of Steps 1 through 3 of the region-to-area screening methodology leading to identification of preliminary candidate areas; (2) the qualitative review and evaluation (Step 4) of new additional information not directly incorporated in Steps 1 through 3 on each preliminary candidate area identified as a result of applying Steps 1 through 3 to support the decision by DOE to proceed with the continued investigation of each area including the review of computer screening data; and (3) the consideration as part of Step 4 of other siting provisions from the Implementation Guidelines of Subpart B of the DOE siting guidelines leading to the identification of candidate areas.

3.1 RESULTS OF REGION-TO-AREA SCREENING METHODOLOGY

This section presents the results of the application of Steps 1 through 3 of the screening methodology. Although the steps were applied one at a time, the sensitivity analyses in Step 3 were conducted and are presented in a slightly different sequence than listed in the SMD to more clearly describe the results. Specifically, summary composite maps used to identify preliminary candidate areas were developed and then the effects of scale modification and the addition of Step 3 geologic variables on the identification of the more favorable areas were analyzed. Various alternatives to elements of the methodology considered were: an equally weighted composite favorability map; an alternate index of aggregate favorability (the geometric mean) (Appendix B); and, alternate types of summary composite maps (Appendix C).

The results of Steps 1 through 3 are displayed in the form of computer-generated plates, some of which are provided as Volume 2* and others which will be provided upon request. The quality control rocedures used to ensure the accuracy of the computer-generated plates described in Sections 3.1.1, 3.1.2, and 3.1.3 are briefly discussed in Appendix D. The ultimate product of Steps 1 through 3 of the methodology is the identification of preliminary candidate areas.

3.1.1 Step 1 - Disqualifying Factors Screen

This section discusses the results of the application of Step 1 of the region-to-area screening methodology.** Step 1 is applied to the land area within the three regions for which data has been gathered and presented in the regional characterization reports. In the North Central Region, this area is approximately 409,700 km^2 (157,600 mi^2) of which 76,060 km^2 (29,250 mi^2) is underlain by crystalline rock bodies. In the Northeastern Region, this area is approximately 250,400 km^2 (96,290 mi^2) of which 65,060 km^2 (25,020 mi^2) is underlain by crystalline rock bodies. In the Southeastern Region, this area is approximately 297,600 km^2 (114,500 mi^2) of which 54,190 km^2 (20,840 mi^2) is underlain by crystalline rock bodies.

The following disqualifying factors were applied to each of the three regions under investigation by the CRP: (1) Federal-protected lands, comprised of components of the National Park System, National Wild and Scenic Rivers System, National Wildlife Refuge System, and National

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* The plates in the accompanying portfolio (Volume 2) include index maps, disqualified features maps, equally weighted composite favorability maps, Phase A and B summary composite maps and transportation networks.

** The disqualification of rock bodies, (or portions thereof) during Step 1 precludes DOE from locating (i) the surface facility, or (ii) the restricted area or repository support facilities, as appropriate within the boundaries of the disqualified areas. In addition, a deep mine or quarry cannot be located within the controlled area.

Wilderness Preservation [illegible] selected components of National forest lands (i.e., research [illegible] areas, primitive areas, and recreation areas); (3) State-protected lands, comprised of components of the State Park System, State Wild and Scenic Rivers System, State Wildlife Management System, and State Wilderness Preservation System; (4) population density and distribution, comprised of highly populated areas and areas with population densities of greater than 1,000 persons per square mile; and (5) deep mines and quarries (deeper than 100 m or 330 ft). Disqualified environmental features mapped had to be at least 130 ha (320 ac) in size because of the scale at which regional-phase work was conducted. Disqualified features smaller than 130 ha (320 ac) in size were not mapped but were listed in the regional characterization reports, and their presence within, or near, a preliminary candidate area was considered in the selection of candidate areas (Step 4).

The results of Step 1 are displayed on six plates, two for each region as follows: Plates NC-2A and NC-2B for the North Central Region, Plates NE-2A and NE-2B for the Northeastern Region, and Plates SE-2A and SE-2B for the Southeastern Region. Federal-protected lands are shown in green, State-protected lands are shown in blue, population density and distribution are shown in purple, and deep mines and quarries are shown in red. Where disqualifiers are coincident, colors are displayed on the plates according to the following priority: (1) deep mines and quarries, (2) population density and distribution, (3) Federal-protected lands and selected components of national forest lands, and (4) State-protected lands.

The data base for application of this step is contained in the six regional characterization reports (DOE, 1985c through h).

3.1.1.1 Disqualifying Factors Screen - North Central Region

In the North Central Region (see Plates NC-2A and NC-2B), Federal-protected lands and State-protected lands make up the greatest proportion of disqualified ... Components of the National Park System and National Wilderness Preservation System are more concentrated in the northern half of the region and generally correspond with other large Federal land holdings such as national forests. The largest single unit of these components is the Boundary Waters Canoe Wilderness Area, located in northeast Minnesota, which encompasses over 400,000 ha (1 million ac). Components of the National Wildlife Refuge System generally are located within larger wetland areas which are scattered throughout the region. One component of the National Wildlife Refuge System which occurs primarily in the north central United States is Federal waterfowl production areas. These units are widely scattered over the North Central Region with a heavy concentration in western Minnesota. The waterfowl production areas are designated to protect the region's prairie pothole habitats to foster the propagation of migratory waterfowl. National and state wild and scenic rivers are found along some of the major rivers in the region.

Components of the State Park, State Wildlife Management, and State Wilderness Preservation Systems exhibit no significant areal extent. However, Minnesota has a greater number of these features than does Wisconsin or the Upper Peninsula of Michigan.

Highly populated areas and areas with population densities equal to or greater than 1,000 persons per square mile tend to be concentrated in the central and southern parts of the region with the greatest concentrations occurring in the vicinity of Minneapolis-St. Paul and Milwaukee. These population features are usually associated with or in close proximity to industrial areas and to major highways.

There are 126 deep mines and quarries within the North Central Region. Most of these disqualifying factors are found in belts along the length of the Mesabi Iron Range in Minnesota in a northeast-southwest direction, the Gogebic Range in Wisconsin and Michigan running in a northeast-southwest direction, and the Marquette Iron District in Michigan trending in an east-west direction.

Table 3-1 summarizes for each disqualifying factor the total area and percentage of area within the region covered by disqualifying factors as reflected in the regional data base, and the extent (areal and percentage) to which crystalline rock bodies are covered by disqualifying factors. The disqualifying factors which are most significant in terms of geographic extent are highly populated areas and areas with population densities of 1,000 or more persons per square mile, Federal-protected lands, and State-protected lands. A total of 36,426 km^2 (14,010 mi^2) are disqualified within the North Central Region, with 7,628 km^2 (2,934 mi^2) covering crystalline rock bodies. This constitutes approximately 9% of the total region and approximately 10% of the area underlain by crystalline rock bodies within the region.

3.1.1.2 Disqualifying Factors Screen - Northeastern Region

In the Northeastern Region (see Plates NE-2A and NE-2B), the largest disqualified Federal-protected lands are wilderness areas in New Hampshire and Vermont, Acadia National Park in coastal Maine, Cape Cod National Seashore in Massachusetts, Delaware Water Gap National Recreation Area in Pennsylvania, and Allagash Wilderness Waterway in northern Maine. The most prominent disqualified State-protected lands are Adirondack State Park in New York and Baxter State Park in Maine. All other disqualified parks, rivers, wilderness areas, and wildlife lands are small areas and are scattered across the region. There are nearly 50 deep mines and quarries in the region and most occur in New Jersey, Connecticut, New York, and Pennsylvania. Highly populated areas and areas with 1,000 or more persons per square mile are concentrated near the coast, with the greatest concentrations occurring in the vicinity of Boston, New York, and Philadelphia.

Table 3-2 summarizes for each disqualifying factor the total area and percentage of area within the region covered by disqualifying factor as reflected in the regional data base, and the extent (areal and percentage) to which crystalline rock bodies are covered by disqualifying

Table 3-1. Summary of Disqualifying Factors Screen - North Central Region

Disqualifying Factors	Areal Extent km² (mi²) of Disqualifiers in Region		Disqualifiers as Percentage of Region	Areal Extent km² (mi²) of Disqualifiers Over Crystalline Rock Bodies		Disqualifiers as Percentage of Crystalline Rock Bodies
Deep Mines and Quarries	2,374	(913)	0.58	585	(222)	0.76
Highly Populated Areas/ Areas with Population Greater than 1,000 Persons per Square Mile	11,210	(4,310)	2.74	806	(310)	1.06
Federal-Protected Lands	12,570	(4,833)	3.07	4,394	(1,695)	5.80
State-Protected Lands	13,260	(5,099)	3.24	1,924	(740)	2.53
Total Areal Extent* or Percentage	36,426	(14,010)	8.89	7,628	(2,934)	10.03

* Disqualifier areas are not additive due to overlaps within and across categories. Therefore, the "Total Areal Extent or Percentage" row reflects the actual land area disqualified and may be less than the sum of the previous rows.

Table 3-2. Summary of Disqualifying Factors Screen - Northeastern Region

Disqualifying Factor	Areal Extent km^2 (mi^2) of Disqualifiers in Region		Disqualifiers as Percentage of Region	Areal Extent km^2 (mi^2) of Disqualifiers Over Crystalline Rock Bodies		Disqualifiers as Percentage of Crystalline Rock Bodies
Deep Mines and Quarries	715	(275)	0.29	309	(119)	0.48
Highly Populated Areas/ Areas with Population Greater than 1,000 Persons per Square Mile	20,972	(8,066)	8.37	4,147	(1,595)	6.38
Federal-Protected Lands	1,907	(732)	0.76	695	(267)	1.06
State-Protected Lands	32,397	(12,461)	12.94	19,638	(7,551)	30.17
Total Areal Extent* or Percentage	54,600	(21,001)	21.81	24,440	(9,401)	37.57

* Disqualifier areas are not additive due to overlaps within and across categories. Therefore, the "Total Areal Extent or Percentage" row reflects the actual land area disqualified and may be less than the sum of the previous rows.

and areas with population densities of 1,000 or more persons per square mile. A total of 54,600 km^2 (21,000 mi^2) are disqualified within the Northeastern Region, with 24,440 km^2 (9,400 mi^2) covering crystalline rock bodies. This constitutes approximately 22% of the total region and approximately 38% of the area underlain by crystalline rock bodies within the region.

3.1.1.3 Disqualifying Factors Screen - Southeastern Region

For the Southeastern Region (see Plates SE-2A and SE-2B), the largest disqualified Federal-protected lands are wilderness areas in western Virginia, the Carolinas, and in north Georgia, Shenandoah and Great Smoky Mountains National Parks, the Blue Ridge Parkway, and a scattering of other components of the National Park and National Wildlife Refuge Systems. Disqualified State-protected lands include a broad scattering of parks and a much smaller number of wild and scenic rivers, wildlife lands, and wilderness (natural) areas. There are at least 25 deep mines and quarries identified in the region. Highly populated areas and areas with population densities of 1,000 or more persons per square mile are scattered throughout the region, but are most concentrated in central Maryland, the Atlanta metropolitan area, and the Piedmont portion of the Carolinas.

Table 3-3 summarizes for each disqualifying factor the total area and percentage of area within the region covered by disqualifying factors as reflected in the regional data base, and the extent (areal and percentage) to which crystalline rock bodies are covered by disqualifying factors. The disqualifying factors most significant in terms of geographic extent are Federal-protected lands and highly populated areas and areas with 1,000 or more persons per square mile. A total of 26,190 km^2 (10,073 mi^2) are disqualified within the Southeastern Region, with 3,279 km^2 (1,[illegible] mi^2) covering crystalline rock bodies.

Table 3-3. Summary of Disqualifying Factors Screen - Southeastern Region

Disqualifying Factors	Areal Extent km^2 (mi^2) of Disqualifiers in Region		Disqualifiers as Percentage of Region	Areal Extent km^2 (mi^2) of Disqualifiers Over Crystalline Rock Bodies		Disqualifiers as Percentage of Crystalline Rock Bodies
Deep Mines and Quarries	564	(217)	0.19	164	(63)	0.30
Highly Populated Areas/ Areas with Population Greater than 1,000 Persons per Square Mile	16,973	(6,529)	5.70	2,010	(773)	3.71
Federal-Protected Lands	5,647	(2,172)	1.89	785	(302)	1.45
State-Protected Lands	4,592	(1,766)	1.54	515	(198)	0.95
Total Areal Extent* or Percentage	26,190	(10,073)	8.80	3,279	(1,261)	6.05

* Disqualifier areas are not additive due to overlaps within and across categories. Therefore, the "Total Areal Extent or Percentage" row reflects the actual land area disqualified and may be less than the sum of the previous rows.

This constitutes appro[illegible] of the total region and approximately 6% of the area [illegible] crystalline rock bodies within the region.

3.1.1.4 Disqualifying Factors Screen - Summary

As a result of applying Step 1 of the region-to-area screening methodology to all three regions, approximately 35,350 km^2 (13,600 mi^2) of area underlain by crystalline rock bodies is disqualified from further consideration as the location for a repository restricted area or for support facilities. The area constitutes approximately 18% of the total area underlain by crystalline rock bodies across the three regions. In addition, of this total, approximately 1,050 km^2 (405 mi^2) of area underlain by crystalline rock bodies is also disqualified from further consideration (due to the presence of deep mines or quarries) as the location for the controlled area, and repository surface and subsurface facilities.

3.1.2 Step 2 - The Scaled Regional Variables Screen

This section discusses the results of Step 2 of the region-to-area screening methodology in terms of development of composite favorability maps, and presents equally weighted composite favorability maps. Step 2 is applied to only those areas that remain after application of Step 1. In terms of land mass underlain by crystalline rock bodies, Step 2 is applied to 159,200 km^2 (61,520 mi^2) across the three regions of which 68,430 km^2 (26,320 mi^2) is in the North Central Region, 40,660 km^2 (15,620 mi^2) is in the Northeastern Region, and 50,910 km^2 (19,580 mi^2) is in the Southeastern Region.

For a description of the screening methodology, refer to Appendix A and the Screening Methodology Document (DOE, 1985b).

3.1.2.1 Results of Step 2

The objective of Step 2 is the application of various weights to variable scale values to determine the overall or aggregate favorability of each grid cell (see Appendix A). Aggregate favorability is calculated for each grid cell overlying crystalline rock bodies by arithmetically averaging the product of each of the 16 Step 2 variables and the associated weights. In mathematical form, the aggregate favorability score for each grid cell is equivalent to:

$$\frac{1}{1,000} \sum_{i=1}^{n} W_i \cdot S_i$$

where:

n = number of variables

$\sum_{i=1}^{n}$ = summation over n items

W_i = weight of variable i

S_i = scale value for variable i

1,000 = total weighting points allocated*

Each composite favorability map depicts the aggregate favorability of all grid cells remaining after Step 1 in the three regions for a given set of weights. The more favorable areas on each composite favorability map will be those with the higher aggregate favorability scores. The higher scores are an indication of generally more favorable variable scale values in conjunction with relatively high weights for those variables. Alternatively, higher aggregate favorability scores may also be an indication of fewer less favorable variable scale values in conjunction with relatively low weights for those variables.

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* For grid cells not overlying crystalline rock bodies, the rock mass extent variable does not apply. Therefore, there is no entry in the numerator for this variable and the weighting points associated with this variable are subtracted from the denominator.

The more favora[illegible]fined by each weight set and as depicted on the composite favorability map(s) for Phase A* are listed in Table 3-4a and b.** The areas are designated by regional abbreviation and then by number (or in some instances by a letter/number identifier). Development of the information reflected in this table occurred over a period of time including several iterations. Thus, although intended to be sequential, the numbering system ended up with some gaps and with some additions (e.g., NC-A5).

The aggregate favorability score at which each area occurs on the composite favorability maps is shown adjacent to each area. The aggregate favorability score at which the twentieth area appears is also shown at the bottom of Table 3-4a and b and is referred to as the benchmark. Additional information on composite favorability maps, how the benchmark is derived, and how the composite favorability maps are used in the development of summary composite maps is described in Section 3.1.3.1.

3.1.2.2 Equally Weighted Composite Favorability Maps

A composite favorability map for which all variables are weighted the same is termed an equally weighted composite favorability map. The majority of States requested that such maps be developed as part of the area recommendation report documentation and decision process; therefore, these maps have been included in Volume 2.

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* Phase A is the application of the nine sets of weights to the 16 Step 2 variables using original scales per the SMD (DOE, 1985b). The nine sets of weights applicable to this Phase are shown on Tables 2-2 and 2-6 (see Section 2.3.1).

** Each of the composite favorability maps displaying the areas listed on Tables 3-4a and b are available from DOE and will be provided upon request. These maps will display the aggregate favorability scores of grid cells within each one of the areas listed in Tables 3-4a and b.

Table 3-4a. [illegible] Areas as Defined by Each CRP [illegible] Subgroup - Phase A

1	2	3	4	5
NC-3/4.9*	NC-3/4.7	NC-3/4.7	SE-3/4.6	NC-3/4.5
SE-3/4.9	NC-4/4.6	NC-4/4.7	NC-3/4.5	NC-4/4.5
NC-9/4.8	NC-12/4.6	NC-6/4.7	NC-4/4.5	NE-N5/4.5
NC-12/4.8	NE-4/4.6	SE-3/4.7	NC-6/4.5	SE-3/4.5
SE-2/4.8	SE-2/4.6	NC-2/4.6	SE-2/4.5	NC-2/4.4
NE-4/4.8	SE-3/4.6	NC-7/4.6	SE-5/4.5	NC-6/4.4
NC-2/4.6	NC-2/4.5	NC-10/4.6	NC-10/4.4	NC-10/4.4
NC-4/4.6	NC-6/4.5	NC-12/4.6	NE-N5/4.4	NE-4/4.4
NC-6/4.6	NC-9/4.5	NE-4/4.6	NE-4/4.4	SE-2/4.4
NC-10/4.6	NC-10/4.5	SE-2/4.5	SE-7/4.4	NE-2/4.3
NE-2/4.6	SE-5/4.5	SE-4/4.5	NC-2/4.3	SE-4/4.3
NE-3/4.6	SE-4/4.4	SE-5/4.5	NC-7/4.3	SE-5/4.3
SE-4/4.6	NC-7/4.3	NC-9/4.5	NC-14/4.3	SE-7/4.3
SE-5/4.6	NC-A2/4.3	NC-14/4.5	NC-A1/4.3	NC-7/4.2
NE-1/4.5	NE-N5/4.3	NE-N5/4.5	NE-5/4.3	NC-9/4.2
NC-7/4.4	NE-2/4.3	SE-7/4.5	SE-1/4.3	NC-14/4.2
NC-14/4.4	NE-3/4.3	NC-11/4.4	SE-S29/4.3	NE-1/4.2
NC-A2/4.4	NE-5/4.3	NC-A5/4.4	SE-4/4.2	NE-3/4.2
SE-7/4.4	SE-7/4.3	NE-2/4.4	SE-6/4.2	NE-5/4.2
NC-11/4.3	NC-11/4.2	NE-3/4.4	NC-12/4.2	SE-1/4.2
NC-A5/4.3	NC-14/4.2	NE-5/4.4	NE-1/4.2	SE-6/4.2
NC-A8/4.3	NE-1/4.2	NE-N10/4.4	NE-2/4.2	
NC-A11/4.3	SE-6/4.2	SE-6/4.4	SE-S4/4.2	
NE-N5/4.3	NC-A5/4.2	SE-S19/4.4	SE-11/4.2	
NE-5/4.3		SE-S29/4.4	SE-B/4.2	
NE-N6/4.3			SE-S31/4.2	
NE-N14/4.3				
SE-S11/4.3				
SE-6/4.3				
Benchmark**				
4.3	4.2	4.4	4.2	4.2

* NC - North Central Region; 3/ Area number; 4.9 Aggregate favorability score at which area appears on composite favorability map

** Benchmark is defined as the aggregate favorability score that yields the twentieth area for each subgroup.

Table 3-4. [illegible] Favorable Areas as Defined by Each State Weighting Subgroup - Phase A

1	2	3	4
NC-3/3.9*	NC-3/4.7	NE-N5/4.4	SE-3/4.5
NC-4/3.9	SE-3/4.7	NC-3/4.1	NC-6/4.4
NC-10/3.9	NC-4/4.6	SE-2/4.1	NC-10/4.4
NC-A2/3.9	NC-6/4.6	SE-3/4.1	NE-N5/4.4
NC-A3/3.9	NC-10/4.6	NC-13/4.1	SE-2/4.4
NE-N5/3.9	NC-2/4.5	NC-4/4.0	SE-5/4.4
NC-5/3.8	NC-12/4.5	NC-6/4.0	SE-7/4.4
SE-3/3.7	NE-4/4.5	NC-7/4.0	NC-3/4.3
NC-2/3.6	SE-2/4.5	NC-10/4.0	NC-7/4.3
NC-9/3.6	SE-4/4.5	SE-7/4.0	NC-A1/4.3
NC-12/3.6	NC-9/4.4	SE-S10/4.0	NC-14/4.3
NC-A6/3.6	NC-A2/4.4	NC-5/3.9	NE-4/4.3
NE-4/3.6	NC-A7/4.4	NC-12/3.9	SE-1/4.3
SE-5/3.6	SE-5/4.3	NC-14/3.9	SE-S31/4.3
NC-A4/3.5	NC-11/4.3	NC-A1/3.9	NC-4/4.2
NC-13/3.5	NC-14/4.3	NC-A9/3.9	SE-B/4.2
NC-A7/3.5	NC-A8/4.2	SE-5/3.9	SE-A/4.2
SE-2/3.5	NC-13/4.2	NE-1/3.9	SE-6/4.2
NC-A12/3.5	NC-A5/4.2	NE-4/3.9	SE-S29/4.2
NC-6/3.3	NC-7/4.2	NE-5/3.9	SE-S1/4.2
NC-A11/3.3	NE-2/4.2	SE-A/3.9	SE-S4/4.2
NE-5/3.3	NE-3/4.2	SE-S20/3.9	SE-4/4.2
NC-7/3.3	SE-B/4.2	SE-S31/3.9	
NC-A13/3.3	SE-7/4.2		
SE-7/3.3	NC-A3/4.2		
	NC-A6/4.2		
	NC-A11/4.2		
Benchmark**			
3.3	4.2	3.9	4.2

* NC -	3/	3.9
North Central Region	Area number	Aggregate favorability score at which area appears on composite favorability map

** Benchmark is defined as the aggregate favorability score that yields the twentieth area for each subgroup.

It is important to note, however, that the region-to-area screening methodology was developed on the basis of screening variables not necessarily being considered equal. The purpose of soliciting sets of weights was to derive and incorporate various views on the relative importance of the variables.

The North Central equally weighted composite favorability maps are shown as Plates NC-3A and NC-3B. The Northeastern and Southeastern equally weighted composite favorability maps are shown as Plates NE-3A and NE-3B and SE-3A and SE-3B, respectively. These equally weighted composite favorability maps display the aggregate favorability scores for the 16 Step 2 variables with original scales.

The aggregate favorability scores for each grid cell on the equally weighted composite favorability maps overlying crystalline rock are determined by simply averaging the 16 individual Step 2 variable scale values, or in mathematical form:

$$\frac{1}{n} \sum_{i=1}^{n} S_i$$

where:

n = number of variables or 16

$\sum_{i=1}^{n}$ = summation over n items

S_i = scale value for variable i

The aggregate favorability scores on each of the maps is displayed for the following ranges (in shades of brown and orange): 1.0 to <3.0, 3.0 to <3.5, 3.5 to <4.0, 4.0 to <4.5, and 4.5 to 5.0. The aggregate favorability scores are only depicted for those areas underlain by crystalline rock to highlight the focus of the region-to-area screening process. [illegible]line rock areas are shown in dark gray. Environmental disqualifying factors (Federal-protected lands, State-protected lands, components of national forest lands, highly populated areas, and areas with population density equal to or greater than 1,000 persons per square mile) are shown in blue and the geologic disqualifying factor (deep mines and quarries) is shown in red.

There are no areas underlain by crystalline rock bodies within any of the three regions that have aggregate favorability scores of 5.0 (the highest score possible). If there were such areas, the application of weights would not change or affect the aggregate favorability of such areas because the weighted average of each grid cell or area would remain 5.0. Therefore, the aggregate favorability of grid cells is affected by the incorporation of weights and, as a result, the application of weights is a necessary step in the determination of more favorable areas.
To evaluate the effect of the application of differential weights on the selection of preliminary candidate areas, the more favorable areas as defined by the equally weighted composite favorability maps can be compared with the more favorable areas as depicted on the composite favorability maps that are developed from weight sets. This comparison indicates that areas which show most favorably on the (weighted) composite favorability maps also are among most favorable on the equally weighted composite favorability map. However, there is a much lower degree of discrimination with the equally weighted case; that is, there are more and larger expanses of highly rated areas on the equally weighted composite favorability map than on the composite favorability maps derived from weight sets. This merely reflects the different emphasis given to different screening variables by certain subgroups.

Specifically, in the North Central Region, grid cell counts indicate that 7% of all grid cells (underlain by crystalline rock bodies) on the equally weighted composite map score 4.5 or higher, while a cumultive total of 52% score 4.[illegible] or higher. In comparison, the percentage of grid cells (underlain by crystalline rock bodies) whose aggregate favorability scores equal or exceed the nine benchmarks associated with the Phase A composite favorability map(s) (see Tables 3-4a and b) range from approximately 12 to 27%. In the Northeastern Region, 1% of all grid cells (underlain by crystalline rock bodies) on the equally weighted composite map score 4.5 or higher, with a cumulative total of 29% scoring 4.0 or higher. In comparison, the percentage of grid cells (underlain by crystalline rock bodies) whose aggregate favorability scores equal or exceed the nine benchmarks associated with the Phase A composite favorability map(s) ranges from 4 to 10%. In the Southeastern Region, 8% of all grid cells (underlain by crystalline rock bodies) on the equally weighted composite map score 4.5 or higher, with a cumulative total of 67% scoring 4.0 or higher. In comparison, the percentage of grid cells (underlain by crystalline rock bodies) whose aggregate favorability scores equal or exceed the nine benchmarks associated with Phase A composite favorability map(s) ranges from 9 to 27%. This information indicates that the aggregate favorability scores associated with the equally weighted composite maps is skewed to the higher end of the favorability scale when compared with the Phase A composite favorability maps. As a result, the equally weighted composite map does not contradict the Phase A results because it conservatively encompasses the more favorable areas identified by each weight set in Phase A.

3.1.3 Step 3 - Sensitivity Analysis

This section discusses the results of Step 3 of the region-to-area screening methodology in terms of describing (1) development of summary composite maps; (2) impact of modifying the scales of three Step 2 variables; and (3) impact of the addition of four geology screening variables.*

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* It should be noted that this sequence is slightly different than described in Section 2.3 and Appendix A. However, it is believed that the sequence noted above will make for a clearer presentation of information and discussion of results.

The results of Step 3 are also defined in terms of four phases. Phase A is defined as the 16 Step 2 screening variables with original scales. Phase B is defined as 13 Step 2 screening variables with original scales plus three Step 2 variables (proximity to highly populated areas, seismicity, rock mass extent) with modified scales. Phase C is defined as the 16 Step 2 regional screening variables with original scales plus four additional geology screen variables (depth of overburden, thickness of rock mass, ground water resources, state-of-stress). Phase D is defined as 13 Step 2 screening variables with original scales, plus three Step 2 variables with modified scales, plus four additional geology variables.

Comparison of Phases A and B will enable determination of the effect of modifying scales on the more favorable areas (comparison of Phases C and D will also enable such a determination, although such a comparison is not presented). Comparison of Phases A and C or comparison of Phases B and D will enable determination of the effect of the additional geology variables on the more favorable areas. Phases A through D are used as the framework for presenting the results of Step 3.

An evaluation of the effects of using the geometric mean as an alternate index of aggregate favorability for deriving composite favorability maps is also spelled out in the SMD as part of Step 3 - Sensitivity Analyses. This evaluation is presented in Appendix B.

Similar to Step 2, Step 3 is only applied to those areas that remain after application of Step 1.

3.1.3.1 Development of Summary Composite Maps and Presentation of Phase A Results

As described in Section 2.3, one objective of Step 3 of the region-to-area screening methodology is to integrate the results of Step 2 (in the form of summary composite maps). The type of summary composite map selected for use [illegible] called the frequency of occurrence-best candidate area summary composite map. It should be noted that DOE considered other methods of developing summary composite maps. These alternatives are called the frequency of occurrence-standard cut point summary composite, the frequency of occurrence-percentile summary composite, and the standard cut point-pure coincidence summary composite. The alternative selected for use more effectively and equitably captures the variety of views expressed in the 9 weight sets than the other alternatives. These latter alternatives are discussed in Appendix C.

The selected summary composite maps display the number of times out of nine (nine being the total number of weighting subgroups) that a given grid cell is rated as one of the most favorable cells, as defined by the nine sets of weights. In selecting this type of summary composite, the DOE has made a programmatic decision to use all nine sets of weights in the selection of preliminary candidate areas in order to capture the widest range of viewpoints.

To develop a frequency of occurrence-best candidate area summary composite, the information on the individual composite favorability maps is used as follows:

1. For each of the nine weight sets, the more favorable areas are identified by lowering the aggregate favorability score on each of the nine composite favorability maps in 0.1 increments from 5.0 until at least 20 areas appeared*. Each area had to be able to contain at least one nominal circle of 11 km (7 mi) in diameter (which is equivalent to an area of 100 km^2 (39 mi^2).** No deep mines or quarries could exist within the

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* The number 20 was specified in the SMD (DOE, 1985b) as the upper bound of the estimated range of the number of preliminary candidate areas (i.e., 15 to 20) that would be identified as a result of applying Steps 1 through 3 of the region-to-area screening methodology.

** The 100 km^2 (39 mi^2) size is equivalent to the area requirement on crystalline rock bodies to be considered for regional phase evaluations (OCRD, 1983) and is consistent with the U.S. Environmental Protection Agency (EPA) requirement for the maximum size of a controlled area.

circle [illegible] number of either environmental disqualifying factors or grid [illegible]s or lower aggregate favorability scores could appear within the circle. The decision not to allow deep mines or quarries within an area but to permit a limited number of environmental disqualifying factors is consistent with the DOE Siting Guidelines. The guideline associated with deep mines and quarries, 960.4-2-8-1(d)(1), prohibits the siting of the repository underground facilities, surface facilities, restricted area, controlled area, or any support facilities where such features are present. The guidelines associated with environmental disqualifying factors, 960.5-2-1(d)(1), (d)(2), 960.5-2-5(d)(2), (d)(3), prohibit the siting of the repository surface facilities, the restricted area or any support facilities where such disqualifying factor are present. However, such surface disqualifying factors could be present in the repository controlled area.

2. The number of areas identified on a specific composite favorability map could exceed 20 if the aggregate favorability score at which the twentieth area appears yielded additional areas. The aggregate favorability score that yields the twentieth area on each composite favorability map is termed the benchmark. The output of these steps is the identification of the more favorable areas as defined by each weight set (see Table 3-4a and b). The areas are designated by regional abbreviation and then by number (or in some instances by a letter/number identifier). The aggregate favorability score at which each area emerges is also noted. It should be noted that the appearance of an identified area for more than one subgroup does not imply geographic coincidence of the areas. However, it does indicate that the area is contained within the same

crystalline rock bo[illegible] for larger crystalline rock bodies that it is in the same general vicinity.*

3. Every grid cell (that remained after the Disqualifying Factors Screen - Step 1) was then examined to determine the number of times (out of nine) that the cell appears as one of the more favorable grid cells, as defined by each of the nine weight sets. This is accomplished by comparing the aggregate favorability score (of each grid cell) with the benchmark associated with each of the nine weight sets. When this examination is completed, the resulting information is displayed on a summary composite map as frequency of occurrence; with, for example, an 8 for a grid cell indicating that for 8 out of 9 weight sets the grid cell's aggregate favorability score equaled or exceeded the benchmark (associated with the eight weight sets).

The frequency of occurrence-best candidate area summary composite maps for Phase A are shown on Plates NC-4A and NC-4B for the North Central Region, Plates NE-4A and NE-4B for the Northeastern Region, and Plates SE-4A and SE-4B for the Southeastern Region. The information on these plates is derived from the 16 Step 2 screening variables and the nine sets of weights developed at the weighting workshops for this phase (see Table 2-2 and 2-6). Phase A is discussed first because it represents a logical base of comparison for evaluating the influence of scale modification and the addition of screening variables. The frequency of occurrence information on these plates is displayed only for areas underlain by crystalline rock to highlight the focus of the

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* Each of the composite favorability maps displaying the areas listed on Tables 3-4a and b are available from DOE and will be provided upon request. These maps will display the aggregate favorability scores of grid cells within each one of the areas listed in Tables 3-4a and b.

region-to-area sc[illegible]. Frequency of occurrence is displayed (in shades of brown and gr[illegible], at levels of 9 out of 9, 8 out of 9, 7 out of 9, 6 out of 9, and 0 to 5 out of 9 (meaning that these lower frequency levels were merged to simplify the display). Noncrystalline rock areas are displayed on the maps in dark gray, the geologic disqualifying factor is shown in red, and the environmental disqualifying factors are shown in blue.

The more favorable preliminary candidate areas identified in the Phase A frequency of occurrence-best candidate areas summary composite are summarized in Table 3-5. Each of the areas designated in this table is large enough to contain a nominal 11-km (7-mi) diameter circle. The circle may not contain any deep mines and quarries, although it may contain a minimal number of environmental disqualifying factors or grid cells of lower frequencies of occurrence (if any). The preliminary candidate areas in this table are designated first by regional abbreviation and then by number (or, in some instances, by letter and number). For reference, the name of the crystalline rock body within which each preliminary candidate area is located is also noted.

The reader is cautioned regarding comparisons between Table 3-4a and 3-4b and Table 3-5. The primary purpose of presenting Table 3-4a and 3-4b is to depict the aggregate favorability scores (or benchmarks) at which, for each of the nine weight sets, approximately 20 more favorable areas would appear on the composite favorability maps. Table 3-5 is a display of those areas for which aggregate favorability scores on the composite favorability maps exceed the associated benchmarks for at least 6 out of the 9 weight sets.

Specifically, there are certain areas that appear more frequently in Table 3-4a and b than in Table 3-5. This is principally because the areas in Table 3-5 require geographic coincidence of grid cells (with the required spatial characteristics described earlier) for the area to be designated at a specific frequency of occurrence. The areas designated

Table 3-5. List of More Favorable Areas as Defined by Phase A Summary Composite

Frequency of Occurrence	Area	Rock Body
9 out of 9	NC-3	Wolf River Batholith
	NC-4	Wolf River Batholith
	NC-6	Undifferentiated Granites
	NC-7	Undifferentiated Granites
	NC-10	Archean Gneisses/Central Minnesota Granites
	NE-4	Sebago Lake Batholith
	NE-N5	Chain Lakes Massif
	SE-2	Lovingston Massif
	SE-3	Virgilina Gneiss
	SE-5	Elk River Complex
	SE-7	Woodland Gneiss Complex
8 out of 9	NE-5	Cardigan Pluton
7 out of 9	NC-2	Puritan Batholith
	NC-9	Undifferentiated Granites
	NC-12	Archean Gneisses
	NC-13	Archean Gneisses
	NC-14	Archean Gneisses
	NC-A5	Undifferentiated Granites
	NE-2	Bottle Lake Complex
	SE-1	Fredericksburg Complex
	SE-4	Rolesville Pluton
	SE-6	Lithonia Gneiss
6 out of 9	NC-A10	Sacred Heart and Ortonvilie Granites
	NE-1	Katahdin Complex
	NE-3	Deblois Complex

in Table 3-4a and b (by more than one weight set) are located within the same crystalline rock body and for larger crystalline rock bodies within the same general vicinity. However, they are not necessarily geographically coincident.

There are also certain areas that appear less frequently in Table 3-4a and b than in Table 3-5. This results principally for two reasons. First, Table 3-5 is generated from an inspection of all individual grid cells and comparison of the aggregate favorability score (as defined by each weight set) with the associated benchmark. Inspection of all grid cells is appropriate because the objective of the analysis is to determine which areas (or clusters of grid cells) are consistently identified as more favorable by the weight sets. Therefore, grid cells that are not contained within the areas designated in Tables 3-4a and b but have aggregate favorability scores that are greater than or equal to the benchmark(s) contribute to the frequency of occurrence score on the summary composite map. Second, the overall frequency of occurrence score for an area (e.g., 7 out of 9) does not imply that the same weight sets were used in the identification of the area. That is, two adjoining grid cells could receive a similar frequency of occurrence scorce (e.g., 7 out of 9) although the composition of the seven weight groups for which the aggregate favorability score exceeded the benchmark could be different for the two grid cells.

3.1.3.2 Scale Modification Analysis - Phase B

To evaluate the effect of scale modification on the identification of preliminary candidate areas, modified scales for three Step 2 screening variables (seismicity, rock mass extent, and proximity to highly populated areas or to 1-square-mile areas with 1,000 or more persons) (see Appendix A) were examined as part of Step 3 of the region-to-area screening methodology. These three variables were selected for scale modification based on State comments and input from DOE staff. The three variables (with modified scales) were considered in conjunction with the other 13 Step 2 screening variables (and their original scales) and the nine sets of weight... ... at the weighting workshops (see Tables 2-3 and 2-7) for use with these modified scales. This evaluation is termed Phase B.

As with Phase A, a frequency of occurrence-best candidate area summary composite map was prepared for Phase B and is shown on Plates NC-5A and NC-5B for the North Central Region, Plates NE-5A and NE-5B for the Northeastern Region, and Plates SE-5A and SE-5B for the Southeastern Region. The process used to prepare this summary composite is as described in Section 3.1.3.1. The only modification is that the benchmarks established for each of the nine subgroups in Phase A were reapplied in Phase B rather than being derived separately from the individual composite favorability maps for Phase B. Because the modified scales used as part of Phase B are generally less penalizing than Phase A, the aggregate favorability scores of grid cells under Phase B would be somewhat higher than Phase A. Therefore, application of the Phase A benchmarks to Phase B would not inappropriately restrict consideration of areas as part of Phase B.

Frequency of occurrence information on the Phase B plates is displayed at identical levels (using identical colors) to the display shown on the Phase A summary composite. Noncrystalline rock areas are shown in dark gray. The geologic disqualifier is shown in red and the environmental disqualifying factors are shown in blue.

The more favorable preliminary candidate areas identified in the Phase B frequency of occurrence summary composite are summarized in Table 3-6. The areas in this table are designated first by regional abbreviation and then by number (or in some instances by letter and number). For reference, the name of the crystalline rock body within which each preliminary candidate area is located also is noted.

Comparison of the Tables 3-5 and 3-6 and the supporting plates demonstrate that preliminary candidate areas occurring at a frequency of

Table 3-6. List of more [illegible] Areas as Defined by Phase B Summary Composite

Frequency of Occurrence	Area	Rock Body
9 out of 9	NC-2	Puritan Batholith
	NC-3	Wolf River Batholith
	NC-4	Wolf River Batholith
	NC-6	Undifferentiated Granites
	NC-7	Undifferentiated Granites
	NC-10	Archean Gneisses/Central Minnesota Granites
	NC-13	Archean Gneisses
	NC-14	Archean Gneisses
	NC-A5	Undifferentiated Granites
	NC-A10	Sacred Heart and Ortonville Granites
	NE-1	Katadin Complex
	NE-4	Sebago Lake Batholith
	NE-5	Cardigan Pluton
	NE-N5	Chain Lakes Massif
	SE-2	Lovingston Massif
	SE-3	Virgilina Gneiss
	SE-4	Rolesville Pluton
	SE-5	Elk River Complex
	SE-6	Lithonia Complex
	SE-7	Woodland Gneiss Complex
8 out of 9	NC-1	Southern Complex
	NC-9	Undifferentiated Granites
	NC-12	Archean Gneisses
	NC-A2	Duluth Gabbro
	NE-2	Bottle Lake Complex
	NE-3	Deblois Complex
	NE-N14	Green Mountain Massif
7 out of 9	NC-11	Archean Gneisses
	NC-A1	Central Wisconsin Intrusive Rocks
	NC-A8	Undifferentiated Granites
	SE-1	Fredricksburg Complex
6 out of 9	NC-5	Undifferentiated Granites
	NE-N6	Rome West Pluton and Rome Pluton
	SE-B	Castalia
	SE-S31	Winnsboro

occurrence level of [illegible] 9 or above on the Phase A map show up at either the same frequency of occurrence [illegible] at a higher frequency on the Phase B map. Specifically, NC-3, -4, -6, -7, and -10; NE-4 and -N5; and SE-2, -3, -5, and -7 appear at a 9 out of 9 frequency on both the Phase A and B summary composites. One area, NE-5 occurs at an 8 out of 9 frequency on Phase A and a 9 out of 9 frequency on Phase B. Six of the areas that occur at a 7 out of 9 frequency on Phase A occur at a 9 out of 9 frequency on Phase B (i.e., NC-2, -13, -14, -A5, SE-4, -6). Three areas (NC-9, NC-12, NE-2) occur at a 7 out of 9 frequency on Phase A and occur at an 8 out of 9 frequency on Phase B. One area (SE-1) occurs at a 7 out of 9 frequency on both the Phase A and B summary composites.

There are other areas that appear at a frequency of occurrence level of 7 out of 9 or above on the Phase B map. These are NC-A10 and NE-1 at a 9 out of 9 frequency; NC-1, NC-A2, NE-3, and NE-N14 at an 8 out of 9 frequency; and NC-11, NC-A1, and NC-A8 at a 7 out of 9 frequency. Three of these areas (NC-A10, NE-1, and NE-3) occur at a 6 out of 9 frequency on the Phase A maps, however, the remainder of the areas occur at lower frequency levels on Phase A.

The DOE believes these results demonstrate that the more favorable preliminary candidate areas identified on the Phase A summary composite map remain as the more favorable preliminary candidate areas as defined by the Phase B summary composite map. That is, the relative favorability of these areas is not affected by scale modification other than the frequency of occurrence is generally higher for these areas in Phase B than in Phase A. This results from the fact that for two of the three variables for which scales were modified (rock mass extent and proximity to highly populated areas), the modified scales are less restrictive in Phase B than the original scales and, therefore, the aggregate favorability scores of grid cells (in Phase B) would generally increase. In addition, the areas as defined by Phase B are generally larger than the areas as defined at Phase A (at the same frequency of occurrence).

3.1.3.3 Additional Variable Analysis - Phases C and D

To evaluate the effec[illegible] additional variables, for which only scattered data are available on the identification of the more favorable preliminary candidate areas, four Step 3 geologic variables (depth of overburden, thickness of rock mass, ground-water resources, and state-of-stress) were examined as part of Step 3 of the region-to-area screening methodology. The four variables were considered in conjunction with the 16 Step 2 screening variables (and their original scales) and the nine sets of weights developed at the weighting workshops (see Tables 2-4 and 2-8) for use with these additional variables. This evaluation is termed Phase C. The evaluation is termed Phase D when these additional Step 3 variables are utilized in conjunction with the Step 2 variables, three of which with modified scales, and the nine sets of weights developed at the weighting workshops for this phase (see Tables 2-5 and 2-9).

Similar to Phases A and B, steps were taken to develop a frequency of occurrence-best candidate area summary composite map. However, in the Southeastern Region essentially no information for these four variables exists in a form that can be directly translated into the scales (e.g., the range of ground-water resources data is not directly compatible with the scale values) and, in the Northeastern Region, the information that does exist either does not affect any of the most favorable preliminary candidate areas identified in Phase A or is not in a form compatible with the scales. As a consequence, the DOE evaluated the effect of the addition of the four Step 3 variables using both original (Phase C) and modified scales (Phase D) only in the North Central Region. To perform the Phase C evaluation, the more favorable preliminary candidate areas for the North Central Region as defined by Phase A were compared with the more favorable areas as defined by Phase C. Similar to Phase B, the benchmarks established for each of the nine weighting subgroups in Phase A were reapplied in Phase C rather than being derived separately from the individual composite favorability maps for Phase C. This was done for the same reason as for Phase B. The effect of the addition of the four Step 3 variables to the 16 Step 2 variables (original scales) on the more favorable preliminary candidate areas in the North Central Region is displayed in Table 3-7. For reference, the name of the crystalline rock body within which each preliminary candidate area is located is also noted.

Examination of the table generally indicates that North Central Region areas appearing at a frequency of occurrence level of 7 out of 9 or above on Phase A generally appear at the same or higher frequency of occurrence on Phase C. Specifically, NC-3, NC-4, NC-6, NC-7, and NC-10 (9 out of 9) appear at the same frequency level on Phases A and C as does NC-12 (7 out of 9). Three areas (NC-2, NC-9, and NC-13) occur at a higher frequency on Phase C than on Phase A (8 out of 9 versus 7 out of 9) because of more favorable scale values associated with the ground-water resources variable (i.e., 4 and 5) within these areas and more favorable scale value (i.e., 5) associated with the thickness of overburden variable within NC-2. Information on other Step 3 variables was not available for these three areas. Two areas (NC-14 and NC-A5) only occur on Phase A because of less favorable scale values associated with ground-water resources (i.e., generally 2) within NC-A5 and thickness of overburden (i.e., generally 1) within NC-14. Information on other Step 3 variables was not available for these two areas.

The DOE believes these results generally demonstrate that the more favorable areas identified in Phase A for the North Central Region also appear as the more favorable areas as defined by Phase C (North Central Region only). That is, the relative favorability of these areas is generally not affected by the addition of the four Step 3 variables when compared to other North Central Region areas.

Table 3-7. List of More Favorable Areas in North Central Region for Phases A and C

Frequency of Occurrence	Area	Rock Body	Area	Rock Body
		PHASE A		PHASE C
9 out of 9	NC-3	Wolf River Batholith	NC-3	Wolf River Batholith
	NC-4	Wolf River Batholith	NC-4	Wolf River Batholith
	NC-6	Undifferentiated Granites	NC-6	Undifferentiated Granites
	NC-7	Undifferentiated Granites	NC-7	Undifferentiated Granites
	NC-10	Archean Gneisses/Central Minnesota Granites	NC-10	Archean Gneisses/Central Minnesota Granites
8 out of 9			NC-2	Puritan Batholith
			NC-9	Undifferentiated Granites
			NC-13	Archean Gneisses
7 out of 9	NC-2	Puritan Batholith	NC-12	Archean Gneisses
	NC-9	Undifferentiated Granites		
	NC-12	Archean Gneisses		
	NC-13	Archean Gneisses		
	NC-14	Archean Gneisses		
	NC-A5	Undifferentiated Granites		
6 out of 9	NC-A10	Sacred Heart and Ortonville Granites	NC-A2	Duluth Gabbro
			NC-A7	Giants Range Batholith

The same analysis of the effect of the addition of four Step 3 variables on the more favorable areas was reexamined by comparing the more favorable areas as defined by Phase B versus the most favorable areas as defined by Phase D. The difference between Phases B and D, i.e., the addition of the four geologic Step 3 variables, is similar to the difference between Phases A and C. The effect of the addition of the four Step 3 variables to the 16 Step 2 variables, three of which with modified scales, on the more favorable areas is displayed in Table 3-8. For reference, the name of the crystalline rock body within which each preliminary candidate area is located is also noted.

Examination of this table generally indicates that North Central Region areas appearing at a frequency of occurrence level of 7 out of 9 or above on Phase B show up at either the same frequency of occurrence on Phase D or at a higher frequency. Specifically NC-2, -3, -4, -6, -7, -10, -13, and -14 occur at a 9 out of 9 frequency on Phase B and occur at the same frequency on Phase D. Three areas (NC-9, -12, -A2) occur at an 8 out of 9 frequency on Phase B and D and two areas (NC-11 and NC-A1) occur at a 7 out of 9 frequency on Phases B and D. Four areas occur at lower frequencies on Phase D than Phase B (i.e., NC-A5 at 9 out of 9 on Phase B and 8 out of 9 on Phase D, NC-A10 on 9 out of 9 on Phase B and 6 out of 9 on Phase D, NC-1 at 8 out of 9 on Phase B and 6 out of 9 on Phase D, and NC-A8 at 7 out of 9 on Phase B and 6 out of 9 on Phase D).

The area NC-A5 drops in frequency because of less favorable scale values associated with the ground-water resource variable (i.e., 2) and the thickness of overburden variable (i.e., 1). The area NC-A10 drops in frequency because scale values of 1 and 4 for the ground-water resources variable and scale values of 1 and 3 for the thickness of overburden variable predominate the area. The area NC-1 drops in frequency because a scale value of 2 for the ground-water resource variable predominates the area. The area NC-A8 drops in frequency because scale values of 2 and 4 for the ground-water resources variable predominates the area.

Table 3-8. List of More Favorable Areas in North Central Region for Phases B and D

Frequency of Occurrence	Area	Rock Body	Area	Rock Body
		PHASE B		PHASE D
9 out of 9	NC-2	Puritan Batholith	NC-2	Puritan Batholith
	NC-3	Wolf River Batholith	NC-3	Wolf River Batholith
	NC-4	Wolf River Batholith	NC-4	Wolf River Batholith
	NC-6	Undifferentiated Granites	NC-6	Undifferentiated Granites
	NC-7	Undifferentiated Granites	NC-7	Undifferentiated Granites
	NC-10	Archean Gneisses/Central Minnesota Granites	NC-10	Archean Gneisses/Central Minnesota Granites
	NC-13	Archean Gneisses	NC-13	Archean Gneisses
	NC-14	Archean Gneisses	NC-14	Archean Gneisses
	NC-A5	Undifferentiated Granites		
	NC-A10	Sacred Heart and Ortonville Granites		
8 out of 9	NC-1	Southern Complex	NC-9	Undifferentiated Granites
	NC-9	Undifferentiated Granite	NC-12	Archean Gneisses
	NC-12	Archean Gneisses	NC-A2	Duluth Gabbro
	NC-A2	Duluth Gabbro	NC-A5	Undifferentiated Granites
7 out of 9	NC-11	Archean Gneisses	NC-11	Archean Gneisses
	NC-A1	Central Wisconsin Intrusive Rock	NC-A1	Central Wisconsin Intrusive Rocks
	NC-A8	Undifferentiated Granites		

Information on other [illegible] was not available for these four areas.

Again, the DOE believes these results generally demonstrate that the more favorable areas identified in Phase B for the North Central Region also appear as the more favorable areas as defined by Phase D (North Central Region only). That is, the relative favorability of these areas is generally not affected by the addition of the four Step 3 variables when compared to other North Central Region areas.

Table 3-9 summarizes the more favorable areas for Phases A and B (for all three regions) and summarizes the more favorable areas for Phases C and D (for the North Central Region only). No summary composite maps were included in this draft area recommendation report depicting either the effect of the four Step 3 variables (Phase C) or the effect of the combination of the four Step 3 variables with the modification of the three Step 2 variable scales (Phase D) because the evaluations described above are applicable only in the North Central Region. However, copies of these maps are available for the North Central Region and will be provided upon request.

3.1.4. Identification of Preliminary Candidate Areas and Definition of Boundaries

The results described in Sections 3.1.3.1, 3.1.3.2, and 3.1.3.3 were used as the basis for identification of preliminary candidate areas. Tables 3-5 and 3-6, which depict the more favorable areas identified in the Phase A and B frequency of occurrence-best candidate areas summary composite maps, respectively, were reviewed as were the accompanying plates (i.e., NC-4A, -4B, -5A, -5B; and NE-4A, -4B, -5A, -5B; SE-4A, -4B, -5A, -5B). The SMD (DOE, 1985b) indicates that approximately 15 to 20 areas will be identified as a result of applying Steps 1 through 3 of the

Table 3-9. Summary of More Favorable Areas by Phase*

Frequency of Occurrence	Phase A	Phase B	Phase C	Phase D
9 out of 9	NC-3 NC-4 NC-6 NC-7 NC-10 NE-4 NE-N5 SE-2 SE-3 SE-5 SE-7	NC-2 NC-3 NC-4 NC-6 NC-7 NC-10 NC-13 NC-14 NC-A5 NC-A10 NE-1 NE-4 NE-5 NE-N5 SE-2 SE-3 SE-4 SE-5 SE-6 SE-7	NC-3 NC-4 NC-6 NC-7 NC-10	NC-2 NC-3 NC-4 NC-6 NC-7 NC-10 NC-13 NC-14
8 out of 9	NE-5	NC-1 NC-9 NC-12 NC-A2 NE-2 NE-3 NE-N14	NC-2 NC-9 NC-13	NC-9 NC-12 NC-A2 NC-A5
7 out of 9	NC-2 NC-9 NC-12 NC-13 NC-14 NC-A5 NE-2 SE-1 SE-4 SE-6	NC-11 NC-A1 NC-A8 SE-1	NC-12	NC-11 NC-A1

Table 3-9. Summary of More Favorable Areas by Phase*
Sheet 2 of 2

Frequency of Occurrence	Phase A	Phase B	Phase C	Phase D
6 out of 9	NC-A10 NE-1 NE-3	NC-5 NE-N6 SE-B SE-S31	NC-A2 NC-A7	NC-1 NC-5 NC-A3 NC-A8 NC-A10 NC-A11 NC-A12

* Phases C and D were only applied in the North Central Region.

region-to-area screening methodology. Using this as a guideline, the DOE determined that the 7 out of 9 frequency of occurrence for Phase A would establish what areas should be considered as preliminary candidate areas. Further, the DOE also determined that Phase B would be used to confirm the suitability of areas identified as more favorable in Phase A. Because analysis of the additional geologic variables (i.e., Phases C and D) was only conducted in the North Central Region, the results of Phases C and D were not used to identify the more favorable areas across the three regions. Therefore, the 22 areas that appear on the Phase A summary composite map at a frequency of 7 out of 9 or above and also appear at a frequency of occurrence of 7 out of 9 or above on the Phase B summary composite map are designated as preliminary candidate areas. These 22 preliminary candidate areas are contained in seven States as follows:

North Central Region	Northeastern Region	Southeastern Region
Minnesota - NC-6, NC-7, NC-9 NC-10, NC-12, NC-13, NC-14, NC-A5	New Hampshire - NE-5	Georgia - SE-6, SE-7
Wisconsin - NC-2, NC-3, NC-4	Maine - NE-2, NE-4, NE-N5	North Carolina - SE-4 SE-5
		Virginia SE-1, SE-2 SE-3.

The boundary for each of the 22 areas appearing on the Phase A summary composite map at frequency of occurrence of 7 out of 9 or greater is defined for each area by the geographic extent of grid cells that occur at the 7 out of 9 frequency level. Any grid cells designated as 7 out of 9 frequency (or greater) that are not contiguous with the 22 areas are not considered as part of the preliminary candidate areas except as described below. In addition to these general rules, a decision was made to include within a preliminary candidate area significant clusters of grid cells that occur at a 7 out of 9 frequency that are nominally 1.6 km (1 mi) from the preliminary candidate area boundary. A 1.6 km (1 mi) distance is used because in the process of digitizing data, features are checked to a $\pm$ 1 mile error tolerance (see Appendix D). The application of this decision is detailed below by preliminary candidate area. Finally, any grid cells within the 22 areas (as defined by the 7 out of 9 frequency on Phase A) that are of lower frequency (e.g., 6 out of 9) are considered part of the preliminary candidate area. The impact, if any, of such isolated lower frequency grid cells on the area will be considered during the area phase investigations.

3.1.4.1 NC-3 and NC-4

At a 7 out of 9 frequency of occurrence on the Phase A summary composite map, there are 14 grid cells of slightly lower frequency of occurrence (i.e., 13 grid cells with a frequency of 6 out of 9 and one cell with a frequency of 5 out of 9) wedged in between the southern boundary of NC-3 and the northern boundary of NC-4. These grid cells are associated with the [illegible] [illegible]ers between the two preliminary candidate areas. In most [illegible], the boundaries of NC-3 and NC-4 are only 1.6 km (1 mi) apart. Accordingly, DOE has decided that preliminary candidate areas NC-3 (702 km^2 [439 mi^2]) and NC-4 (1026 km^2 [641 mi^2]) should be merged into one area (called NC-3) and these 14 grid cells of slightly lower frequency are part of the preliminary candidate area. This decision reduces the number of preliminary candidate areas from 22 to 21.

3.1.4.2 NC-6

At a 7 out of 9 frequency of occurrence on the Phase A summary composite map, there are 11 grid cells of slightly lower frequency of occurrence (i.e., seven grid cells with a frequency of 6 out of 9, three grid cells with a frequency of 5 out of 9, and one grid cell with a frequency of 0 to 4 out of 9) and eight grid cells containing environmental disqualifying factors (state wildlife management area) between NC-6 (328 km^2 [205 mi^2]) and an adjacent area (122 km^2 [76 mi^2]) of about one-third its size. This adjacent area contains 68 grid cells with a frequency of occurrence of (at least) 7 out of 9, 7 grid cells not underlain by crystalline rock bodies, and one grid cell with a frequency of occurrence of 5 out of 9. These areas are 1.6 km (1 mi) apart. Accordingly, the DOE has decided to connect these two areas with the abutting 19 grid cells also being included as part of the preliminary candidate area. The presence of the environmental disqualifying factors will be considered during area phase studies.

3.1.4.3 NC-9

At a 7 out of 9 frequency of occurrence on the Phase A summary composite map there are 30 grid cells of slightly lower frequency of occurrence (i.e., 15 grid cells with a frequency of 6 out of 9, 13 grid cells with a frequency of 5 out of 9, and two grid cells with a frequency of 0 to 4 out of 9) and two grid cells containing environmental disqualifying factors (state park) between NC-9 (240 km^2 [150 mi^2])

and an adjacent area ([illegible] mi^2]) of almost one half its size. This adjacent area contains 6[illegible] grid cells with a frequency of occurrence of (at least) 7 out of 9, three grid cells with a frequency of occurrence of 6 out of 9, one grid cell with a frequency of 5 out of 9, and three grid cells containing environmental disqualifiers (Federal waterfowl production areas). These areas are 1.6 km (1 mi) apart. Accordingly, the DOE has decided to connect these two areas with the abutting 32 grid cells also being included as part of the preliminary candidate area. The presence of the environmental disqualifying factors will be considered during area phase studies.

3.1.4.4 NC-12

At a 7 out of 9 frequency of occurrence on the Phase A summary composite map, there are 13 grid cells of slightly lower frequency of occurrence (i.e., one grid cell with a frequency of 6 out of 9, four grid cells with a frequency of 5 out of 9, and eight grid cells with a frequency of 0 to 4 out of 9) and four grid cells containing environmental disqualifying factor (state wildlife management area and population feature) between NC-12 (187 km^2 [117 mi^2]) and an adjacent area (59 km^2 [37 mi^2]) of about one third its size. This adjacent area contains 35 grid cells with a frequency of occurrence of (at least) 7 out of 9, and 2 grid cells with a frequency of 6 out of 9. These areas are 1.6 km (1 mi) apart. Accordingly, the DOE has decided to connect these two areas with the abutting 17 grid cells also being included as part of the preliminary candidate area. The presence of the environmental disqualifying factors will be considered during area phase studies.

3.1.4.5 NC-14

At a 7 out of 9 frequency of occurrence on the Phase A summary composite map, there are 20 grid cells of slightly lower frequency of occurrence (i.e., 17 grid cells with a frequency of 6 out of 9, and three grid cells with a frequency of 0 to 4 out of 9) protruding into NC-14 from the eastern edge. This string of grid cells is generally 1.6 km (1 mi) in width. Accordingly, the DOE has decided to include these 20 grid cells as part of the preliminary candidate area.

3.1.4.6 NE-2

At a 7 out of 9 frequency of occurrence on the Phase A summary composite map, there are 10 grid cells of slightly lower frequency of occurrence (i.e., 6 grid cells with a frequency of 6 out of 9, and 4 grid cells with a frequency occurrence of 5 out of 9) between NE-2 (82 km^2 [51 mi^2]) and an adjacent area (46 km^2 [29 mi^2]) of 7 out of 9 frequency of occurrence of almost half its size. This adjacent area contains grid cells with a frequency of occurrence of (at least) 7 out of 9. These areas are 1.6 km (1 mi) apart. Accordingly, the DOE has decided to connect these two areas with the abutting 10 grid cells also being included as part of the preliminary candidate area.

3.1.4.7 NE-4

At a 7 out of 9 frequency of occurrence on the Phase A summary composite map, there are 11 grid cells containing an environmental disqualifier (State Wild and Scenic River) between NE-4 (341 km^2 [213 mi^2]) and an adjacent area (258 km^2 [161 mi^2]) of 7 out of 9 frequency of occurrence of more than half its size. This adjacent area contains 154 grid cells with a frequency of occurrence of (at least) 7 out of 9, 2 grid cells with a frequency of 6 out of 9, 4 grid cells with a frequency of 5 out of 9, and 1 grid cell with a frequency of 4 out of 9. These areas are 1.6 km (1 mi) apart. Accordingly, the DOE has decided to connect these two areas with the abutting 12 grid cells also being considered as part of the preliminary candidate area.

3.1.4.8 SE-6

At a 7 out of 9 frequency of occurrence on the Phase A summary composite map, there are two grid cells of slightly lower frequency of occurrence (i.e., one grid cell with a frequency of 6 out of 9 and one grid cell with a frequency of 5 out of 9) between SE-6 (62 km^2 [39 mi^2]) and an adjacent area (42 km^2 [26 mi^2]) of 7 out of 9 frequency of more than half its size. This adjacent area contains grid cells with a frequency of occurrence of (at least) 7 out of 9. These areas are 1.6 km (1 mi) apart. Accordingly, the DOE has decided to connect these two areas with the abutting two grid cells also being considered as part of the preliminary candidate area.

3.1.4.9 Summary

The list of the 21 preliminary candidate areas (reduced from 22 because of combining NC-3 and 4) and their areal extent using the decision rules described above is shown in Table 3-10. The DOE recognizes that there may be natural features or other reasons to tailor the boundaries of the candidate areas or potentially acceptable sites prior to initiation of area phase activities. Any information provided will be considered and evaluated in preparing the final area recommendation report and the boundaries of the candidate areas and potentially acceptable sites will be modified as necessary (see Plates NC-1A, -1B, NE-1A, SE-1A, -1B).*

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* A plate for the southern half of the Northeastern Region is not included with the draft area recommendation report because no preliminary candidate areas and thus no proposed potentially acceptable sites occur within this part of the Northeastern Region.

Table [illegible]. List of Preliminary Candidate Areas and Areal Extent

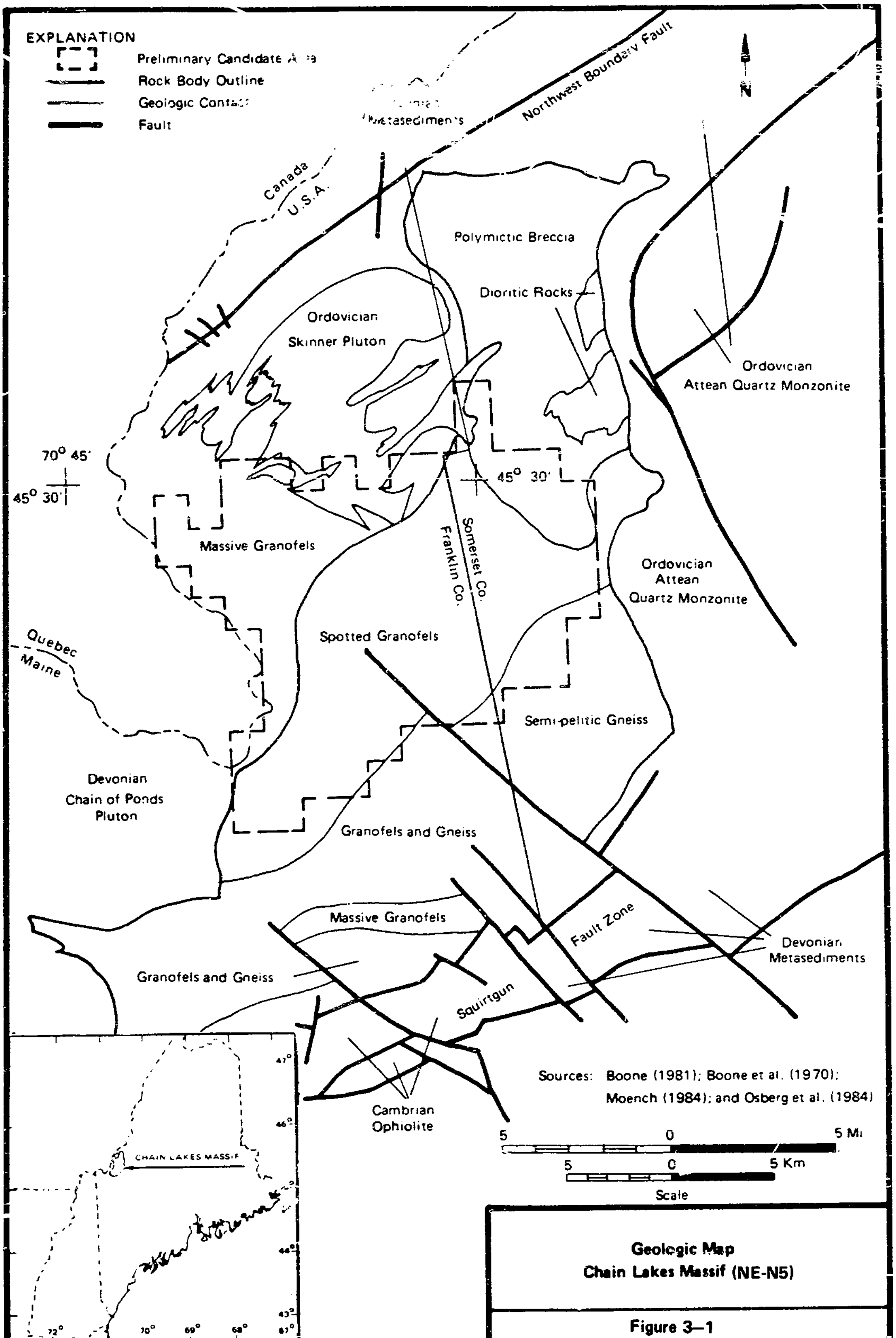
Area	Areal Extent km^2	(mi^2)
NC-2	445	(171)
NC-3	2,844	(1,094)
NC-6	780	(300)
NC-7	294	(113)
NC-9	647	(249)
NC-10	1,032	(397)
NC-12	445	(171)
NC-13	156	(60)
NC-14	746	(287)
NC-A5	182	(70)
NE-2	239	(92)
NE-4	1,000	(385)
NE-5	203	(78)
NE-N5	244	(94)
SE-1	166	(64)
SE-2	543	(209)
SE-3	798	(307)
SE-4	369	(142)
SE-5	273	(105)
SE-6	174	(67)
SE-7	556	(214)

These 21 preliminary candidate areas are in seven different states (Minnesota, Wisconsin, Maine, New Hampshire, Georgia, North Carolina, and Virginia) and occur within 15 different rock bodies (i.e., four of the preliminary candidate areas are in Archean Gneisses, four of the preliminary candidate areas are in Undifferentiated Granites and 13 in separate discrete rock bodies). The areal extent of the 21 preliminary candidate areas is approximately 12,200 km^2 (4,700 mi^2) which is equivalent to 6.3% of the land mass underlain by crystalline rock bodies prior to application of Step 1 and is equivalent to 7.7% of the land mass underlain by crystalline rock bodies prior to application of Steps 2 and 3.

3.1.5 Exclusion of Preliminary Candidate Area NE-N5

Of these 21 preliminary candidate areas, one (NE-N5), the Chain Lakes Massif, is located in west central Maine, in Franklin and Somerset Counties. In fact, the western boundary of the preliminary candidate area is coincident with the USA-Canada border, for about 10 km (6 mi) (Figure 3-1), with the center of the preliminary candidate area located at approximately 45°08' latitude and 70°33' longitude. The preliminary candidate area has an areal extent of approximately 244 km^2 (94 mi^2). The maximum distance from the international border to the eastern boundary of the preliminary candidate area is approximately 19 km (13 mi).

To fully characterize this area and to provide sufficient evidence including ground water flow-modeling and repository performance assessments, particularly to identify potential impacts across the border into Canada to support site nomination, recommendation, and ultimately licensability, it appears highly probable that sampling/field work in Canada would be necessary. These would include geology, hydrology (ground-water flow), environmental and socioeconomic investigations,



Geologic Map
Chain Lakes Massif (NE-N5)

Figure 3–1

descriptions, and impact analyses needed for preparing environmental assessments to support nomination and recommendation for site characterization and environmental impact statements to support site selection and licensing. DOE has determined that areas which are at close proximity to the Canadian border, and which would require sampling/field work in Canada for the necessary study of the potentially acceptable sites, would not be considered. As a result, NE-N5 is being excluded from further consideration and, therefore, will not be studied in the area phase. This decision reduces the number of preliminary candidate areas from 21 to 20.

3.2 QUALITATIVE/DESCRIPTIVE REVIEW OF LITERATURE

The section provides the available information for, and the Step 4 deferral analysis on, preliminary candidate areas NC-2, NC-3, NC-6, NC-7, NC-9, NC-10, NC-12, NC-13, NC-14, NC-A5, NE-2, NE-4, NE-5, SE-1, SE-2, SE-3, SE-4, SE-5, SE-6, and SE-7. It includes data considered in Steps 1 through 3 and significant new information to be evaluated in the Step 4 deferral analyses. Prior to commencing the qualitative/descriptive review, data utilized in Steps 1 through 3 were reviewed to ensure the accuracy and technical defensibility of the results of the region-to-area screening methodology (see Appendix D). The Step 4 deferral analyses are conducted to ensure that there is reasonable expectation, within the constraints of a regional study that the candidate area warrants further examination in the area phase.

The Step 4 qualitative/descriptive literature review considered new information that was not directly incorporated in the application of Steps 1 through 3 of the region-to-area screening process as the basis for deferral analyses.

The new information considered for each preliminary candidate area is presented by topic. The focus of the discussion under each topic is to identify the presence (or absence) of the features and/or conditions within each preliminary candidate area and, in some cases, to identify the presence (or absence) of these features in proximity to each preliminary candidate area.* Given the areal extent of each preliminary

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* The figures in Chapter 3 portray relative orientation of geologic and environmental information, or features within and in the vicinity of a preliminary candidate area and are presented for illustrative purposes only. They have not been used in the application of screening Steps 1 through 3 and cannot and should not be used for verification of screening results. The figures are not to the same scale because (1) large geographic extent of some preliminary candidate areas would render maps difficult to read, and (2) environmental features maps were photomechanically enlarged for presentation. In addition, these maps were derived from sources based on different map projections.

candidate area in relation to the assumed size and depth of a repository, conclusions as to whether favorable characteristics or characteristics which could detract from siting and performance in the absence of further evaluation are based on consideration of the relationship of the characteristics to the entire preliminary candidate area. For example, the presence of a limited number of disqualified State-protected lands less than 130 ha (320 ac) in size within a preliminary candidate area would still result in a conclusion that the preliminary candidate area exhibited a favorable characteristic from this perspective.

Topics included in this section are:

- Host Rock Geometry and Overburden Thickness - Data on thickness and areal extent of rock mass and overburden thickness not considered in Steps 1 through 3 are presented and evaluated with respect to flexibility in selecting the depth, configuration, and location of surface and underground facilities.

- Lithology and Tectonics - Data not considered in Steps 1 through 3 on complex geologic features (i.e., active faults, shear zones, and other structural features); igneous activity, tectonic processes (i.e., folding, faulting, and uplift and subsidence); and composition of the host rock are presented and evaluated with respect to the potential for tectonic deformations that could affect the regional ground-water flow system and the potential for affecting repository performance.

- Seismicity - Data not considered in Steps 1 through 3 on historical earthquakes within the vicinity of the preliminary candidate area are presented and evaluated with respect to the potential for induced ground motion that could affect repository performance.

- Mineral Resources - Data on strategic, metallic, and energy-related resources in or within 3 km (2 mi) of the preliminary candidate area are presented and evaluated (not considered in Steps 1 through 3) with respect to the potential for future extraction and the possibility that any existing deep mines or drill-holes could affect waste isolation.

- Topography and Surface Water Characteristics - Data on topographic relief, surface water, wetland distribution, and drainage characteristics are presented and evaluated (not considered in Steps 1 through 3) with respect to the potential for flooding of surface or underground facilities that could affect repository performance.

- Ground-Water Resources - Data not considered in Steps 1 through 3 on nature and occurrence of aquifers and well yields in crystalline bedrock and surficial deposits are presented and evaluated with respect to the presence of potable ground-water resources between the repository and the accessible environment.

- Quaternary Climate - Data not considered in Steps 1 through 3 on rates and magnitudes of glacial erosion during the Quaternary Period are presented and evaluated with respect to the possibility of adversely affecting repository performance through potential future glaciation.

- Federal Lands - Data on Federal lands, including those not considered in Steps 1 through 3 (i.e., less than 130 ha [320 ac]), which are inside the boundaries and within 10 km (6 mi) of the preliminary candidate area are presented and evaluated to determine whether there is sufficient areal extent and flexibility within the preliminary candidate area for the repository restricted area and support facilities.

- State Lands - Data on State lands, including those not considered in Steps 1 through 3 (i.e., less than 130 ha [320 ac]), which are inside the boundaries and within 10 km (6 mi) of the preliminary candidate area are presented and evaluated to determine whether there is sufficient areal extent and flexibility within the preliminary candidate area for the repository restricted area and support facilities.

- Population Density and Distribution - Data on population disqualifiers within 16 km (10 mi) of the preliminary candidate area, the average density of the preliminary candidate area, and the average density within 80 km (50 mi) of the preliminary candidate area are presented and evaluated to determine whether there is sufficient areal extent and flexibility within the preliminary candidate area for the repository surface facilities and whether there is a low population density in the general region of the preliminary candidate area. Only population disqualifiers were considered in Steps 1 through 3. Average population densities are estimates based on information contained in the U.S. Bureau of Census Master Area Reference File 2 (MARF2) computer tapes (U.S. Bureau of the Census, 1983) and census boundaries of minor civil division and places obtained under license from Rand McNally/Infomap (Rand McNally, 1984).

- Site Ownership - Data not considered in Steps 1 through 3 on the presence of DOE-owned lands, Federally-owned lands, and any Federal Indian Reservations within the preliminary candidate area and nearby are identified to determine if there are any projected land-ownership conflicts.

* <u>Offsite Installations</u> - Data on the nearest operating commercial nuclear reactor, reactor(s) under construction, and other nuclear installations are presented and evaluated to assess whether the closeness of such facilities to the preliminary candidate area could be of concern.

* <u>Transportation</u> - Data not considered in Steps 1 through 3 on distances from the boundaries of preliminary candidate area to interstate, U.S., and State highways and mainline and branchline railroads are presented and evaluated to determine whether there is reasonable access to the national ground transportation systems. The evaluation does not consider the condition of specific access routes (road and railroad) in the vicinity of the preliminary candidate areas, since this requires field investigations, which will be done in the area phase.

The above topics are related to the DOE siting guideline conditions listed below.* Individual guidelines were used to help frame the discussion for each of the topics.

* Host Rock Extent - 960.4-2-3(b)(1), 960.4-2-5(b)(1), 960.5-2-9(b)(1), and 960.5-2-9(c)(1)
* Lithology and Tectonic Setting - 960.4-2-7(b), 960.4-2-7(c)(1), 960.4-2-7(c)(6), 960.5-2-9(c)(5), and 960.5-2-11(c)(1)
* Seismicity - 960.4-2-7(c)(2), 960.4-2-7(c)(3), 960.4-2-7(c)(4), 960.5-2-11(c)(2), and 960.5-2-11(c)(3)

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* The DOE siting guidelines identified above are those for which it appears that information is available at this time for consideration in the deferral analyses. If as a result of comments received on this draft report new significant data which affects deferral conclusions are received, DOE will evalulate and use them as appropriate.

- Mineral [illegible] 960.4-2-8-1(b)(1), 960.4-2-8-1(c)(1)(i), 960.4-2-8-1(c)[illegible], 960.4-2[illegible](3), and 960.4-2-8-1(c)(4)
- Topography and Surface Water Characteristics - 960.5-2-8(b)(1), 960.5-2-8(b)(2), 960.5-2-8(c), and 960.5-2-10(b)(2)
- Ground Water Resources - 960.4-2-1(b)(4)(ii), 960.4-2-1(c)(2), 960.5-2-10(b)(1), and 960.5-2-10(c)
- Quaternary Climate - 960.4-2-4(b)(2)
- Environmental Quality - 960.5-2-5(c)(3), 960.5-2-5(c)(4), and 960.5-2-5(c)(6)
- Population Distribution and Density - 960.5-2-1(b)(1), 960.5-2-1(b)(2), and 960.5-2-1(c)(2)
- Site Ownership - 960.4-2-8-2(b), 960.4-2-8-2(c), 960.5-2-2(b), and 960.5-2-2(c)
- Offsite Installations - 960.5-2-4(b) and 960.5-2-4(c)(2)
- Transportation - 960.5-2-7(b)(2) and 960.5-2-7(b)(3).

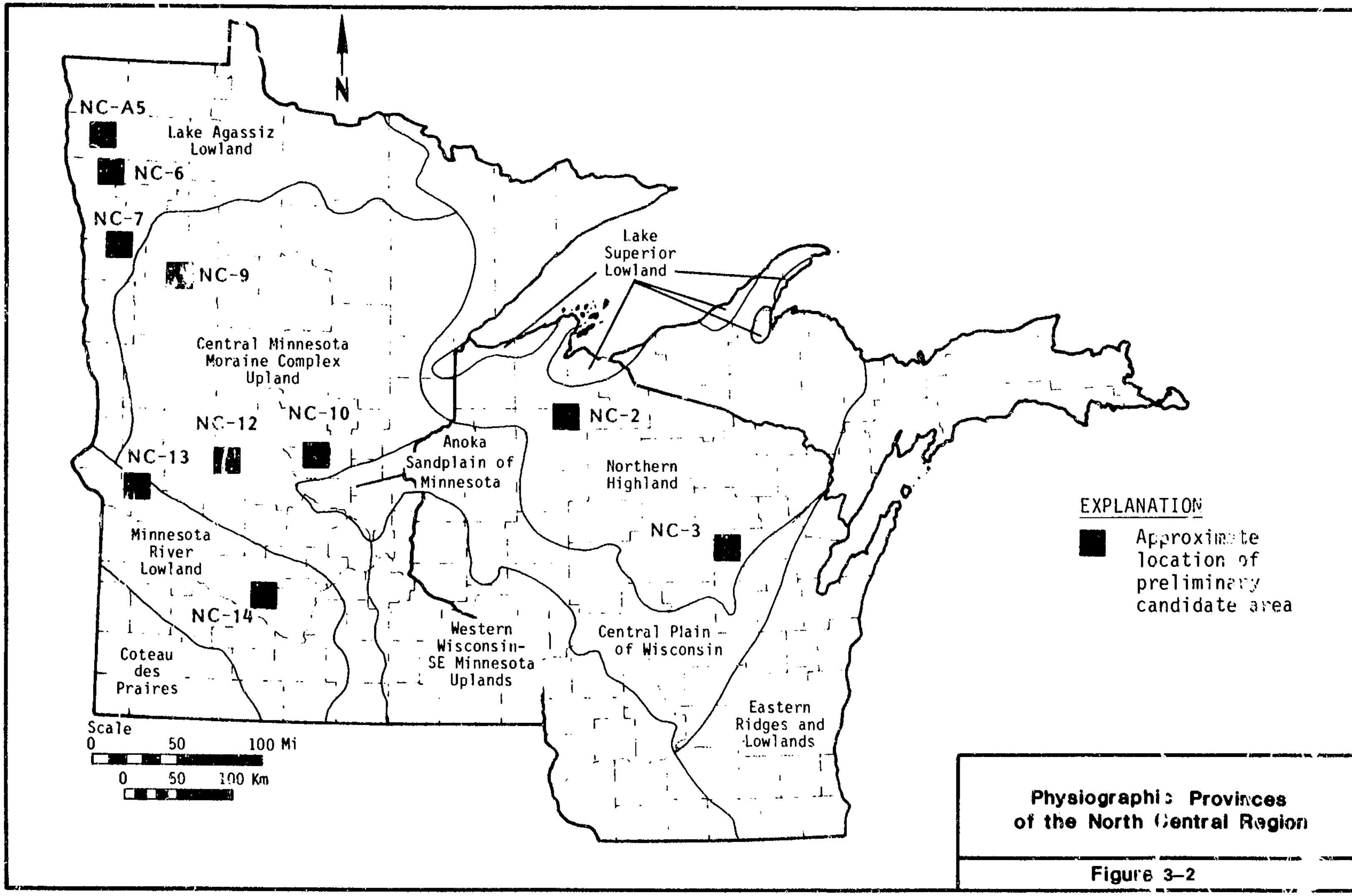
3.2.1 North Central Region

3.2.1.1 Regional Setting

3.2.1.1.1 Geological. The North Central Regional Geologic Characterization Report (RGCR) (DOE, 1985c) describes the regional setting and related features. The regional setting and the geologic setting for the 10 preliminary candidate areas in the North Central Region are defined as the Precambrian Shield.

3.2.1.1.1.1 Physiography, Geomorphology, and Quaternary Geology. The 10 preliminary candidate areas fall within four of the nine physiographic provinces recognized in the North Central Region (Figure 3-2): (1) Northern Highland, (2) Central Minnesota Moraine Complex Upland, (3) Lake Agassiz Lowland, and (4) Minnesota River Lowland. The Northern Highland is underlain mainly by Precambrian igneous and metamorphic rocks that form an upland of gentle relief. The Northern Highland is generally blanketed with glacial deposits in Wisconsin, whereas in Minnesota it has been generally subjected to glacial erosion, resulting in a discontinuous veneer of glacial materials. The Central Minnesota Moraine Complex Upland, which is of low to moderate relief, is dominated by glacial material deposited during Wisconsinan glaciation. The Lake Agassiz Lowland in northern Minnesota is largely underlain by silt and clay deposited in glacial Lake Agassiz. The Minnesota River Lowland is formed by the Olivia and Blue Earth till plains. The greatest thickness of glacial deposits occur in western Minnesota. In northeastern Minnesota, and to a lesser degree in Wisconsin, there is only a thin veneer of glacial sediments. The detailed stratigraphy of the overburden at each preliminary candidate area is currently unavailable.

The Quaternary geology of the region resulted from a series of Pleistocene glacial and interglacial cycles. The glacial maximum of the Laurentide ice sheet during the Wisconsinan, the latest Pleistocene glacial stage, occurred approximately 18,000 years ago (Flint, 1971; Mickelson et al., 1983) and the last advance in the North Central Region



Physiographic Provinces of the North Central Region

Figure 3–2

before retreat was less than [illegible],000 years ago. This retreat was followed by an interglacial stage that has continued to present. Based on a model of climatic response to orbital variation, Imbrie and Imbrie (1980) have forecasted that the next glacial advance will occur approximately 23,000 years from now. This suggests that during the next 100,000 years, a glacial advance and retreat may occur and that up to 10 glacial cycles could occur over the next 1 million years, assuming a glacial cycle every 100,000 years (Hays et al., 1976).

Field studies of the Laurentide ice sheet have determined varying amounts of glacial erosion depending on the technique used and the time frame considered. Bell and Laine (1985) concluded that a regional average of 120 m (394 ft) of erosion occurred since major glaciation began 3 million years ago. Their estimate is based on the volume of glacial sediments on the continental margins and ocean basins surrounding North America. This estimate indicates an average rate of 40 m (131 ft) per million years. Assuming an average glacial cycle every 100,000 years (Hays et al., 1976), there would be about 4 m (13 ft) of erosion per cycle. In another study, Kaszycki and Shilts (1980) mapped the glacial dispersal of distinctive rock types in the Keewatin region of the Precambrian Shield and estimated that between 6 and 20 m (20 and 66 ft) of glacial erosion occurred during the Wisconsinan glaciation. Bell and Laine's (1985) estimate of glacial erosion represents a long-term regional average, whereas the Kaszycki and Shilts (1980) estimate represents erosion in a specific area for a single glacial period. The crystalline rocks of the North Central Region have attributes including high rock strength and low relief that increase resistance to glacial erosion. One estimate of modern erosion rates for the Mississippi drainage basin is reported as 5 cm/1,000 yr (2 in/1,000 yr) Judson and Ritter (1964). Hence, the long-term average erosion of 120 m (394 ft) as calculated by Bell and Laine (1985) represents a maximum. The maximum amount of localized short-term erosion has been probably produced by catastrophic floods. Sudden lowering (breeching) of glacial Lake

Agassiz, which occupied [illegible] western Minnesota and much of North Dakota and Canada, incised a channel 60 m (197 ft) deep; this channel is presently occupied by the Minnesota River (Matsch, 1983).

Based on the regional aspects of the Quaternary climatic conditions and erosion and deposition rates presented above and the vertical crustal motions presented in Section 3.2.1.1.1.3, it is assumed that if glaciation recurred in the North Central Region, conditions would probably be similar to those that existed during the Pleistocene Epoch. No geomorphic features that might intensify or concentrate glacial or fluvial erosion (DOE, 1985c) are observed in any of the preliminary candidate areas in the North Central Region. Thus, the rate and magnitude of glacial erosion in the vicinity of the preliminary candidate areas are not expected to exceed the range established for the region.

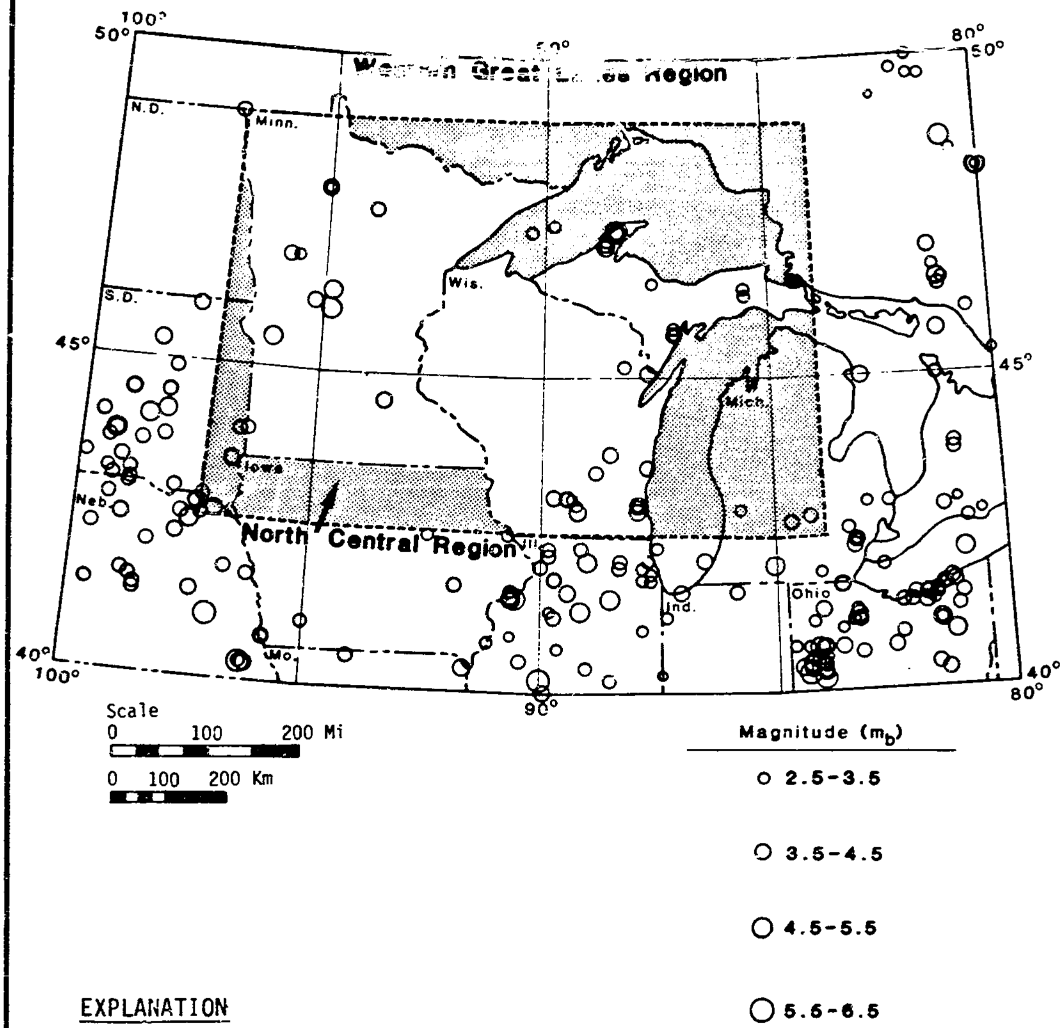
The information on maximum depth of glacial erosion (120 m [394 ft]) when compared to the assumed repository depth (Section 1.5) indicates that the integrity of a repository developed in the preliminary candidate area will not be affected by glacial erosion over the next 100,000 years. Although the setting is one in which climatic changes have certainly affected the hydrologic system throughout the Quaternary Period, it is uncertain to what degree these changes have affected the hydrologic system.

3.2.1.1.1.2 Geology and Tectonics. The regional geologic framework consists of an Archean basement overlain by metasedimentary and metavolcanic rocks of early Proterozoic age. These rocks were intruded by Proterozoic granitic to tonalitic rocks, and subsequently transected by and partly overlain by volcanic and sedimentary rocks of the Middle Proterozoic Midcontinent rift system. Paleozoic and Mesozoic sedimentary rocks border the Precambrian terrane on three sides where they are preserved in flanking basins.

The Archean basement [illegible] be divided into two terranes on the basis of age, rock assemblage, metamorphism, and structural style: a mostly older (2,600 to 3,550 million years) gneiss terrane recognized in the southern part of the region (northern portion of NC-10, NC-12, NC-13, and NC-14), and a 2,600- to 2,750-million year greenstone-granite terrane to the north (Morey and Sims, 1976) (NC-2, NC-6, NC-7, NC-9, and NC-A5). The gneiss and greenstone-granite terranes were juxtaposed and intruded by granitic rocks during the Algoman orogeny (2,600 to 2,700 million years ago) (Sims, 1980). The boundary between the Archean terranes generally coincides with the Great Lakes tectonic zone, a major Archean and Proterozoic structural feature of the region.

Early Proterozoic clastic, volcanic, and nonclastic strata (including the well known iron formations of the region) were deposited in basin that developed over and subparallel to the Great Lakes tectonic zone. The sediments were deformed, metamorphosed, and intruded by igneous plutons (southern portion of NC-10) and gneiss domes during the Penokean orogency 1,830 to 1860 million years ago (Van Schmus, 1984). Following the Penokean orogeny, an anorogenic granite--rhyolite suite formed 1,760 million years ago, and was subsequently buried beneath a thick wedge of clastic sediments. The granite-rhyolite suite and overlying sediments were deformed prior to intrusion of anorogenic granitic to syenitic rocks 1,520 and 1,485 million years ago (Van Schmus, 1980; Van Schmus et al., 1975; Dott, 1983) (NC-3). The last major igneous and tectonic event occurred 1,110 million years ago (Van Schmus et al., 1982) during the formation of Midcontinent rift system. Intrusive and extrusive mafic igneous rocks and clastic sediments of this system were deposited in a long, segmented, structural trough that transected preexisting structural patterns. Table 3-11 shows the temporal distribution of tectonic events and rocks in the North Central Region and relates the preliminary candidate areas to these events and rocks.

3.2.1.1.1.3 Seismicity and Recent Crustal Movement. The distribution and magnitude of historical earthquakes in the North Central Region are shown on Figure 3-3. The largest historical earthquake in the



EXPLANATION

Area included into North Central Region for Seismology studies

Source: Mooney and Morey, 1981;
Nuttli and Brill, 1981

Earthquake Epicenters for the Western Great Lakes and North Central Regions, 1804-1979

Figure 3-3

Table 3-11. Temporal Distribution of Tectonic Events, Rocks, and Crystalline Rock Bodies Containing Preliminary Candidate Areas in the North Central Region

Time, Million Year	Tectonic Events	Lithology		Preliminary Candidate Areas
		Igneous Extrusive and Sedimentary Rock	Igneous Intrusive and Metamorphic Rocks	
600		clastic and carbonate sediments		
	Uplift, faulting			
1,000		clastic sediments		
	KEWEENAWAN RIFTING	basalt, clastic sediments	gabbro, granite	
1,400	uplift			
			quartz monzonite, granite, syenite, anorthosite	NC-3 (Wolf River Batholith)
	faulting, rifting(?), metamorphism			
		clastic sediments		
	uplift	rhyolite	granite	
1,800				
	PENOKEAN OROGENY	rhyolite to basalt	granite, tonalite, minor gabbro	NC-10 (Central Minn. Granites)
	rifting	clastic and chemical sediments, rhyolite to basalt		
	metamorphism		granite	
2,200				
	local metamorphism uplift, faulting		local granite	

Table 3-11. Temporal Distribution of Tectonic Events, Rocks, and Crystalline Rock Bodies Containing Preliminary Candidate Areas in the North Central Region
Sheet 2 of 2

Time, Million Year	Tectonic Events	Lithology: Igneous Extrusive and Sedimentary Rock	Lithology: Igneous Intrusive and Metamorphic Rocks	Lithology: Preliminary Candidate Areas
2,600				
	ALGOMAN OROGENY	basalt, clastic sediments	granite, quartz monzonite granodiorite, tonalite	NC-2 Puritan Batholith NC-6 (Undifferentiated Granites) NC-7 (Undifferentiated Granites) NC-9 (Undifferentiated Granites) NC-A5 (Undifferentiated Granites)
	metamorphism		igneous activity (nature and extent uncertain)	
	metamorphism		granite, quartz monzonite	
3,400			granite, quartz monzonite (between 3050 and 3600 MA)	NC-10 (Archean Gneisses) NC-12 (Archean Gneisses) NC-13 (Archean Gneisses)
	folding		tonalites, basalt dikes and sills, gneiss	NC-14 (Archean Gneisses)
		basalt, andesite, dacite and/or pyroclastic flows		
3,800				

Source: Van Schmus and Woolsey (1975), Peterman (1979), and Doe and Delevaux (1980), Goldich and Wooden (1980), Peterman et al. (1980), Van Schmus and Bickford (1981), Sims and Peterman (1983).

NOTE:
Major tectonic events are capitalized
Time scale is used to give relative position of tectonic events and lithologic units.

region was a shallow tect[illegible] event in 1905 with an intensity of MM VIII (Modified Mercalli scale). The event was possibly induced by mining activity in the Keweenaw Peninsula of Michigan (Figure 3-3) (Frantti and Rowlands, 1967). Three earthquakes of maximum intensity (MM V to VII) occurred in central Minnesota between 1860 and 1950 (Figure 3-3) (Mooney and Morey, 1981). The questions of the largest earthquake likely to occur in the region and the resulting horizontal acceleration have been studied by a number of investigators. Probabilistic studies by Algermissen et al. (1982) suggest that no part of the North Central Region should experience a horizontal acceleration greater than 0.1 g, (90% probability of not being exceeded in a 250-year period). Most areas of the region will be less than or equal to 0.08 g (Algermissen et al., 1982).

Studies by Nuttli and Herrmann (1978) estimated that the maximum body wave magnitude (m_b) earthquake with a 1,000-year recurrence interval for the North Central Region is m_b 5.3. Assuming that this maximum magnitude earthquake could occur within any of the preliminary candidate areas at a minimum distance of 15 km (9 mi) from the epicenter (Nuttli and Herrman, 1981; Mooney and Morey, 1981) and using the attenuation relationships developed by Nuttli and Herrmann (1981), the associated mean peak horizontal acceleration at the surface would be 0.14 g (63% probability of occurrence in 1,000 years). Nuttli and Herrman (1981) have identified the Great Lakes tectonic zone in central Minnesota as an extension of the Colorado lineament seismic source zone. Other studies (e.g., EPRI, 1985) also identify the extension of the Colorado lineament into Minnesota as a seismic source zone. The low level of seismicity within the North Central Region would not influence design parameters.

Recent crustal uplift in the North Central Region is primarily due to glacioisostatic rebound. Rates of postglacial rebound for the region are estimated to be 0 to 3 mm/yr (0 to 0.0098 ft/yr) (Gable and Hatton, 1983). Should this rate continue to increase the result would be 30 m

(98 ft) in 10,000 [illegible] the current rate is expected to decrease as post-glacial rebound diminishes.

3.2.1.1.1.4 Strategic, Metallic, and Energy-Related Resources A review of known rock and mineral resources in the North Central Region is presented in the RGCR (DOE, 1985c). Resources discussed in this section are strategic, metallic and energy-related resources that occur within 10 km (6 mi) of the preliminary candidate area. Nonstrategic, nonmetallic resources are not addressed because they are not considered to be unique (i.e., there are alternate sources within a comparable distance from the market) and because nonmetallic resources within 10 km (6 mi) of the preliminary candidate areas are shallow (less than 100 m [328 ft] in depth) and their exploitation would not affect ground-water flow paths in the host rock.

The majority of strategic, metallic, and energy-related resources in the North Central Region occur within country rocks bordering the crystalline rock bodies. There are no deep mines or quarries either in or within 10 km (6 mi) of any of the preliminary candidate areas. Occurrences of metallic, strategic, and energy-related resources have been reported within crystalline rock bodies in the region, and minor occurrences are present within or near some of the preliminary candidate areas. Exploration activity is continuing in a few of these areas, but none of these prospects have been proven to be economic to date.

3.2.1.1.1.5 Hydrology. The North Central Region is drained by three major surface water drainage systems: the Red River system, the Great Lakes system, and the Mississippi River system. Preliminary candidate areas occur in all three major drainage systems, with several areas straddling drainage divides between two of these drainage systems. The North Central Region contains many large lakes including the western Great Lakes, numerous rivers, streams, small lakes, and wetlands.

Ground water in the North Central Region occurs in Quaternary aquifers composed of glacial and alluvial sediments, consolidated sandstone and carbonate aquifers of Paleozoic and Mesozoic age, Proterozoic rocks associated with the Midcontinent rift system and Precambrian crystalline rocks. Ground water at all preliminary candidate areas can be discussed in terms of shallow (surficial) aquifers (i.e., alluvium and glacial till) which can be characterized as porous flow media, and generally deeper crystalline bedrock aquifers which can be characterized as a fracture flow media and is largely controlled by the geometry of secondary interstices (fractures, faults, etc.). Glacial sediments are widespread across the North Central Region and are highly variable in their water-bearing characteristics. These sediments, which contain unconfined aquifers, are present over portions of all 10 preliminary candidate areas and normally provide well yields from less than 0.1 to over 63 L/s (1 to 1,000 gpm) (DOE, 1985c). Paleozoic and Mesozoic sedimentary rocks occur principally in the southern half of the North Central Region where they form important aquifers commonly under confined conditions. Significant thicknesses of Paleozoic and Mesozoic sedimentary rocks are generally absent in the preliminary candidate areas and therefore are not a major factor influencing ground-water resources.

Precambrian crystalline rock underlying the preliminary candidate areas generally does not yield significant water to wells. However, crystalline rocks may have locally high yields where wells intersect faults and major fracture zones. Yields are limited by the size of fractures and joints and their degree of interconnection. The abundance of interconnected fracture systems probably decreases with depth, as does their ability to transmit water. Sparse data are available pertaining to ground-water flow in crystalline rocks at depth (100 to 1,000 m [328 to 3,280 ft]), with essentially no data available at the assumed repository depths in the North Central Region. Studies by Toth (1962; 1963), Freeze and Witherspoon (1966; 1967; 1968), Stokes (1978), and Gale (1982) indicate that, in general, ground-water levels at depth may be a subdued replica of the topography, with flow generally moving from topographic highs to topographic [illegible] inherent assumption in such studies is that ground water at depth [illegible] on a regional basis, in hydraulic connection with the shallow ground-water table. The validity of this assumption is questionable where thick unconsolidated deposits may contain continuous confining layers over a large region. While the overburden is relatively thick in some locations, there are currently no data to suggest the presence of regional confining layers within the surficial deposits of the preliminary candidate areas. Accordingly, these deposits are assumed to represent a regionally unconfined system, with ground-water flow occurring in the direction of local surface-water drainage outlets.

Crystalline rocks in the preliminary candidate areas are not extensively used for ground-water supplies because of their generally poor well yielding capacity and the occurrence of readily available alternative sources from glacial and alluvial sediments. Locally, where other sources are unavailable or where significant yields can be obtained from fracture zones, crystalline rock constitutes a ground-water source. In the 10 preliminary candidate areas, development of ground water from crystalline rock is very limited (DOE, 1985c).

3.2.1.1.2 Environmental. The environmental setting of the North Central Region is described in detail in the North Central Regional Environmental Characterization Report (RECR) (DOE, 1985d).

3.2.1.1.2.1 Climate. The climate of the North Central Region is characterized by warm, humid summers and cool, dry winters, with an annual average temperature generally ranging from 2°C (36°F) in International Falls, Minnesota, to 7.5°C (46°F) in La Crosse, Wisconsin. Regional precipitation is moderate with average annual precipitation varying from 48 to 86 cm (19 to 34 in). The region experiences moderately heavy snowfall from October through May, with total annual snowfall exceeding 254 cm (100 in) in the northern portions. The region has experienced severe weather including tornadoes which are common in the southern half of the region. Although the northern half has historically been free of tornadoes, severe tornadoes and high wind damage have occurred in recent years.

3.2.1.1.2.2 Land Use. Land use patterns in the North Central Region are predominantly rural. Agricultural production occurs in every county within the region; however, the northern portion of the region is primarily forest, woodland, and lake areas with relatively little agricultural use. These areas are devoted primarily to forestry and recreational uses. A band of agricultural land, most of which is cropland, extends along the southern and western edges of the region. Between the agricultural and forested areas is a broad transition zone of cropland and pasture mixed with some woodland and forest. This transitional area covers central and southwestern Wisconsin and much of central Minnesota.

Private land ownership dominates within the region, but there are extensive tracts of public land administered by Federal, State, and local governments, most of which are located within the forest-dominated northern part of the region.

National forest lands and Federal wildlife refuges account for most of the Federal-protected lands within the region. Recreation and natural resource management are the prevailing uses of these Federal lands. The North Central Region includes half of all existing national lakeshores, and the Federal wildlife refuges within the region are located along the Mississippi Flyway which is heavily used by waterfowl. None of the preliminary candidate areas are located within a coastal zone or the Coastal Barrier Resources System.

Extensive and varied systems of State recreation areas, preserves, and State forests are maintained within the region. In addition to numerous State parks, the North Central Region states have designated units comparable to Federal wildlife refuges, wilderness areas, wild and scenic rivers, and selected natural areas. State forests occupy extensive areas in northern Minnesota and Wisconsin.

3.2.1.1.2.3 Demography. Urban areas in the North Central Region are generally concentrated in the southeastern, central, and north central portions of the region. The largest population concentrations are located in the southeastern and central portions of the region and reflect the two major urban centers of Milwaukee and Minneapolis-St Paul, respectively. The total 1980 population of these areas was 5.82 million, which represented 64% of the regional population.

3.2.1.1.2.4 Ecological Systems. Only one Federally designated threatened plant species is within North Central Region (Wisconsin). State-protected plant species are more numerous, with 84 species in Wisconsin and 191 in Minnesota.

Six Federally designated threatened or endangered animal species are included within the region. In addition, Minnesota has listed 12 endangered and 8 threatened (plus 76 species of special concern) animal species, and Wisconsin has listed 27 endangered and 15 threatened species.

A critical habitat has been Federally designated for only the gray wolf in the North Central Region (see Plate 8 in DOE, 1985d). Within the region, the critical habitat is confined to northern Minnesota. This critical habitat is neither within any of the preliminary candidate areas in the North Central Region nor within 10 km (6 mi) of these preliminary candidate areas.

3.2.1.1.2.5 Federal Indian Reservations. There are 27 Federal Indian Reservations within the North Central Region. These include 11 reservations in Minnesota (see Plate NC-1A), 12 reservations in Wisconsin and four reservations in Michigan (upper Peninsula) (see Plate NC-1B). Of the tribes associated with the 11 reservations in Minnesota, four (Fond du Lac, Grand Portage, Mille Lacs, Nett Lake) have

Federal off-reservation treaty rights. Of the tribes associated with the 12 reservations in Wisconsin, six (Bad River, Lac Courte Oreilles, Lac du Flambeau, Red Cliff, St. Croix, Sokaogan, Chippewa) have Federal off-reservation treaty rights. Of the tribes associated with the four reservations in Michigan's Upper Peninsula, three (Bay Mills, Grand Traverse, and Keweenaw Bay) have Federal off-reservation treaty rights.

3.2.1.1.3 <u>Transportation</u>. Transportation networks (highways and railroads) for the North Central Region are shown on Plates NC-6A and NC-6B (Volume 2).* Highway and railroad data bases used in generating the plates and the transportation analyses presented are derived from USGS data and are updated (through 1985) by the Oak Ridge National Laboratory, Tennessee.** A brief description of highway and railroad networks in the vicinity of the preliminary candidate areas in the North Central Region is presented in Sections 3.2.1.2.14 through 3.2.1.11.14. The highway network is broadly classified as interstate highways, U.S. highways, and State highways. The rail network is classified based on the volume of freight movements as mainline railroads and branchline railroads. It should be emphasized that all references to distances are approximate and measured from the edges of the preliminary candidate area, not the center. Furthermore, all distances are "straight line" since specific access routes and regional routes for waste transportation to the preliminary candidate area are yet to be defined.

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* Because the base map used to generate the transportation plates is a different projection than the base map used to generate the other plates in the accompanying portfolio, there will be some distortion if the transportation plates are overlain on the other plates.

** Although the plates show only primary State highways, discussions provided in this report take into consideration additional State highways.

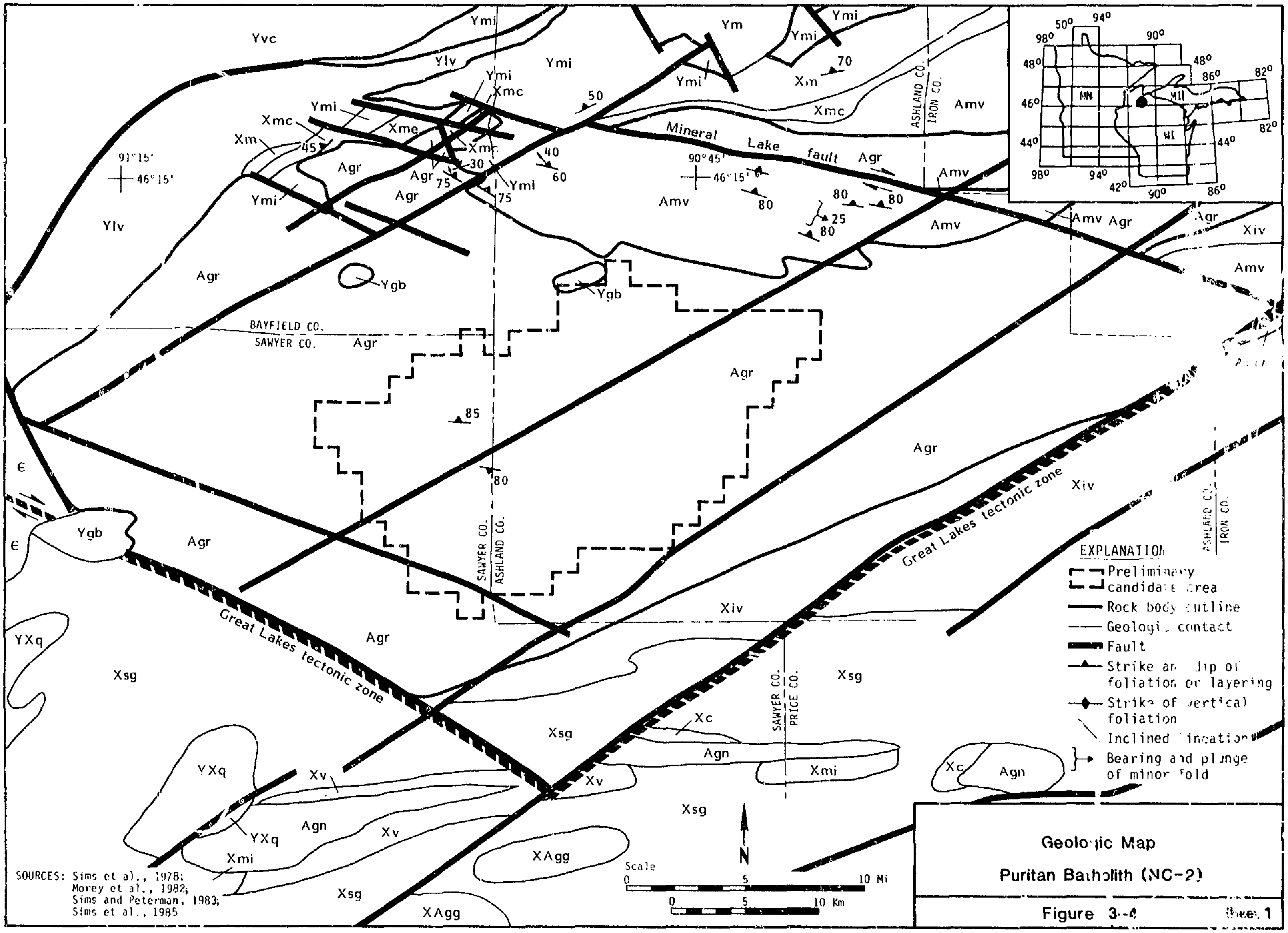
3.2.1.2 Preliminary Candidate Area Description - Puritan Batholith (NC-2)

The Puritan batholith (formerly designated the Migmatite Complex of Northern Wisconsin [DOE, 1985c]) is located within the Northern Highlands physiographic province in northern Wisconsin and in the Upper Peninsula of Michigan. The preliminary candidate area identified in the Puritan batholith is located entirely within Wisconsin, in Ashland, Sawyer and Bayfield Counties at approximately 46°05' N latitude and 90°50' W longitude.

3.2.1.2.1 Host Rock Geometry and Overburden Thickness. The preliminary candidate area shown on Figure 3-4 has an area of approximately 445 km^2 (171 mi^2) and overlies the Puritan batholith, the mapped extent of which is largely inferred from geophysical data and scattered outcrops. The batholith is approximately 125 km (76 mi) long and varies in width from 5 to 47 km (3 to 29 mi). Gravity modeling at the northeast end of the batholith suggests a minimum depth of approximately 6 km (4 mi) for the Puritan batholith (Klasner and Sims, 1984). This information provides a strong correlation with depth data developed from the present understanding of the mode of emplacement of batholiths and seismic reflection studies in batholithic terranes, which suggest that most batholiths are tabular in shape and extend to a depth of 6 to 10 km (4 to 6 mi) (Lynn et al., 1981; Hamilton and Myers, 1967).

Approximately 4% of the preliminary candidate area has exposed bedrock. Contours of overburden thickness indicate that a major portion of the area is covered by less than 30 m (100 ft) of overburden (Figure 3-5).

On the basis of the data presented above and the assumed depth and size of a repository in crystalline rock (see Section 1.5), the Puritan batholith within the preliminary candidate area is sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation.



Geologic Map
Puritan Batholith (NC-2)

Figure 3-4 Sheet 1

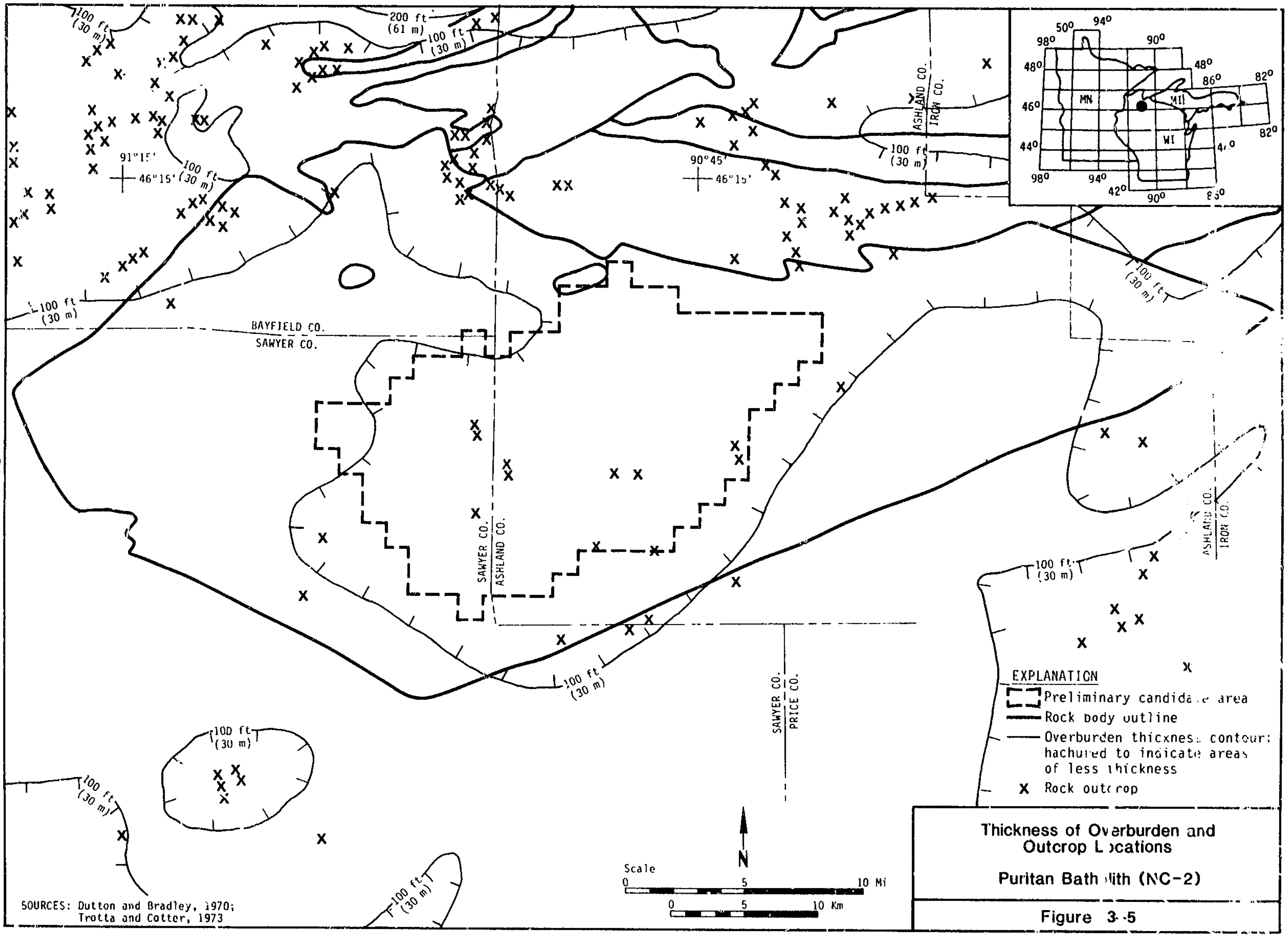
EXPLANATION OF GEOLOGIC UNITS

CAMBRIAN	€	Cambrian rocks, undivided
MIDDLE PROTEROZOIC	Yvc	Chengwatana Volcanic Group
	Ym	Granite of the Mellen Intrusive Complex
	Ygb	Gabbroic rocks of uncertain affinity
	Ymi	Layered mafic rocks of Mellen Intrusive Complex and of intrusive complex at Mineral Lake
	Ylv	Powder Mill Group and Bessemer Quartzite
MIDDLE PROTEROZOIC / EARLY PROTEROZOIC	YXq	Quartzite
EARLY PROTEROZOIC	Xmi	Metamorphosed mafic intrusive rocks
	Xm	Baraga Group
	Xsg	Quartzose sedimentary rocks
	Xiv	Metavolcanic rocks
	Xv	Mafic metavolcanic rocks
	Xc	Chocolay Group
	Xmc	Menominee and Chocolay Groups
EARLY PROTEROZOIC / ARCHEAN	XAgg	Gneiss, amphibolite and granitoid rocks
ARCHEAN	Agr	Granitoid rocks
	Amv	Metamorphosed mafic-intermediate volcanic rocks
	Agn	Migmatitic gneiss, amphibolite and granite

Explanation for Figure 3-4

Puritan Batholith (NC-2)

Figure 3-4 Sheet 2



Thickness of Overburden and Outcrop Locations

Puritan Batholith (NC-2)

Figure 3-5

3.2.1.2.2 Lithology and Tectonics. The Puritan batholith is a weakly to prominently foliated, dominantly granitoid rock ranging from granite to tonalite, with associated biotite gneiss, tonalite gneiss, amphibolite, and migmatite (Figure 3-4). The rocks consist of plagioclase, quartz, potassium feldspar, biotite, hornblende, epidote, and trace amounts of opaque oxides and accessory minerals. The batholith is also cut by granite, leucogranite, pegmatite, and metagabbro dikes, and has been intruded by small gabbro and granite stocks (Sims et al., 1985).

The Puritan batholith is part of the Archean greenstone-granite terrane identified in northwestern Minnesota, northern Wisconsin, and the Upper Peninsula of Michigan (Morey and Sims, 1976; Sims, 1980). The regional tectonics are summarized in Section 3.2.1.1.1.2. The batholith formed 2,735 ± 16 million years ago by the intrusion of tonalite and granodiorite into country rocks composed of metavolcanics (Sims et al., 1985). The batholith was affected by two major episodes of deformation and metamorphism. The older synorogenic event produced a gneissic layering and foliation and was accompanied by a lower amphibolite facies metamorphism. The younger deformational event about 1,050 million years ago was associated with the Keweenawan rifting resulting from brittle-ductile deformation and was accompanied by retrogressive greenschist-facies metamorphism (Sims et al., 1985).

Faults within the Puritan batholith (Figure 3-4) have been inferred from aeromagnetic surveys (Sims et al., 1978; Morey et al., 1982). Sims et al. (1978) inferred two northeast-trending faults and one northwest trending fault that transect the preliminary candidate area but are not shown on the map of Morey et al. (1982) (Figure 3-4). Because the reason for this different interpretation is not known, all previously identified faults within the batholith are shown in Figure 3-4. Within the batholith are four northeast-trending faults greater than 50 km (31 mi) long and four northwest-trending faults that are 10 to 50 m (6 to 31 mi) long. Two of the faults (Figure 3-4) form part of the boundary of the

Great Lakes tectonic [illegible]ms et al., 1980; Sims and Peterman, 1983). The west-northwest-trending Mineral Lake fault cuts the central portion of the batholith and has an apparent right-lateral horizontal displacement of about 6 km (4 mi) (Sims et al., 1985). Displacement and movement characteristics have not been reported for the other faults shown on Figure 3-4, however, their linear persistence over tens of kilometers suggests they are high-angle faults. There is no evidence of Quaternary activity along the faults within either the preliminary candidate area, or the geologic setting.

The discussion of rate of recent crustal uplift is presented in the regional geologic setting (Section 3.2.1.1.1.3). There is no evidence to suggest tectonic uplift. The uplift due to glacioisostatic rebound is relatively uniform and occurs at slow rates that will continue to decrease in the future such that this uplift is unlikely to result in any measurable changes in the regional ground-water flow system over the next 10,000 years. There are no in situ stress data available for the preliminary candidate area and its vicinity.

The absence of any igneous activity in and near the preliminary candidate area for the last 1,000 million years and the absence of Quaternary volcanism in the geologic setting (Section 3.2.1.1.1.2) indicates that future igneous activity in the area is highly unlikely.

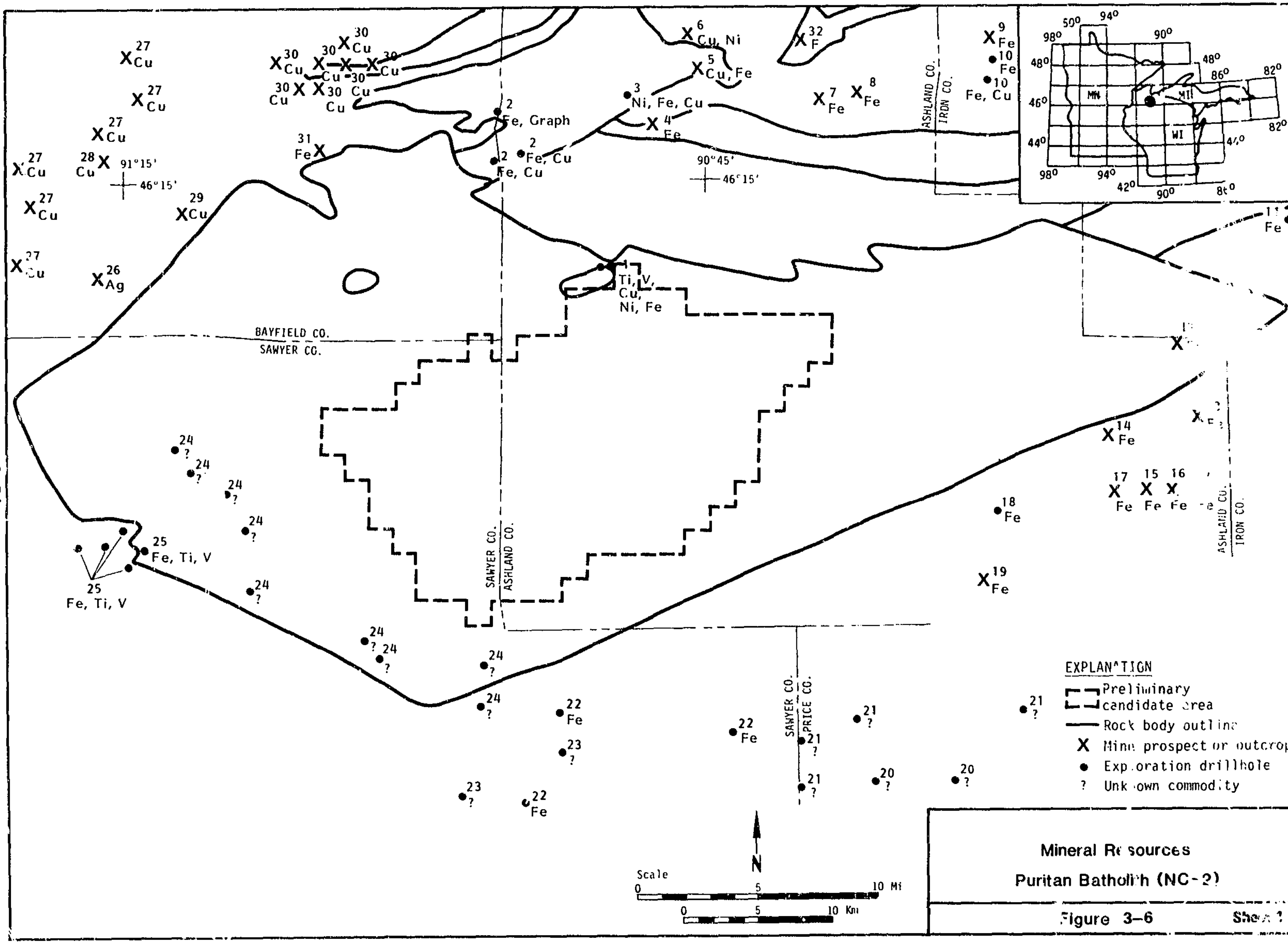
There is no evidence of igneous activity, folding, faulting, uplift, subsidence or other tectonic processes within the geologic setting during the Quaternary period. There appears to be no significant potential for tectonic deformations that could affect the regional ground-water flow system.

3.2.1.2.3 Seismicity. There are no historical earthquakes within the vicinity of the preliminary candidate area. The regional seismicity is discussed in Section 3.2.1.1.1.3.

Considering the low level and magnitude of seismic activity in the region and the absence of active tectonic processes within the geologic setting during the Quaternary Period, it is unlikely that future seismic activity would produce ground motion in excess of reasonable design limits or could affect waste containment or isolation, and it is unlikely that the frequency of occurrence of earthquakes in the area will increase in the future.

3.2.1.2.4 Mineral Resources. All strategic, metallic, and energy-related resources known to occur within 3 km (2 mi) of the preliminary candidate area are shown on Figure 3-6 and consist of several exploration drillholes (Dutton and Bradley, 1970; WGNHS, 1985). No strategic, metallic, or energy-related resources or deep mines or quarries are located within the preliminary candidate area. The nearest deep mine or quarry is the Berkshire iron mine, located approximately 15 km (9 mi) north of the preliminary candidate area (location 8 on Figure 3-6). Location 1 on Figure 3-6 is a potential strategic mineral resource site located within 3 km (2 mi) of the boundaries of the preliminary candidate area. This prospect occurs in one of several Middle Proterozoic gabbroic bodies within the Puritan batholith. These rocks have been explored for their titanium-vanadium potential because of their similarities to the Duluth Complex in Minnesota. The prospect, which is 0.8 km (0.5 mi) north of the preliminary candidate area within the Clam Lake gabbroic intrusion, has been drilled by National Lead and Inland Steel for the strategic metals titanium, vanadium, copper, nickel, and iron (WGNHS, 1985). The results of this exploration program are not available at this time and the potential depth of mineralization is unknown.

Dutton and Bradley (1970) and the WGNHS (1985) show several exploration drillholes, mines, and prospects for iron, copper, and unidentified metallic commodities within 10 km (6 mi) of the preliminary candidate area, both within and beyond the boundaries of the Puritan



Mineral Resources
Puritan Batholith (NC-2)

Figure 3-6 Sheet 1

Number	Commodity	Name	Reference
1	Ti, V. [illegible]	[illegible] Lead-Inland [illegible] Drillholes	WGNHS, 1985
2	Fe, Cu, Graphite	Bear Creek Drillholes	WGNHS, 1985
3	Ni, Fe, Cu	Bear Creek Drillholes	WGNHS, 1985
4	Fe	Guest Mine	WGNHS, 1985
5	Cu, Fe	Mineralized Outcrops	WGNHS, 1985
6	Cu, Ni	Mellen Prospect	USBM, 1983
7	Fe	Penokee Deposit	USBM, 1983
8	Fe	Berkshire (Pioneer) Mine	USBM, 1983
9	Fe	Tylers Fork Mine	WGNHS, 1985
10	Fe, Cu	International Mineral and Chemical Exploration Drillholes	WGNHS, 1985
11	Fe	Moose Lake Area Drillhole	WGNHS, 1985
12	Fe	Mineralized Outcrop	WGNHS, 1985
13	Fe	Agenda Deposit	USBM, 1983
14	Fe	Broomhandle Exploration	WGNHS, 1985
15	Fe	Unnamed Prospects	WGNHS, 1985
16	Fe	Whiteside Exploration Prospect	WGNHS, 1985
17	Fe	Ford-Lucas Exploration Prospect	WGNHS, 1985
18	Fe	North Butternut Exploration	WGNHS, 1985
19	Fe	South Butternut Deposit	USBM, 1983
20	Unknown	AMAX Exploration Drillholes	WDNR, 1985
21	Unknown	E. K. Lehman & Assoc. Drillholes	WDNR, 1985
22	Fe	Drillholes	WGNHS, 1985
23	Unknown	Loretta Exploration Drillholes	Dutton and Bradley, 1970
24	Unknown	American Immigration Exploration Drillholes	Dutton and Bradley, 1970
25	Fe, Ti, V	Round Lake Drillholes	WGNHS, 1985
26	Ag	Unknown	WGNHS, 1985
27	Cu	Mineralized Outcrops	WGNHS, 1985
28	Cu	Unnamed Prospect	USBM, 1983
29	Cu	Unnamed Prospect	WGNHS, 1985
30	Cu	Unnamed Prospects	USBM, 1983
31	Fe	Mineralized Outcrops	WGNHS, 1985
32	F	Mineralized Outcrop	WGNHS, 1985

Key to Mineral Occurrences on Figure 3-6 Puritan Batholith (NC-2)

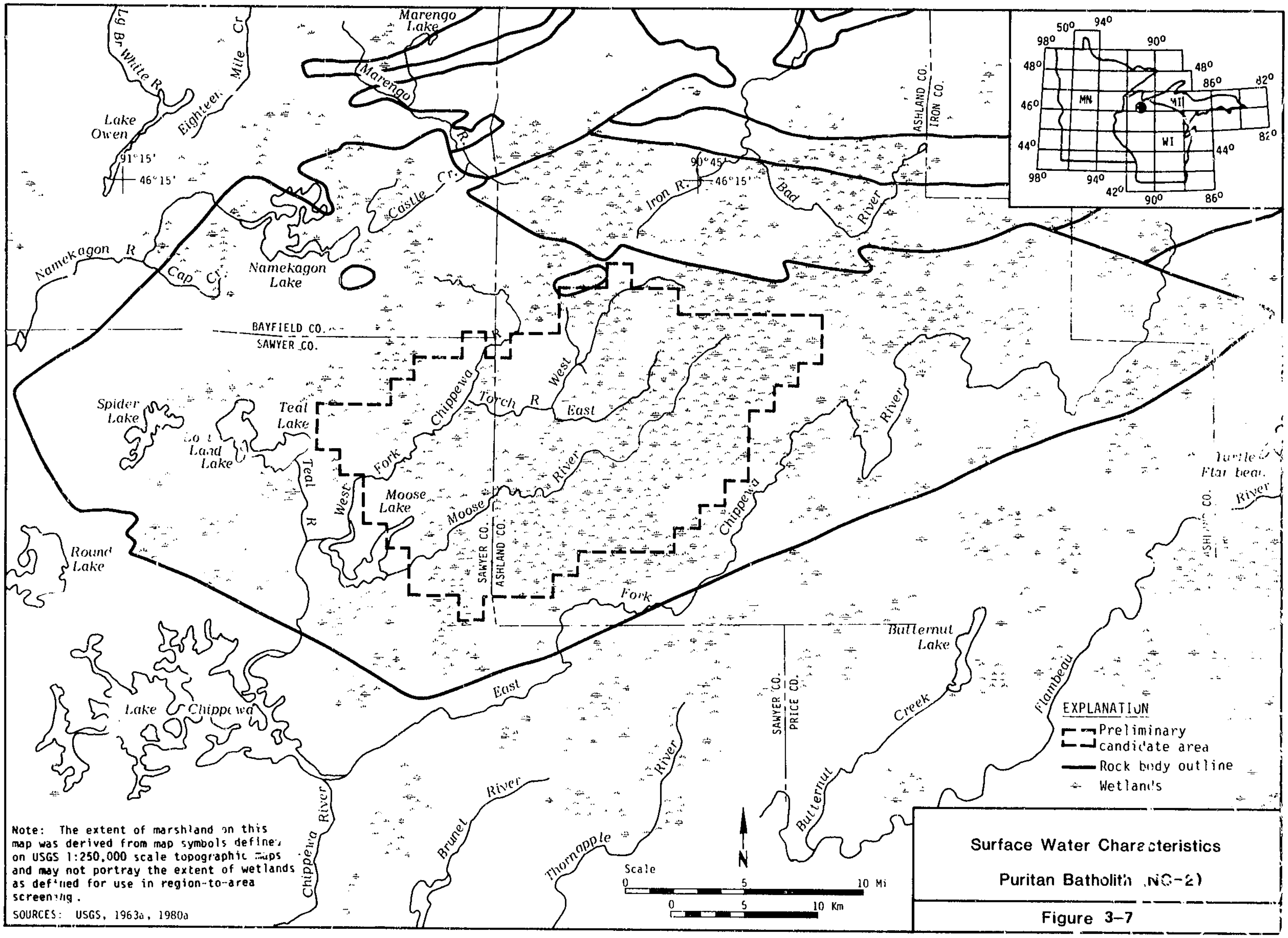
Figure 3-6 **Sheet 2**

batholith (Locations 2, 6, 22, 23, and 24 on Figure 3-6). The Guest iron mine (Location 4 on Figure 3-6), approximately 10 km (6 mi) north of the preliminary candidate area, is currently inactive and is less than 100 m (328 ft) deep. None of these resource locations are known to be unique in the North Central Region. Other natural resources within and near the preliminary candidate area (i.e., gravel pits) are shallow and widely available throughout the region.

There is no evidence for mining to a depth sufficient to affect waste isolation, and no information is available to indicate that deep exploration drillholes (greater than 100 m [328 ft] in depth) are present in the preliminary candidate area.

3.2.1.2.5 Topography and Surface Water Characteristics. The topographic relief of the preliminary candidate area is generally low with elevations ranging from 434 to 488 m (1,425 to 1,600 ft). The preliminary candidate area is drained mainly by the west fork of the Chippewa River, the Torch River, and the Moose River, which drain southwest and ultimately to the Mississippi River. Some areas to the north of the preliminary candidate area drain to Lake Superior via rivers and streams. The locations of major lakes, rivers, and wetlands in the area are shown on Figure 3-7.

As represented by the region-to-area screening data base, the preliminary candidate area is covered by less than 2% surface water and 34% wetland (USGR, 1965; USGS, various dates; Wisconsin Dept. of Natural Resources, various dates). The location of lakes, rivers, and marshlands in the preliminary candidate area shown on Figure 3-7 are based on surface water features shown on USGS 1:250,000 Ashland and Rice Lake topographic maps. Surface water bodies within the preliminary candidate area include the west fork of the Chippewa River, Moose River, Torch River, and Moose Lake. Other surface water bodies near the preliminary candidate area include the east fork of the Chippewa River, Teal River, Iron River, Bad River, Lost Land Lake, Teal Lake, Spider Lake, Namekagon Lake, and Lake Chippewa, as well as numerous small streams and lakes.



Note: The extent of marshland on this map was derived from map symbols defined on USGS 1:250,000 scale topographic maps and may not portray the extent of wetlands as defined for use in region-to-area screening.

SOURCES: USGS, 1963a, 1980a

Surface Water Characteristics

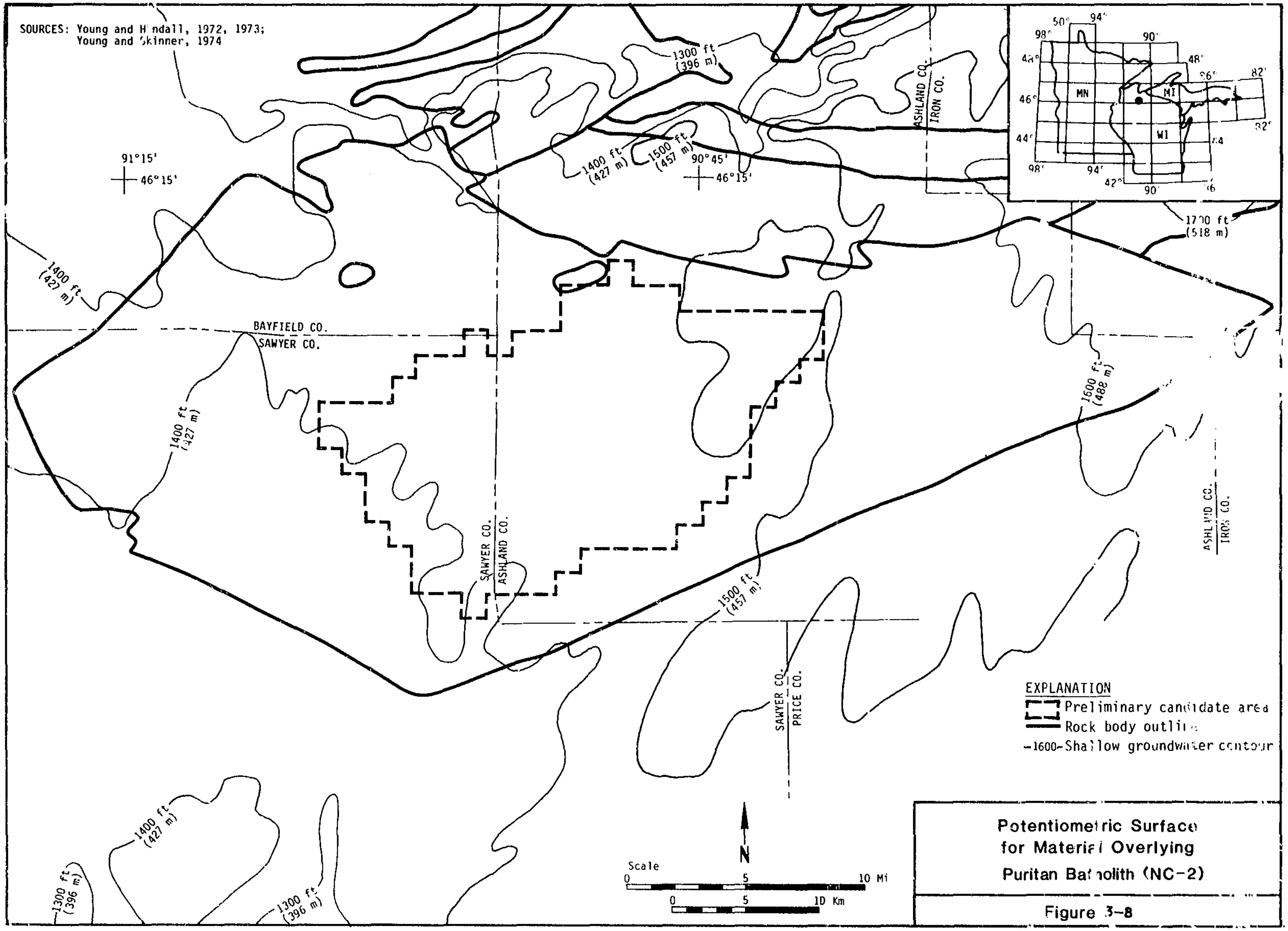
Puritan Batholith (NC-2)

Figure 3-7

The territory within [illegible] the preliminary candidate area has not been identified as a major flo[illegible] area under the Wisconsin Land Resources Analysis Program (Wisconsin Dept. of Administration, 1975). Significant flooding is generally associated with major streams, steep slopes, and well-developed floodplains. These features are essentially absent in the preliminary candidate area and most of the streams that drain the area are minor streams with relatively low discharges. No reservoirs or impoundments are known to exist in or upstream of the preliminary candidate area.

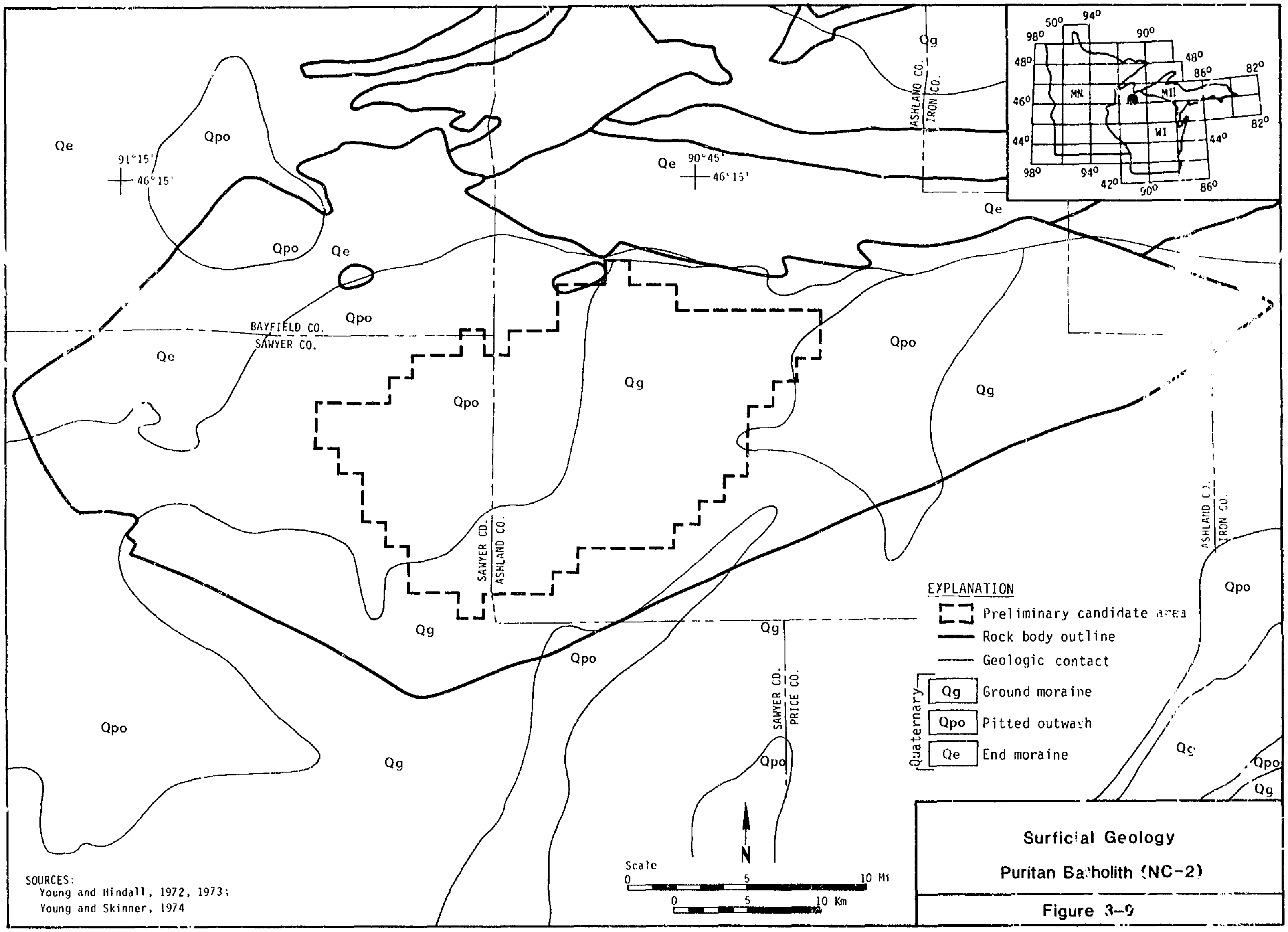
3.2.1.2.6 Ground-Water Resources. The regional hydrology is discussed in Section 3.2.1.1.1.5. Shallow ground-water movement is generally southwestward toward the Chippewa River. Figure 3-8 shows shallow ground-water contours reported by Young and Hindall (1972; 1973) and Young and Skinner (1974). Areas that displayed significant convergence of shallow water table contours, based on a 30-m (100-ft) contour interval, were considered potential major discharge zones. These generally correspond to locations of major streams and rivers. No major discharge zones have been identified in the preliminary candidate area (DOE, 1985c).

Ground water in and near the preliminary candidate area is primarily obtained from glacial sediments that include till, sand, and gravel within ground and end moraines and sand and gravel within outwash deposits (Young and Hindall, 1972; 1973; Young and Skinner, 1974). The horizontal extent of surficial deposits is shown on Figure 3-9. Aquifers in the preliminary candidate area have relatively low yields (0.3 to 0.9 L/s [5 to 15 gpm]), but can yield up to 6.3 to 12.6 L/s (100 to 200 gpm) locally. Surficial outwash deposits that are located at the eastern edge of the preliminary candidate area are known to yield an average of 63 L/s (1,000 gpm) and as high as 150 L/s (2,400 gpm) in some



Potentiometric Surface for Material Overlying Puritan Batholith (NC-2)

Figure 3-8



Surficial Geology

Puritan Batholith (NC-2)

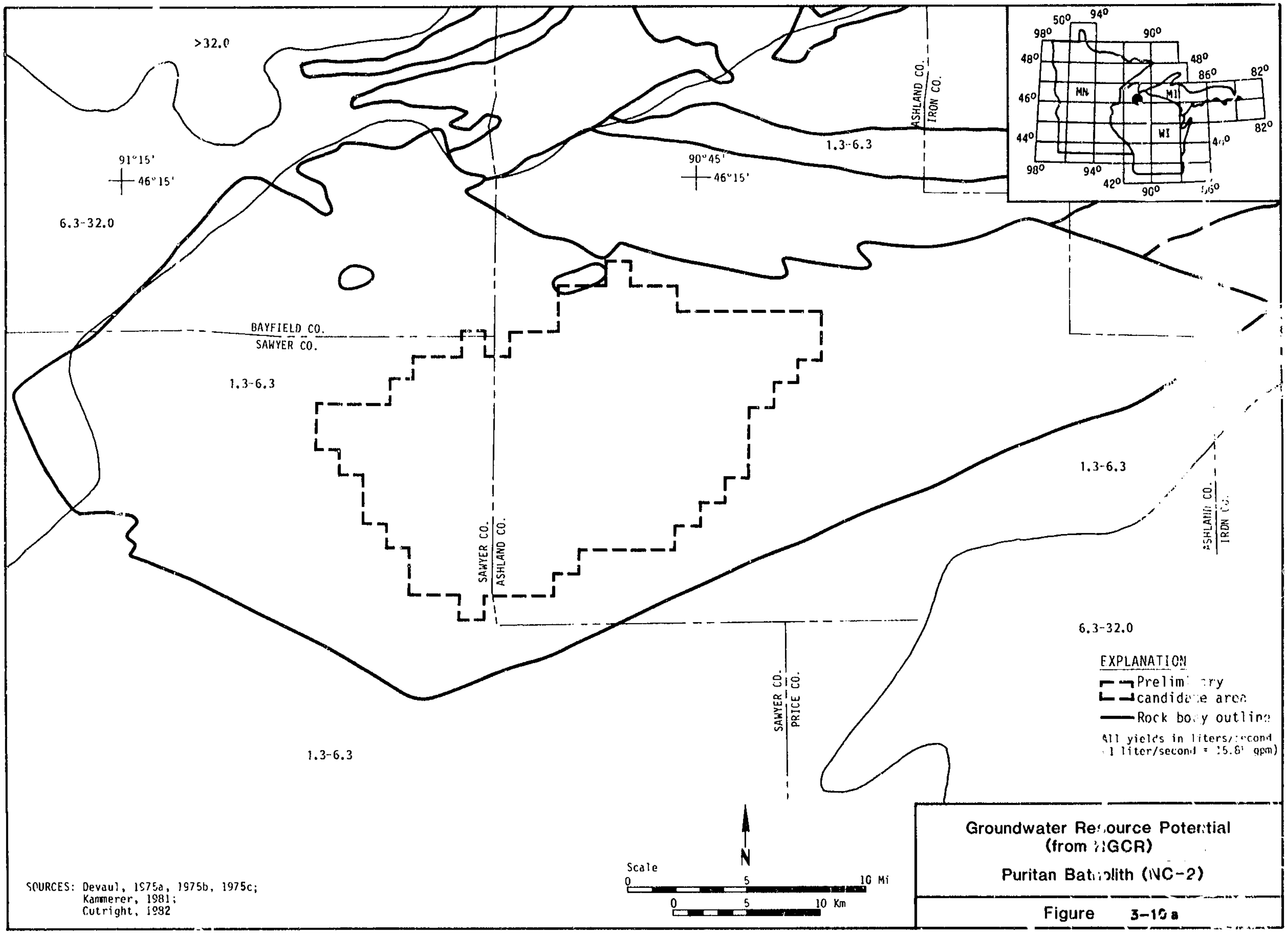
Figure 3-9

areas in the Chippewa River [illegible]. Well yields presented in the North Central RGCR (DOE, 1985c) were estimated from maps by Devaul (1975a; 1975b; 1975c), Kammerer (1981), and Cutright (1982) and are shown on Figure 3-10a. Additional detailed well yield information has been reported by Young and Hindall (1972, 1973) and Young and Skinner (1974) in USGS Hydrologic Atlasses and is shown on Figure 3-10b. Some estimated well yields shown on these two figures may not agree; however, there is currently no basis for determining which data set is more representative of actual well yields. Both data sets are shown for comparison.

The data indicate that relatively shallow Quaternary aquifers that contain potable ground water are present within the candidate area. No deep wells (i.e., greater than 100 m [328 ft.] in depth) have been reported in the literature. Therefore, local ground-water conditions in the deeper crystalline rock are currently unknown.

3.2.1.2.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including erosion and deposition, and vertical crustal movement is in Section 3.2.1.1.1.1.

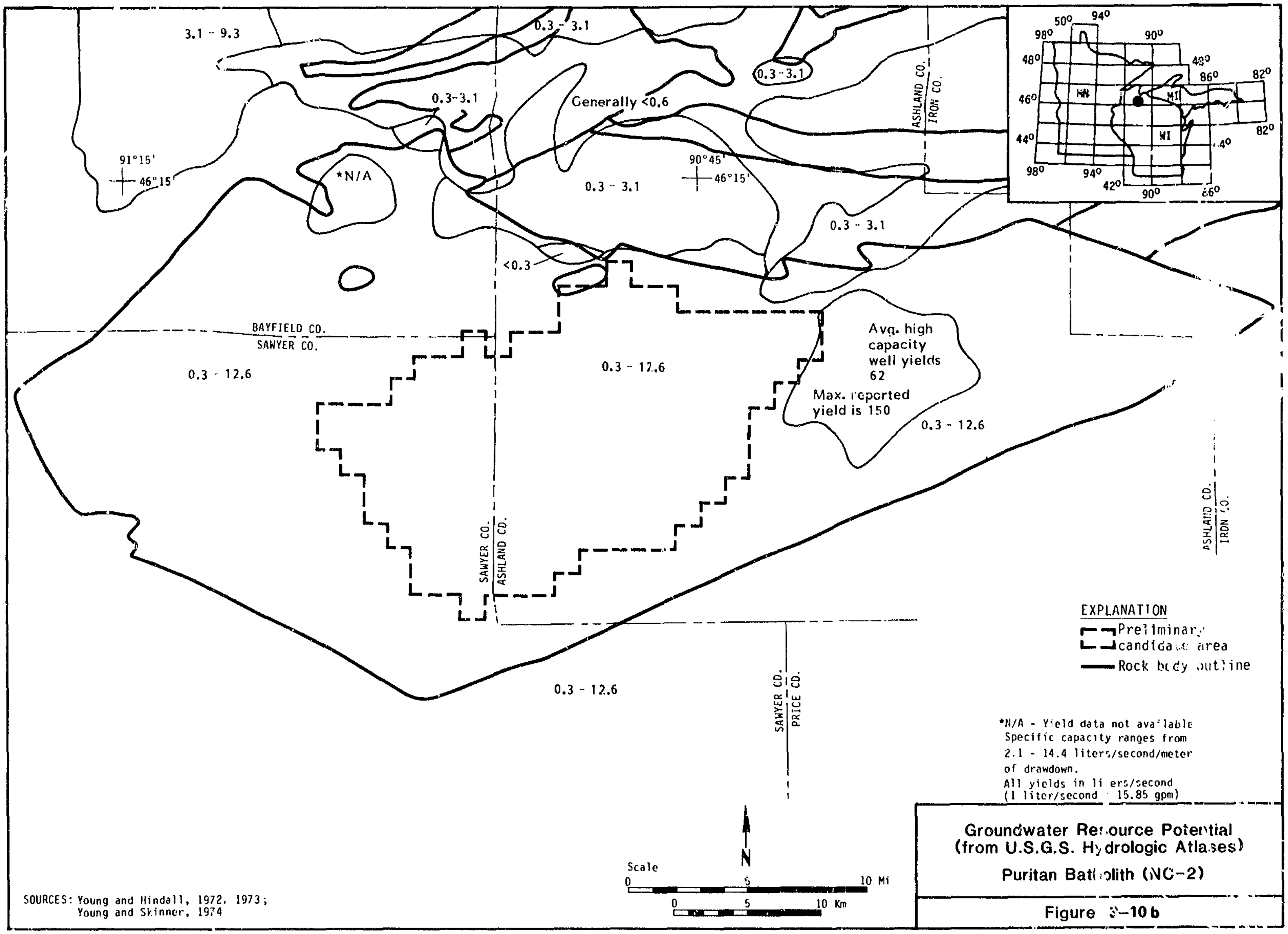
3.2.1.2.8 Federal Lands. There are no disqualified Federal lands located within the boundaries of the preliminary candidate area. However, virtually the entire preliminary candidate area lies within the Chequamegon National Forest (which was not disqualified) (Figure 3-11). No research natural areas (disqualified components of National forest lands) have been identified in or within 10 km (6 mi) of the preliminary candidate area. The Chequamegon National Forest is greater than 130 ha (320 ac) in size and is depicted on Plate 2B of the North Central RECR (DOE, 1985d). There is no evidence in the data base that Federal lands less than 130 ha (320 ac) in size are located in or within 10 km (6 mi) of the preliminary candidate area.



Groundwater Resource Potential (from NGCR)

Puritan Batholith (NC-2)

Figure 3-10a



Groundwater Resource Potential (from U.S.G.S. Hydrologic Atlases)

Puritan Batholith (NC-2)

Figure 3-10b

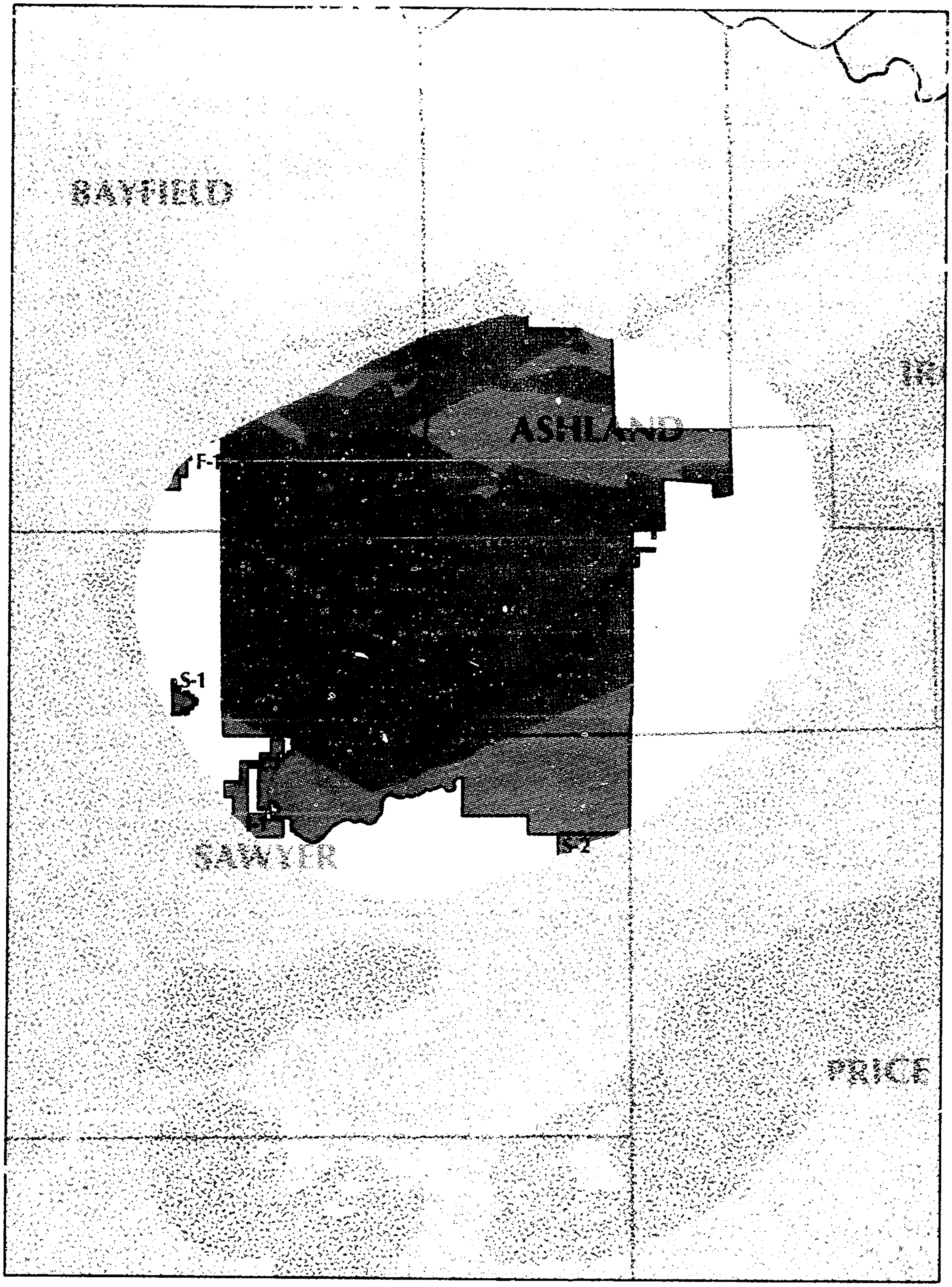


Figure 3- 11 Sheet 1

Environmental Features
Puritan Batholith (NC-2)

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

P Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile

F Federal Lands Greater Than 320 Acres

S State Lands Greater Than 320 Acres

I Federal Indian Reservations

● Federal or State Lands Less Than 320 Acres

F-5 Map Alpha-numeric Codes are Keyed to Environmental Features

Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

0 miles 20

0 kilometers 20

Figure 3-11 Sheet 2

ENVIRONMENTAL FEATURES WITHIN 16 KM (10 MI) OF PRELIMINARY CANDIDATE AREA NC-2*

Code	Feature
Population Features	
None	
Federal Lands	
F-1	St. Croix National Wild and Scenic River
F-2	Rock Lake National Recreation Trail
F-3	Chequamegon National Forest
State Lands	
S-1	Chief River Wildlife Area
S-2	Flambeau River State Forest
Indian Reservations	
I-1	Lac Courte Oreilles Indian Reservation

* The accompanying text identifies only those environmental features within 10 km (6 mi) of the preliminary candidate area.

Figure 3-11, Sheet 3

3.2.1.2.9 State Lands. No State lands lie in or within 10 km (6 mi) of the preliminary candidate area. State lands greater than 130 ha (320 ac) in size which occur in Wisconsin are depicted on Plates 3B or 4B of the North Central RECR (DOE, 1985d). There is no evidence in the data base that State lands less than 130 ha (320 ac) in size are located in or within 10 km (6 mi) of the preliminary candidate area.

3.2.1.2.10 Environmental Compliance. There are no air quality nonattainment areas or Prevention of Significant Deterioration (PSD) Class I Areas located in or within 40 km (25 mi) of the preliminary candidate area (40 CFR 81). No sites listed on the National Register of Historic Places (NRHP) and no proposed NRHP sites are located within the preliminary candidate area. In the regional data base, there are no known existing archaeological sites or districts nor any proposed for designation within the preliminary candidate area. No National Trails are located within the preliminary candidate area. The Rock Lake National Recreation Trail passes within 6.5 km (4 mi) of the northwest corner of the preliminary candidate area (USFS, n.d.). The North Country National Scenic Trail passes within 18 km (11 mi) of the preliminary candidate area's northern boundary (NPS, 1982).

3.2.1.2.11 Population Density and Distribution. There are no highly populated areas in or within 16 km (10 mi) of the preliminary candidate area. In addition, there are no areas with population densities greater than or equal to 1,000 persons per square mile in or within 16 km (10 mi) of the preliminary candidate area. Duluth/Superior is located approximately 96 km (60 mi) northwest of the preliminary candidate area. The highly populated areas and areas with population densities greater than or equal to 1,000 persons per square mile in Wisconsin are depicted on Plates 5B and 6B of the North Central RECR (DOE, 1985d). The average population density of the preliminary candidate area is 3 persons per square mile. The average population density within 80 km (50 mi) of the preliminary candidate area is approximately 13 persons per square mile.

Low population density is defined as a density in the general region (80 km or 50 mi) of the site less than the average population density for the conterminous United States (76 persons per square mile) based on the 1980 census.

3.2.1.2.12 Site Ownership. There are no DOE-owned lands located within the preliminary candidate area. As mentioned in Section 3.2.1.2.8, the Chequamegon National Forest encompasses virtually the entire preliminary candidate area. The Lac Courte Oreilles Indian Reservation is located approximately 8 km (5 mi) southwest of the preliminary candidate area, the Bad River Indian Reservation is located approximately 20 km (12.4 mi) northeast of the preliminary candidate area, and the Lac du Flambeau Indian Reservation is located approximately 50 km (31 mi) east of the preliminary candidate area (see Figure 3-11 and Plate NC-1B). The U.S. Navy maintains a test facility for its Extremely Low Frequency (ELF) submarine communication project within the preliminary candidate area. The facility consists of several buildings occupying approximately 0.8 ha (2 ac) and four antennas, each of which extends 11 km (7 mi) from the buildings (with one antenna extending in each of the north, south, east, and west directions). The buildings are located approximately 10 km (6 mi) south of the village of Clam Lake (Klessig and Strite, 1980).

3.2.1.2.13 Offsite Installations. No commercial nuclear reactors are located within the preliminary candidate area. The nearest operating commercial nuclear reactors are Prairie Island 1 and 2 which are approximately 195 km (122 mi) to the southwest (Michelewicz and Vann, 1983; DOE, 1984c). The nearest commercial nuclear reactor under construction is Byron 2, which is 484 km (300 mi) to the south (Nuclear News, 1985). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.1.2.14 Transportation. The interstate highways near the preliminary candidate area are I35 in Minnesota, which is about 105 km (65 mi) northwest, and I94, to the south southwest approximately 144 km (90 mi). U.S. highways near the preliminary candidate area are U.S. 2, 8, 51, 53, and 63. U.S. 63 is the nearest, located about 24 km (15 mi) west and northwest of the preliminary candidate area. U.S. 2 is approximately 40 km (25 mi) north. U.S. 51 is about 40 km (25 mi) east, and U.S. 8 is approximately 56 km (35 mi) south. U.S. 53, which is an important U.S. highway in this part of Wisconsin, is over 64 km (40 mi) to the southwest. U.S. 53 is a limited access road from near Eau Clair to north of Rice Lake, Wisconsin. State Route 77 crosses the preliminary candidate area from east to west and extends from U.S. 63 at Hayward, Wisconsin, in the west to State Route 13 at the eastern edge of the preliminary candidate area. State Route 13, a principal highway, is within 0.6 km (1 mi) of the eastern boundary of the preliminary candidate area. This highway is one of the more important State highways in Wisconsin between Ashland in the north and Wisconsin Dells on I90/94 in the south central portion of the State. State Route 70 runs about 11 km (7 mi) from the southern edge of the preliminary candidate area.

The Soo/Milwaukee mainline railroad between Chicago and Duluth is approximately 40 km (25 mi) southwest of the preliminary candidate area. The Soo/Milwaukee has a branchline that passes within 5 km (3 mi) of the eastern edge of the preliminary candidate area. This rail line parallels State Route 13 between Marshfield and Ashland, Wisconsin. This line used to extend from Hayward to Ashland (approximately 24 km [15 mi] from the preliminary candidate area) before it was abandoned in the late 1970s.

Based on the data presented above, access to the preliminary candidate area from both local and regional highway and railway systems appears to be available.

3.2.1.2.15 <u>Preliminary Candidate Area Deferral Analysis</u>. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area NC-2 that could affect DOE's decision to defer further consideration of the area. Based on evaluation of this additional available information, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]
- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]
- low potential for tectonic deformations suggest that the regional ground-water flow systems should not be significantly affected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]
- absence of historical earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that the frequency of earthquake occurrence within the geologic setting may increase [960.4-2-7(c)(3)]

- the frequ[illegible]rrence or magnitude of earthquakes within the ge[illegible]ic setting are no higher than within the region [960.4-2-7(c)(4)]
- absence of historical earthquakes that, if they recurred, could produce ground motion in excess of reasonable design limits [960.5-2-11(c)(2)]
- absence of evidence, based on correlations of earthquakes with tectonic processes and features within the geologic setting, that the magnitude of earthquakes during repository construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]
- no evidence of subsurface mining or extraction for resources that could affect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence of drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]
- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]
- presence of generally flat terrain [960.5-2-8(b)(1)]
- general absence of surface characteristics or surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]
- absence of Federal lands less than 130 ha (320 ac) within and in proximity to (i.e., within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(3)]
- absence of State lands less than 130 ha (320 ac) within and in proximity to (i.e., within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(4)]
- The preliminary candidate area is beyond 16 km (10 mi) from highly populated areas or areas containing more than 1,000 persons per square mile [960.5-2-1(b)(2) and (c)(2)]

- low population density within its boundaries and within 80 km (50 mi) of the preliminary candidate area [960.5-2-1(b)(1)]
- absence of nuclear installations [960.5-2-4(b) and (c)(2)]
- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2), 960.5-2-7(b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)]
- projected land ownership conflicts (i.e., presence of Chequamegon National Forest and the Elf Project) that may not be resolvable through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings [960.4-2-8-2(c), 960.5-2-2(c)].

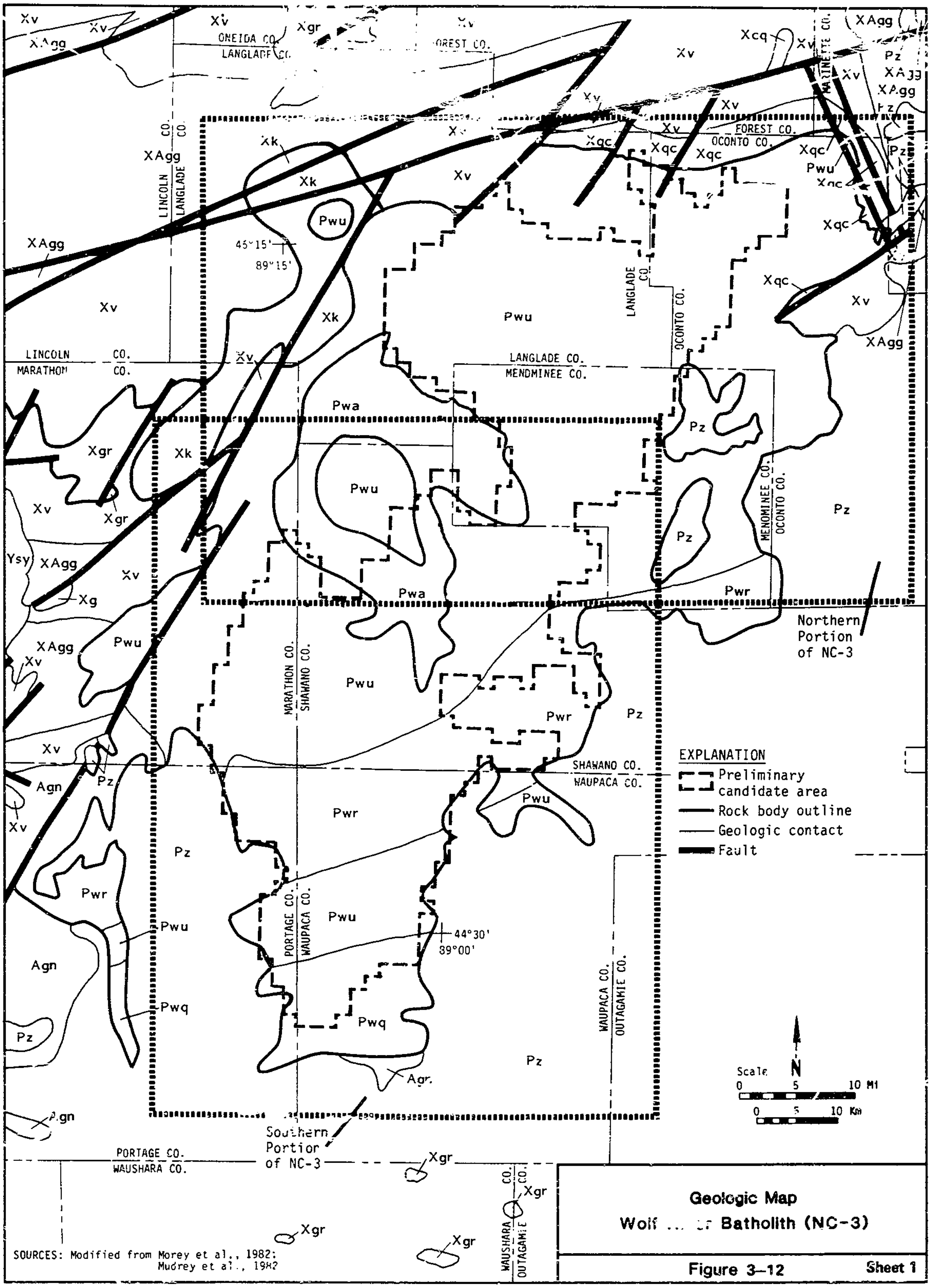
The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area NC-2 at this time.

3.2.1.3 Preliminary Candidate Area Description - Wolf River Batholith (NC-3)

The Wolf River batholith is located within the Northern Highlands physiographic province in east-central Wisconsin. The preliminary candidate area identified in the Wolf River batholith is located within Langlade, Oconto, Shawano, Menominee, Marathon, Portage, and Waupaca Counties centered at approximately 45° N latitude and 89° W longitude. Because of the large areal extent of the preliminary candidate area, the geologic discussions and figures (except for the Geologic Map, Figure 3-12) have been divided into a northern portion and a southern portion. Figure 3-12 shows the locations of the northern and southern portions described in the following sections.

3.2.1.3.1 Host Rock Geometry and Overburden Thickness. The preliminary candidate area shown on Figure 3-12 has an area of approximately 2,844 km^2 (1,094 mi^2) and overlies the Wolf River batholith, the mapped extent of which is largely inferred from geophysical data and scattered outcrops (Morey, et al., 1982). The batholith is approximately 145 km (88 mi) long and varies in width from 5 to 47 km (3 to 29 mi). Data on the vertical extent of the Wolf River batholith are not available within the preliminary candidate area; however, the batholith is inferred to extend to depths on the order of several kilometers (miles) based on the present understanding of the mode of emplacement of batholiths and seismic reflection studies in batholithic terranes which suggest that most batholiths are tabular in shape and extend to a depth of 6 to 10 km (4 to 6 mi) (Hamilton and Myers, 1967; Lynn et al., 1981). Furthermore, no postemplacement deformational processes such as large-scale thrust faulting are known to have diminished the vertical extent of the batholith.

Approximately 10% of the preliminary candidate area has exposed bedrock. Contours of overburden thickness (Figures 3-13a and 3-13b) for the preliminary candidate area indicate that the central part is generally



Geologic Map
Wolf ... Batholith (NC-3)

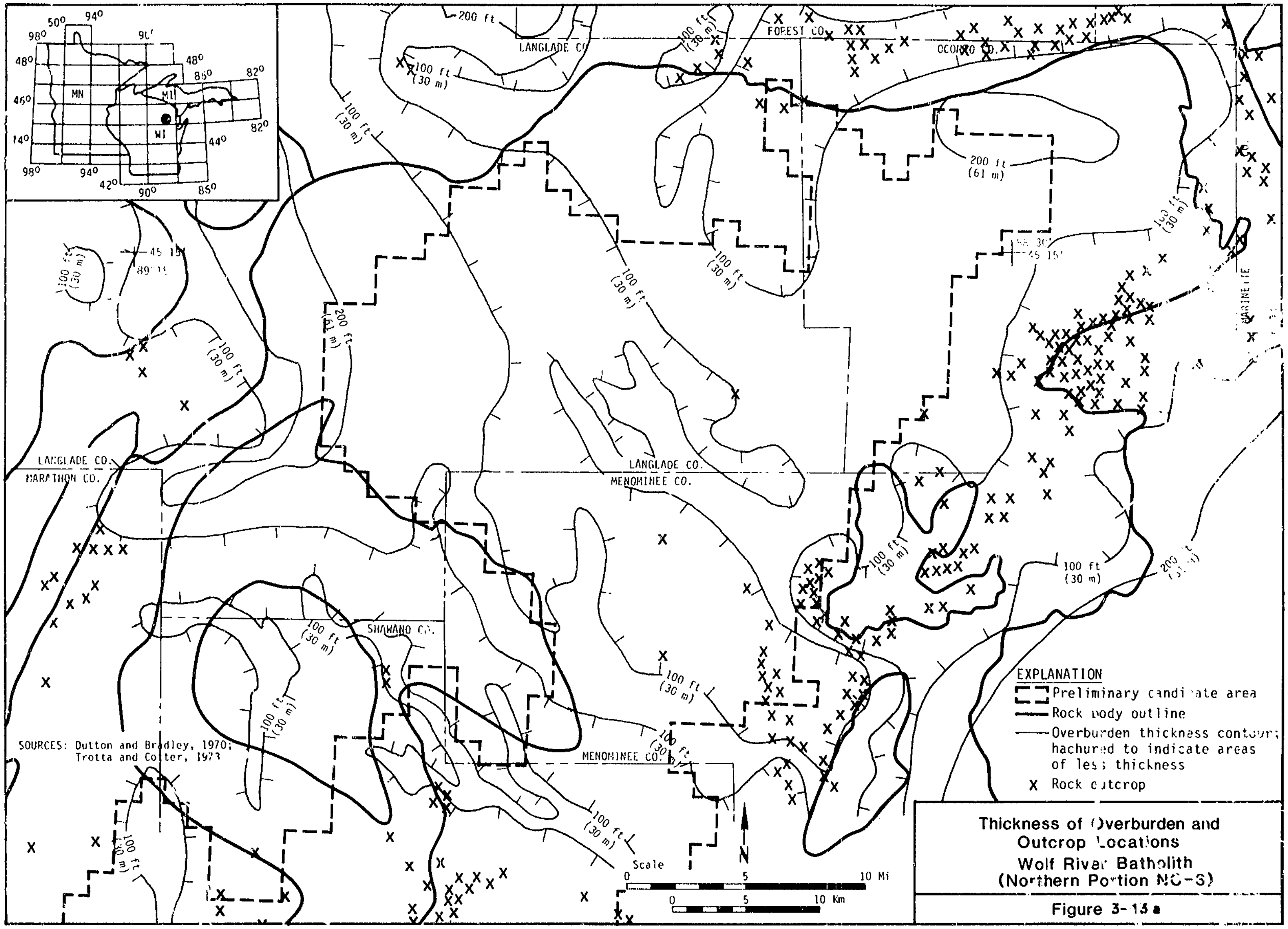
Figure 3–12 Sheet 1

EXPLANATION OF GEOLOGIC UNITS

PALEOZOIC	Pz	Sedimentary rocks, undivided
MIDDLE PROTEROZOIC	Ysy	Rocks of the syenite complex at Wausau, Wisconsin
MIDDLE PROTEROZOIC	Pwu	Wolf River Batholith, undivided
MIDDLE PROTEROZOIC	Pwr	Wolf River Batholith, quartz monzonite
MIDDLE PROTEROZOIC	Pwq	Wolf River Batholith, rapakivi-textured quartz monzonite
MIDDLE PROTEROZOIC	Pwa	Wolf River Batholith, anorthosite
EARLY PROTEROZOIC	Xgr	Rhyolite, coeval granite and epizonal granite
EARLY PROTEROZOIC	Xg	Granitoid rock
EARLY PROTEROZOIC	Xk	Kalinke Quartz Monzonite
EARLY PROTEROZOIC	Xv	Felsic and mafic metavolcanic rocks, subvolcanic intrusive rocks, and intrusive rocks
EARLY PROTEROZOIC	Xqc	Quartzite and Conglomerate
EARLY PROTEROZOIC / ARCHEAN	XAgg	Gneiss, amphibolite, and granitoid rocks
ARCHEAN	Agn	Migmatitic gneiss, amphibolite, and granite

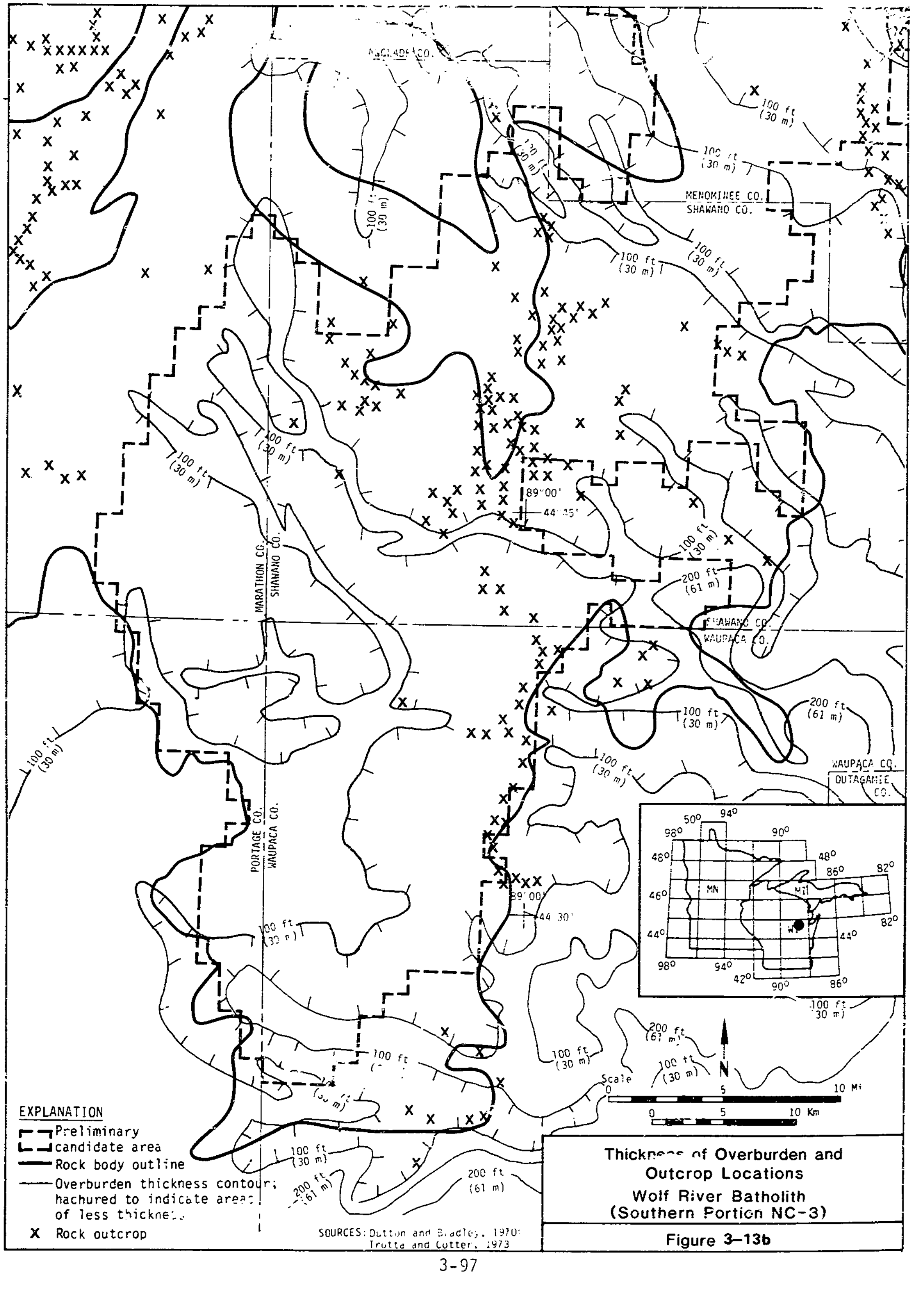
Explanation for Figure 3-12
Wolf River Batholith (NC-3)

Figure 3-12 Sheet 2



Thickness of Overburden and Outcrop Locations
Wolf River Batholith
(Northern Portion NC-3)

Figure 3-15a



Thickness of Overburden and Outcrop Locations
Wolf River Batholith
(Southern Portion NC-3)

Figure 3–13b

covered by less than 30 m (100 ft) of overburden, whereas the northern portion (Figure 3-13a) is covered by 30 to 61 m (100 to 200 ft) of overburden (Trotta and Cotter, 1973). The majority of the southern portion (Figure 3-13b) contains less than 30 m (100 ft) of overburden (Trotta and Cotter, 1973); however, there are several narrow irregular-shaped areas where overburden is between 30 and 61 m (100 and 200 ft) thick.

On the basis of the data presented above and the assumed depth and size of a repository in crystalline rock (see Section 1.5), the preliminary candidate area overlying the Wolf River batholith is sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation.

3.2.1.3.2 Lithology and Tectonics. The Wolf River batholith is a rapakivi massif consisting of 10 distinct plutons. These include the Waupaca adamellite, Red River adamellite, Wiborgite porphyry, Hager granite, Wolf River granite, Belongia coarse granite, Belongia fine granite, High Falls granite, the Peshtigo monzonite and the Tigerton anorthosite (Van Schmus et al., 1975; Anderson, 1975; Anderson and Cullers, 1978). The batholith is composed of potassium feldspar, quartz, plagioclase, biotite, hornblende, and minor amounts of grunerite, olivine, clinopyroxene, orthopyroxene, sphene, zircon, apatite, fluorite, and allanite (Anderson, 1975; Anderson and Cullers, 1978).

The contacts between the plutons of the batholith differ in shape and location on the available geologic maps (Weis, 1965; Van Schmus et al., 1975; Anderson, 1975; Anderson and Cullers, 1978; Fitzsimonds et al., 1982; Morey et al., 1982; Mudrey et al., 1982; LaBerge and Myers, 1983), probably as a result of the rock exposure, geophysical interpretations, and different map scales. The map by Mudrey et al. (1982) is the most recent of the batholith and is shown on Figure 3-12. However, the most detailed pluton descriptions are given by Anderson (1975), Anderson and Cullers (1978), and Van Schmus et al. (1975) and were used to develop the following summary. The Wolf River granite and Red River adamellite comprise over 75% of the batholith. Most of the other plutons are exposed in the northeast corner of the batholith. The majority of the preliminary candidate area is underlain by the Wolf River granite and the Red River adamellite, although the northeast tip of the area may be underlain by the Belongia or Hager granites.

Anderson (1975) noted that there was sparse evidence for stoping in the batholith as there are few inclusions of the country rock. The Tigerton anorthosite forms a large inclusion in the batholith (Weis, 1965). Contacts between the batholith and country rocks to the west and north are intrusive, sharp, and vary from concordant to discordant (Anderson, 1975; Mudrey et al., 1982). The batholith is unconformably overlain by Cambrian sandstone and siltstone to the south and east (Mudrey et al., 1982). Contacts between the plutons comprising the batholith range from sharp to gradational over distances of 2 to 3 km (1 to 2 mi) (Anderson, 1975).

Van Schmus et al. (1975) obtained a uranium-lead date of 1,485 ± 15 million years from cogenetic zircon fractions from the Wolf River batholith. Anderson (1975) and Anderson and Cullers (1978) suggested a crustal fusion origin at intermediate to lower crustal levels (25 to 36 km [15 to 22 mi]) and emplacement and crystallization at less than 4 km (2.5 mi) for the batholith based on pluton compositions.

All of the plutons of the batholith are cut by pegmatite and aplite dikes. These dikes are abundant in the Tigerton anorthosite and common in the Red River adamellite and the eastern portion of the Wolf River granite (Anderson, 1975).

The Wolf River batholith has been interpreted to be an anorogenic intrusive associated with a major belt of 1,370 to 1,485 million years predominately rhyolitic volcanic rocks and shallow granitic plutons that extends from northern Texas to northwestern Ohio (Van Schmus and Bickford, 1981). Based on chemical and mineralogical similarity with younger magmatic analogs. A[illegible] and Anderson and Cullers (1978) proposed a tectonic model for the batholith. They suggested that the intrusion was in response to thermal doming in an extensional tectonic regime leading to continental separation in the western Cordillera (pre-belt) and extensive crustal fusion with no rifting or separation across the North American craton. Subsequent to the intrusion of the batholith, the only major tectonic event in the North Central Region was the development of the Midcontinent rift system at 1,110 million years ago (Van Schmus et al., 1982). The effect of the rifting on the batholith was very minor and is limited to the intrusion of two diabase dikes (Sims et al., 1978).

Three 14- to 17-km (8- to 10-mi) long, northeast-trending faults terminate within or near the northern part of the preliminary candidate area. The type of faults and displacement characteristics have not been reported in the literature. The major Eau Claire River shear zone may form much of the western border of the batholith. This northeast-trending shear zone has been mapped for about 64 km (39 mi) and its nearest approach to the preliminary candidate area is approximately 5 km (3 mi). The existence of this shear zone is controversial (LaBerge, 1973, 1976; Ard, 1979; and Maass, 1983). There is also no evidence of Quaternary activity along the faults or within the geologic setting.

Foliation and joints have been described in the batholith. Anderson (1975) described the plutons of the batholith as ranging from massive to weakly foliated. The foliation trends predominantly northeast except in the northeastern portion of the batholith where it changes to a northwest trend (Anderson, 1975). Weis (1965) identified the regional joint trends (a primary joint trend of N 20° W and a secondary joint trend of N 75° E) superimposed on the Tigerton anorthosite and the surrounding granites.

A discussion of recent crustal uplift is presented in the regional geologic setting (Section 3.2.1 1.1.3). There is no evidence to suggest tectonic uplift. The uplift due to glacioisostatic rebound is relatively uniform and occurs at slow rates that will continue to decrease in the future such that the uplift is unlikely to result in any measurable changes in the regional ground-water flow system over the next 10,000 years. There are no in situ stress data available for the vicinity of the preliminary candidate area.

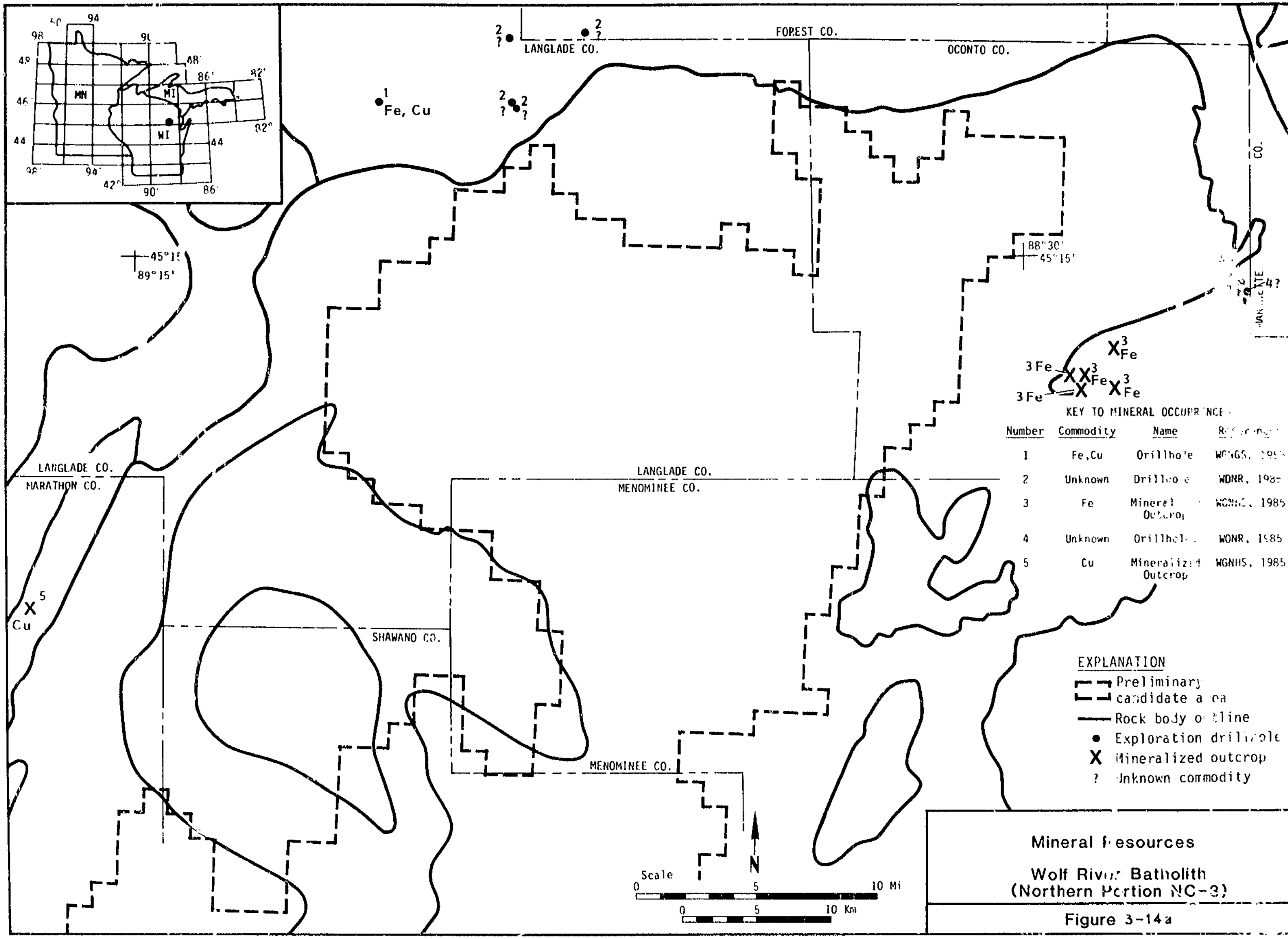
The absence of any igneous activity in and near the preliminary candidate area for the last 1,000 million years and the absence of Quaternary volcanism in the geologic setting (Section 3.2.1.1.1.2) indicate that future igneous activity in the area is highly unlikely.

There is no evidence of igneous activity, folding, faulting, uplift, subsidence, or other tectonic processes within the geologic setting during the Quaternary Period. There appears to be no significant potential for tectonic deformations that could affect the regional ground-water flow system.

3.2.1.3.3 Seismicity. There are no historical earthquakes reported within the vicinity of the preliminary candidate area. There are no known geologic structures near the preliminary candidate area that might be expected to induce seismic activity of greater frequency of intensity than that which is typical of the region. The regional seismicity is discussed in Section 3.2.1.1.1.3.

Considering the low level and magnitude of seismic activity in the region and the absence of active tectonic processes within the geologic setting during the Quaternary Period, it is unlikely that seismic activity would produce ground motion in excess of reasonable design limits or could affect waste containment or isolation, and it is unlikely that the frequency of occurrence of earthquakes in the preliminary candidate area will increase in the future.

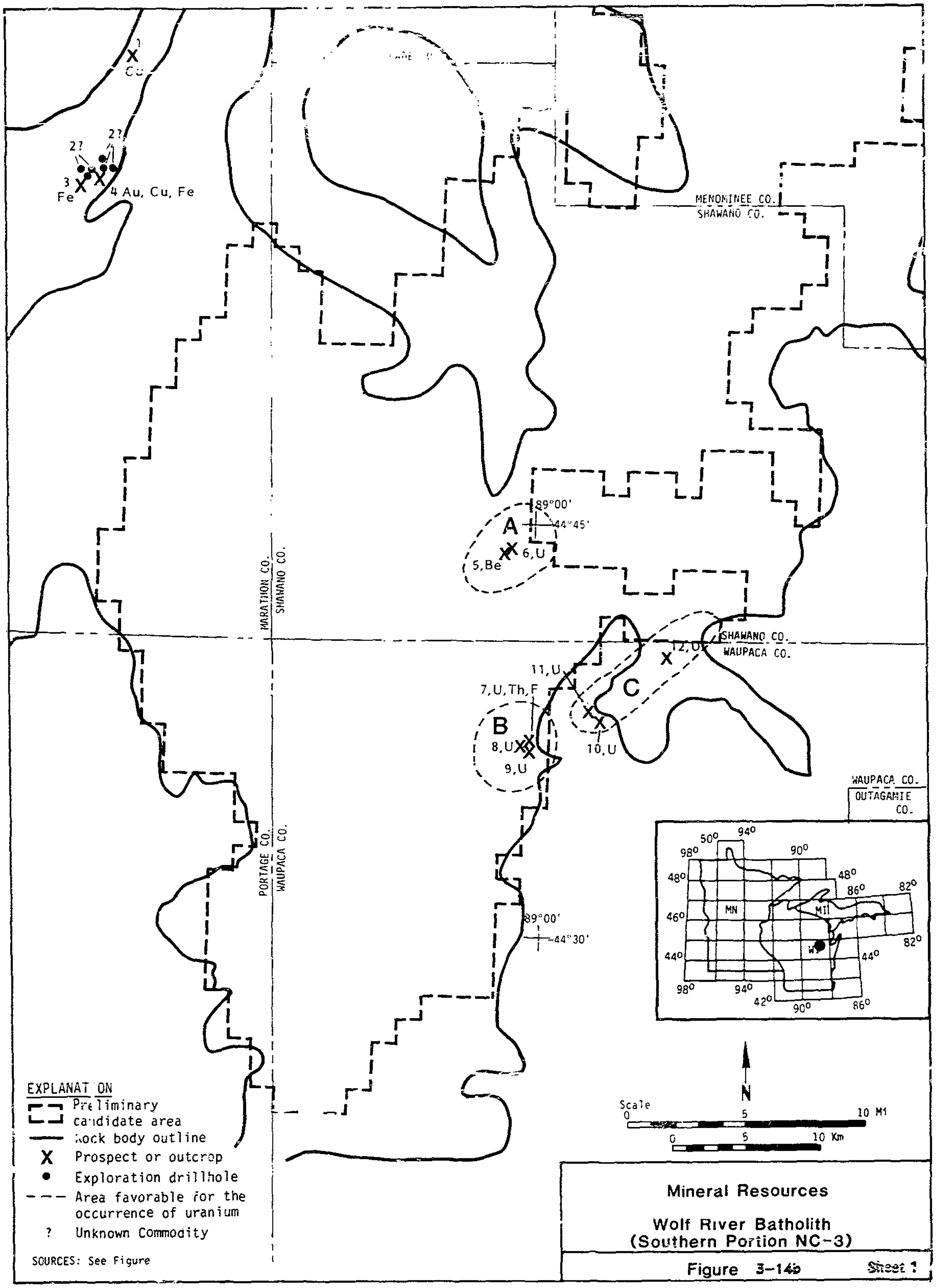
3.2.1.3.4 Mineral Resources. All strategic, metallic, and energy-related resources known to occur either in or within 3 km (2 mi) of the preliminary candidate area are shown on Figures 3-14a and 3-14b and



Mineral Resources

Wolf River Batholith (Northern Portion NC-3)

Figure 3-14a



1
Cu
2?
2?
3
Fe
4 Au, Cu, Fe
MENOMINEE CO.
SHAWANO CO.
MARATHON CO.
SHAWANO CO.
89°00'
44°45'
A
5,Be
6,U
SHAWANO CO.
WAUPACA CO.
12,U
11,U
7,U,Th,F
C
B
8,U
9,U
10,U
WAUPACA CO.
OUTAGAMIE CO.
PORTAGE CO.
WAUPACA CO.
89°00'
44°30'
MN
MI
WI
N
Scale
0
5
10 Mi
0
5
10 Km
EXPLANATION
Preliminary candidate area
Rock body outline
X Prospect or outcrop
• Exploration drillhole
Area favorable for the occurrence of uranium
? Unknown Commodity
SOURCES: See Figure
Mineral Resources
Wolf River Batholith
(Southern Portion NC-3)
Figure 3-14b Sheet 1

Number	Commodity	Name	Reference
1	Cu	Mineralized Outcrop	WGNHS, 1985
2	Unknown	Exploration Drillholes	WDNR, 1985
3	Fe	Mineralized Outcrop	WGNHS, 1985
4	Au, Cu, Fe	Easton Gold Prospect	LaBerge and Meyers, 1983
5	Be	Split Rock Beryllium Occurrence	WGNHS, 1961
6	U	Tigerton Dells East and West Uranium Occurences	Fitzsimonds et al., 1982
7	U, Th, F	Anklam Farm	Fitzsimonds et al., 1982
8	U	Radies Shaft	Fitzsimonds et al., 1982
9	U	Radies Farm	Fitzsimonds et al., 1982
10,11	U	F and K Claims	Fitzsimonds et al., 1982
12	U	Marion Occurrence	Fitzsimonds et al., 1982

Areas Favorable for the Occurrence of Uranium (Fitzsimonds et al., 1982)

A Pegmatitic environment at Tigerton Dells

B Autometasomatic environment in Red River quartz monzonite near contact with Wolf River granite

C Contact metasomatic environment along contact of Red River quartz monzonite with Wolf River granite

Key to Mineral Occurrences on Figure 3-14b
Wolf River Batholith (Southern Portion NC-3)

Figure 3-14b **Sheet 2**

include several uranium prospects and one beryllium prospect in the southern portion of the preliminary candidate area (Dutton and Bradley, 1970; Fitzsimonds et al. [illegible]; USBM, [illegible], WDNR, 1985; WGNHS, 1985). No deep mines or quarries (greater than 100 m [328 ft] in depth) are located within the preliminary candidate area. The nearest deep mines or quarries are the iron mines in the Menominee mining district, which is located approximately 65 km (40 mi) northeast of the preliminary candidate area.

Localities labeled A, B, and C on Figure 3-14b are potential energy-related resource sites within the boundaries of the preliminary candidate area and consist of areas identified as being favorable for the occurrence of uranium (Fitzsimonds et al., 1982). Within these localities are several shallow uranium prospects and exploration drillholes, including the Tigerton Dells east and west, F & K claims, Radies shaft and farm, and Marion uranium prospects, and a uranium-thorium-fluorite prospect at the Anklam property (Kalliokoski, 1976; Fitzsimonds et al., 1982). These prospects are small and undeveloped. Although they have been evaluated by both private concerns and government agencies since the 1950s, no commercial uranium deposits have been identified. A beryllium occurrence (number 5 on Figure 3-14b) in a pegmatite within the preliminary candidate area was reported by the WGNHS (1961). It is unlikely that economic development for any of these resources will occur in the foreseeable future. Mudrey and Kalliokoski (1985) state that the Belongia granite phase of the Wolf River batholith in the northeastern part of the preliminary candidate area has speculative potential for strategic tin-tungsten deposits based on similarities to a rapakivi-granite complex in Finland that is host to subeconomic greisen tin-tungsten minerals. However, no tin and tungsten values have been reported to date from the Wolf River batholith. The Tigerton anorthosite, which occurs in the west-central portion of the preliminary candidate area, is reported by Mudrey and Kalliokoski (1984) to have been considered as a potential feldspar resource. The potential for tin-tungsten andfeldspar resources within the Wolf River batholith is speculative at present and it is unlikely that economic extraction of these resources will occur in the forseeable future.

Prospects and [illegible] drillholes for gold, copper, iron, and unknown metallic commodities have been reported by Fitzsimonds et al. (1982), WDNR (1985), and the WGNHS (1985) within and along the margins of the Wolf River batholith within 10 km (6 mi) of the preliminary candidate area. A gold-copper-iron prospect (including a shaft to a depth of 30 m [98 ft] and several shallow drillholes) (LaBerge and Myers, 1983; WDNR, 1985) within Lower Proterozoic mafic metavolcanic rocks near the town of Easton, approximately 9 km (5.5 mi) west of the southern portion of the preliminary candidate area (number 4 on Figure 3-14b), is presently being evaluated; its commercial potential is currently unknown. Other natural resources within and near the preliminary candidate area (i.e., quarries and gravel pits) are shallow and widely available throughout the region.

Based on the data presented in this section, there are areas within the southern portion of the preliminary candidate area in which there are metallic, strategic, and energy-related resources. There is no evidence of mining to a depth sufficient to affect waste isolation, and no information is currently available to indicate that deep exploration drillholes (greater than 100 m [328 ft] in depth) are present in the preliminary candidate area.

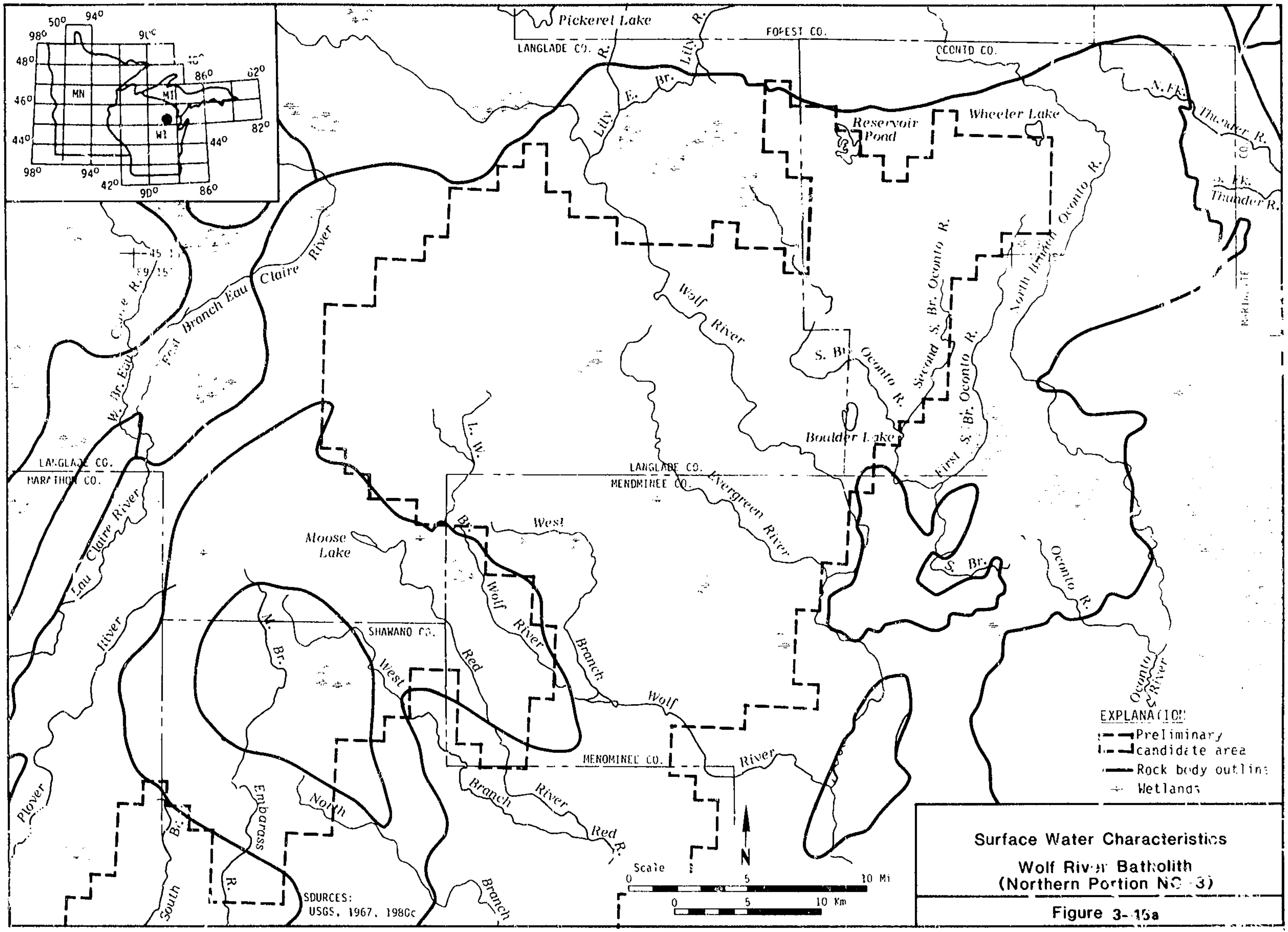
3.2.1.3.5 Topography and Surface Water Characteristics. The topographic relief in the preliminary candidate area is generally low with elevations ranging from 274 to 568 m (900 to 1,865 ft). The north-central portion of the preliminary candidate area has low hills and elevations between 457 and 568 m (1,500 and 1,865 ft). The remainder of the preliminary candidate area has low relief with low rolling hills.

The preliminary candidate area does not appear to contain large areas of floodplains. Examination of topographic maps indicates that only localized portions of the preliminary candidate area along major drainages (e.g., Wolf River) and small stream valleys are potentially flood prone. No reservoirs or impoundments are known to exist in or upstream of the preliminary candidate area.

The preliminary candidate area is drained mainly by the Wolf River, the Oconto River, the Red River, the [illegible] River, and the Little Wolf River (see Figures 3-15a and 3-15b). Approximately 98% of the preliminary candidate area drains south-southeast toward Lake Michigan. The remaining 2% drains toward the Eau Claire River, which discharges to the Mississippi River. As represented by the region-to-area screening data base, the preliminary candidate area is covered by less than 2% surface water and approximately 4% wetland (USGS, 1965; USGS, various dates; Wisconsin Dept. Natural Resources, various dates). The locations of lakes, rivers, and marshlands in the preliminary candidate area shown on Figures 3-15a and 3-15b are based on surface water features shown on USGS 1:250,000 Green Bay and Iron Mountain topographic maps. Major surface water bodies within the preliminary candidate area include the Wolf; Evergreen; north branch of the Little Wolf; north, middle, and south branches of the Embarass; west branch and little west branches of the Wolf; the south branch of the Oconto, Red; west branch of the Red; north and south branches of Pigeon; and south branch of Little Wolf Rivers, Reservoir Pond, Wheeler Lake, and Boulder Lake. Other surface water bodies near the preliminary candidate area include the Eau Claire River, Lily River, Tomorrow River, Moose Lake, Plover River, Columbia Lake, Pike Lake, and other small lakes and streams.

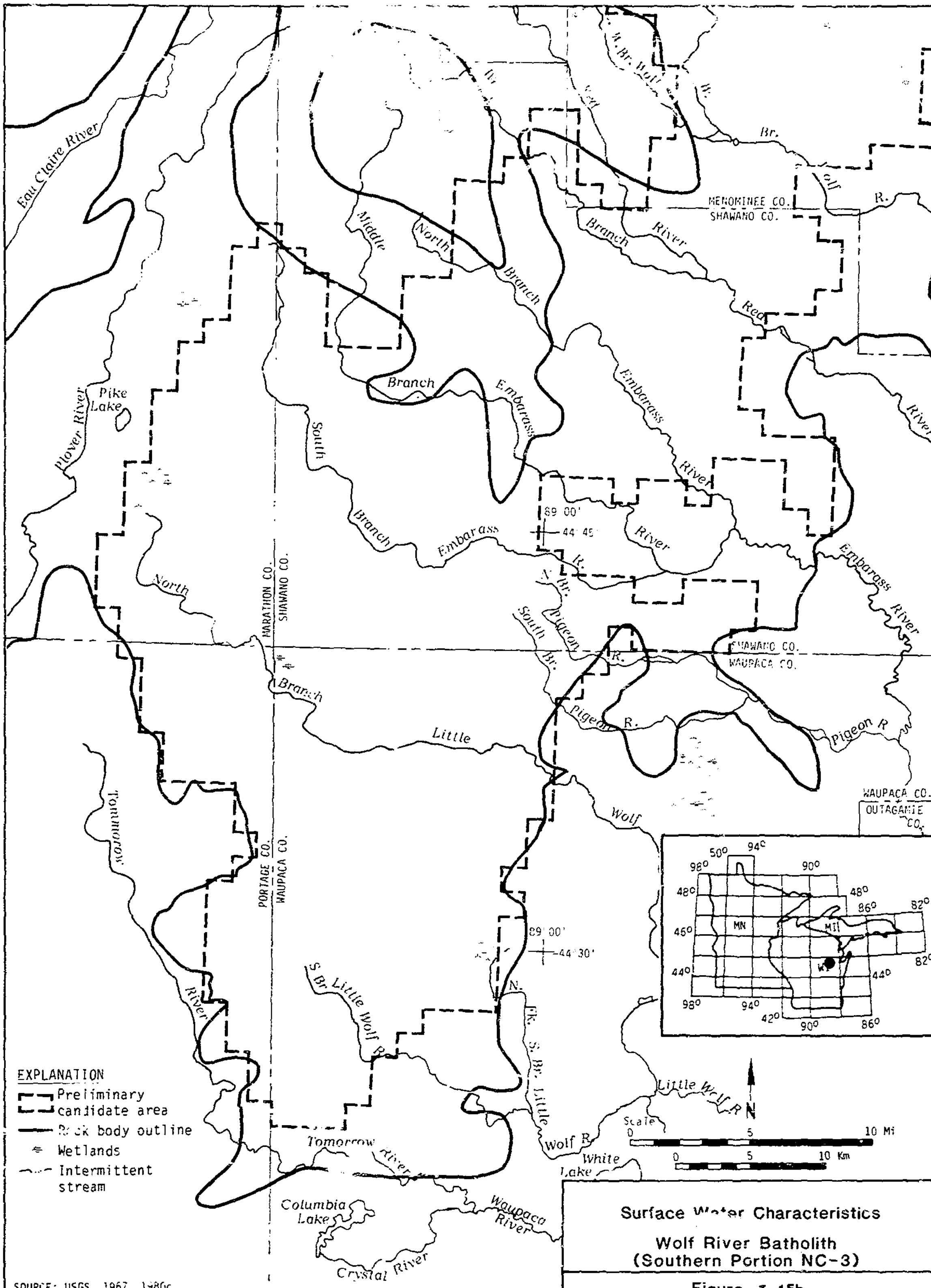
The data presented in this section indicate that the relief of the preliminary candidate area is generally low and the terrain is generally well drained, with scattered wetlands.

3.2.1.3.6 <u>Ground-Water Resources</u>. The regional hydrology is discussed in Section 3.2.1.1.1.5. Shallow ground-water movement in the northern portion of the preliminary candidate area is generally southwestward toward the Wolf River. In the southern portion, shallow ground-water movement is generally eastward toward the Little Wolf River. Figures 3-16a and 3-16b show shallow ground-water contours in the northern and southern portions of the preliminary candidate area, respectively, as reported by Olcott (1968), Oakes and Hamilton (1973), and Devaul and Green (1971). Areas that displayed convergence of shallow



Surface Water Characteristics
Wolf River Batholith
(Northern Portion NC-3)

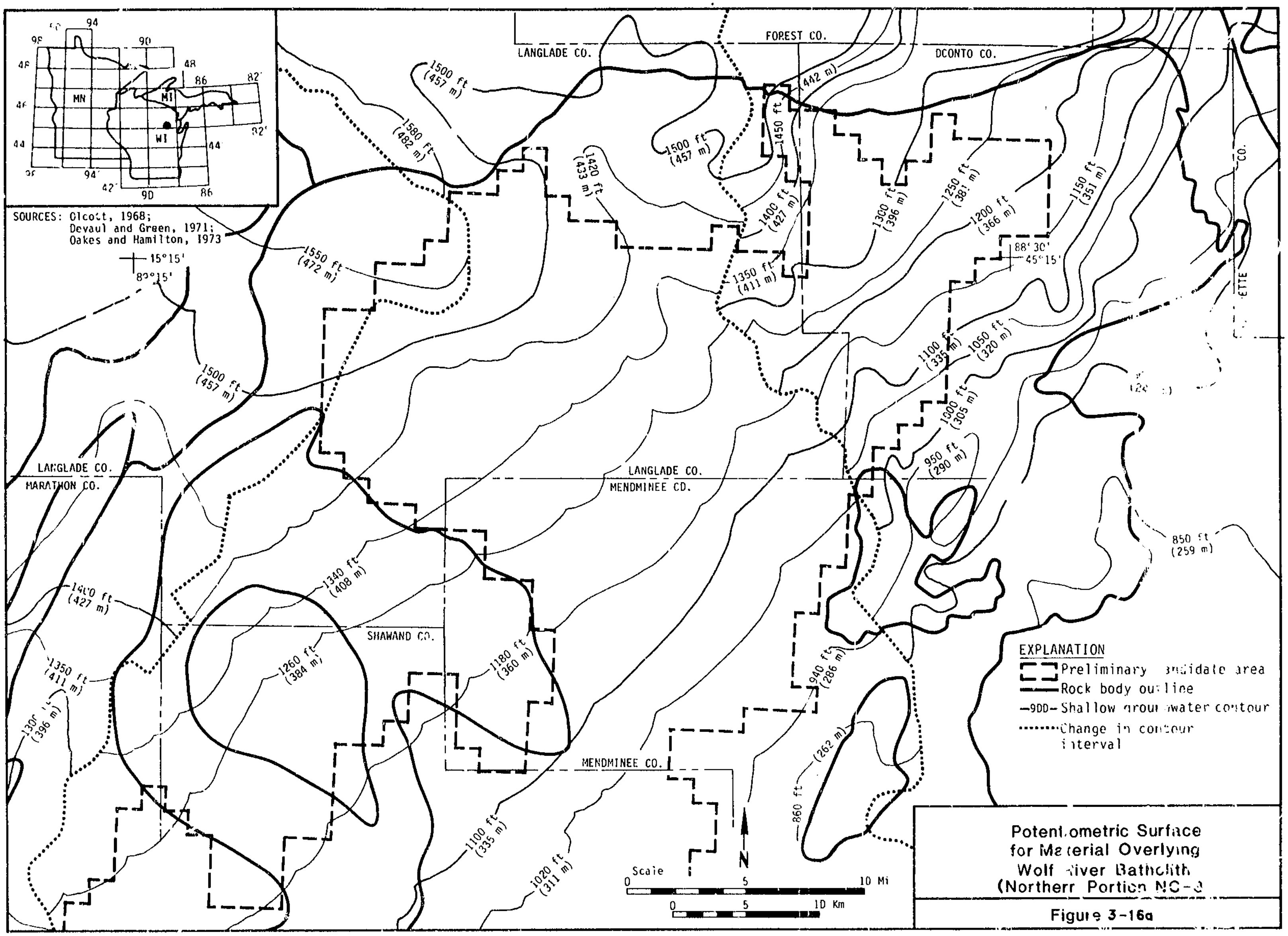
Figure 3-15a



Surface Water Characteristics

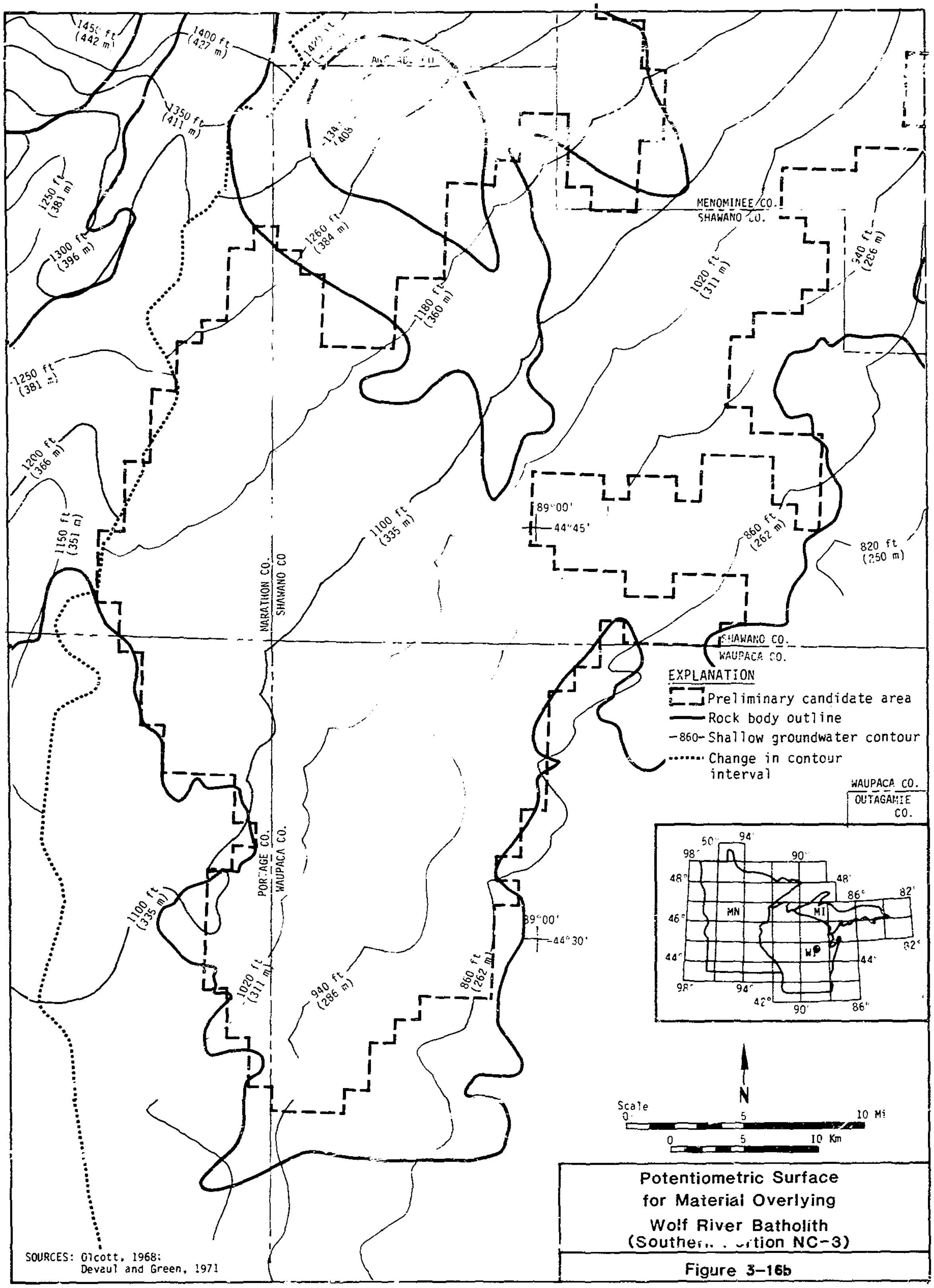
Wolf River Batholith
(Southern Portion NC-3)

Figure 3-15b



Potentiometric Surface for Material Overlying Wolf River Batholith (Northern Portion NC-3)

Figure 3-16a



Potentiometric Surface for Material Overlying Wolf River Batholith (Southern Portion NC-3)

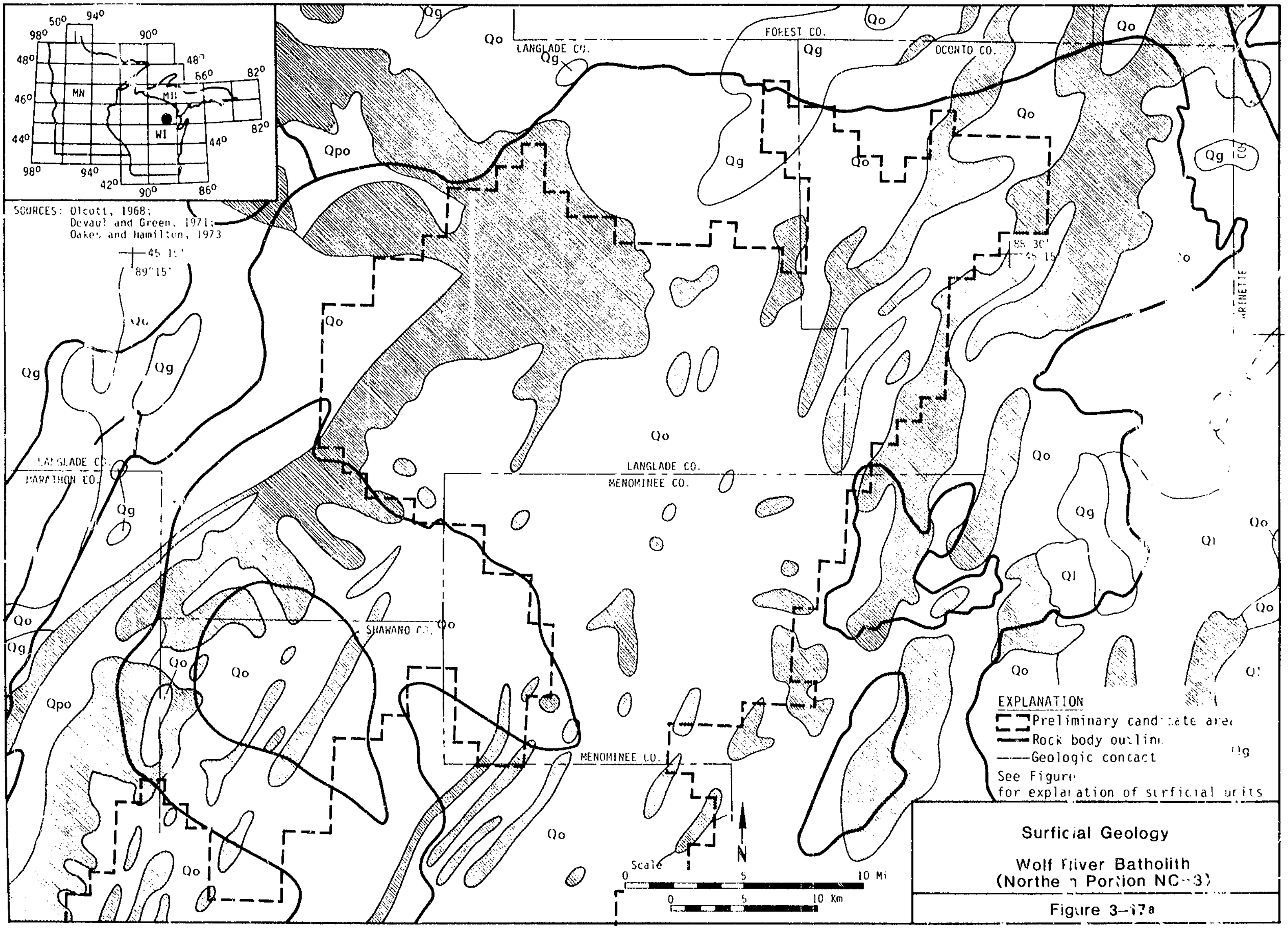
Figure 3-16b

water-table cont[illegible] 30-m (100-ft) contour interval, were considered potential major discharge [illegible]. These generally correspond to locations of major streams and rivers. No major discharge zones have been identified in the preliminary candidate area (DOE, 1985c).

Ground water in and near the preliminary candidate area is primarily obtained from glacial sediments that include morainal deposits of unsorted silt, clay, sand, and gravel; glacial lake deposits of silt and clay; pitted outwash deposits of well-sorted sand and gravel and poorly sorted sandy till; and outwash deposits of sand and gravel (Olcott, 1968; Devaul and Green, 1971; Oakes and Hamilton, 1973). The horizontal extent of surficial deposits is shown on Figures 3-17a and 3-17b.

Well yields presented in the North Central RGCR (DOE, 1985c) were estimated from maps by Devaul (1975a; 1975b; 1975c), Kammerer (1981), and Cutright (1982) and are shown on Figures 3-18a and 3-18b. Additional detailed well yield information has been reported by Olcott (1968); Oakes and Hamilton (1973); Devaul and Green (1971) in USGS Hydrologic Atlases and is shown in Figures 3-18c and 3-18d. Some estimated well yields shown on these two figures may not agree; however, there is currently no basis for determining which data set is more representative of actual well yields. Both data sets are shown for comparison. The extensive outwash deposits are generally thick, permeable sands and gravels that form excellent aquifers. Yields range from 6.3 to 63 L/s (100 to 1,000 gpm). Terminal and recessional moraines in this area are also permeable because they contain large amounts of sand and gravel. Yields range from 3.2 to greater than 32 L/s (50 to 500 gpm).

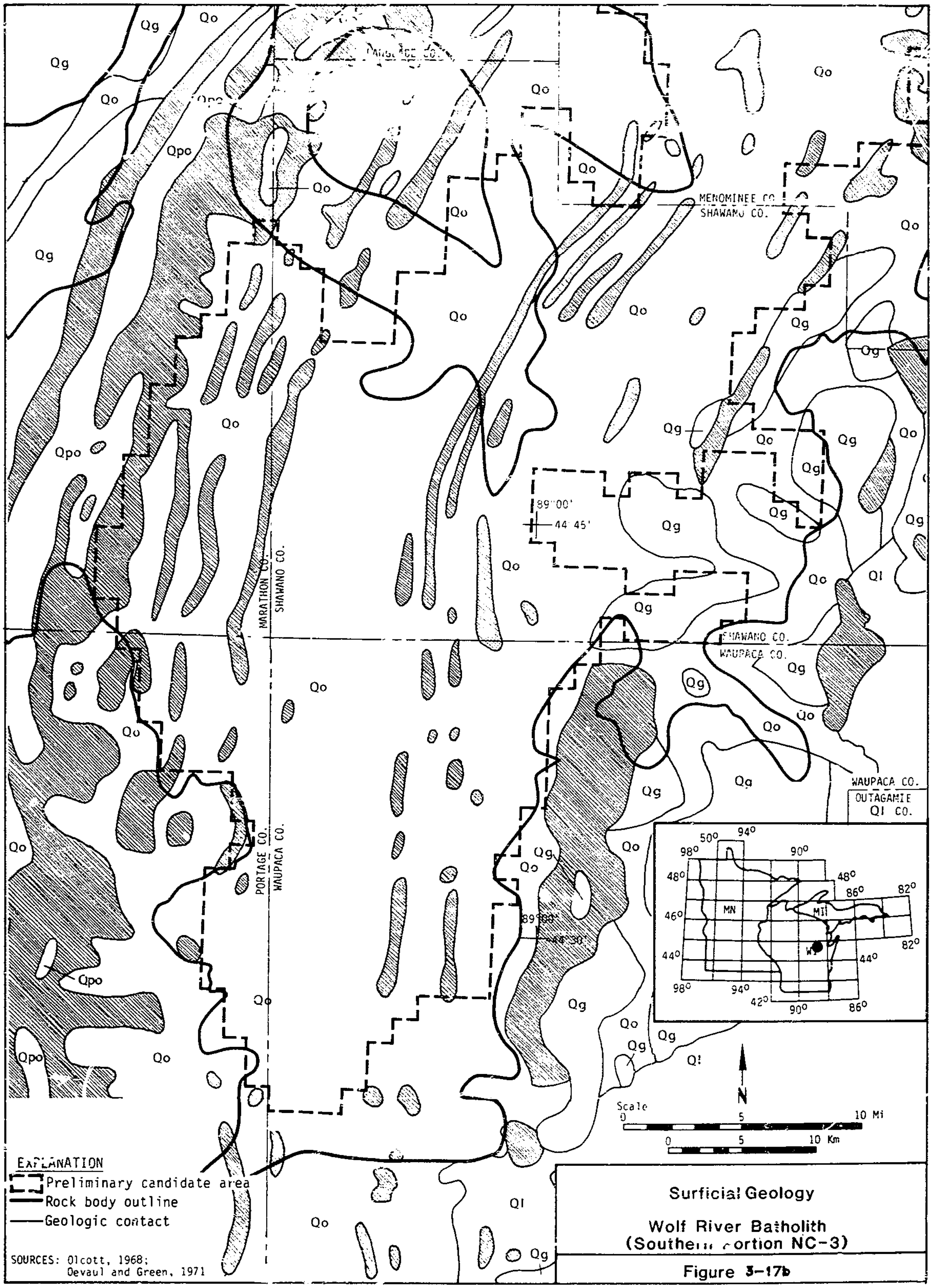
The data indicate that relatively shallow Quaternary aquifers that contain potable ground water, are present within the candidate area. No deep wells (i.e., greater than 100 m [328 ft] in depth) have been reported in the literature. Therefore, local ground-water conditions in the deeper crystalline rock are presently unknown.



Surficial Geology

Wolf River Batholith
(Northern Portion NC-3)

Figure 3-17a



Surficial Geology

Wolf River Batholith
(Southern Portion NC-3)

Figure 3-17b

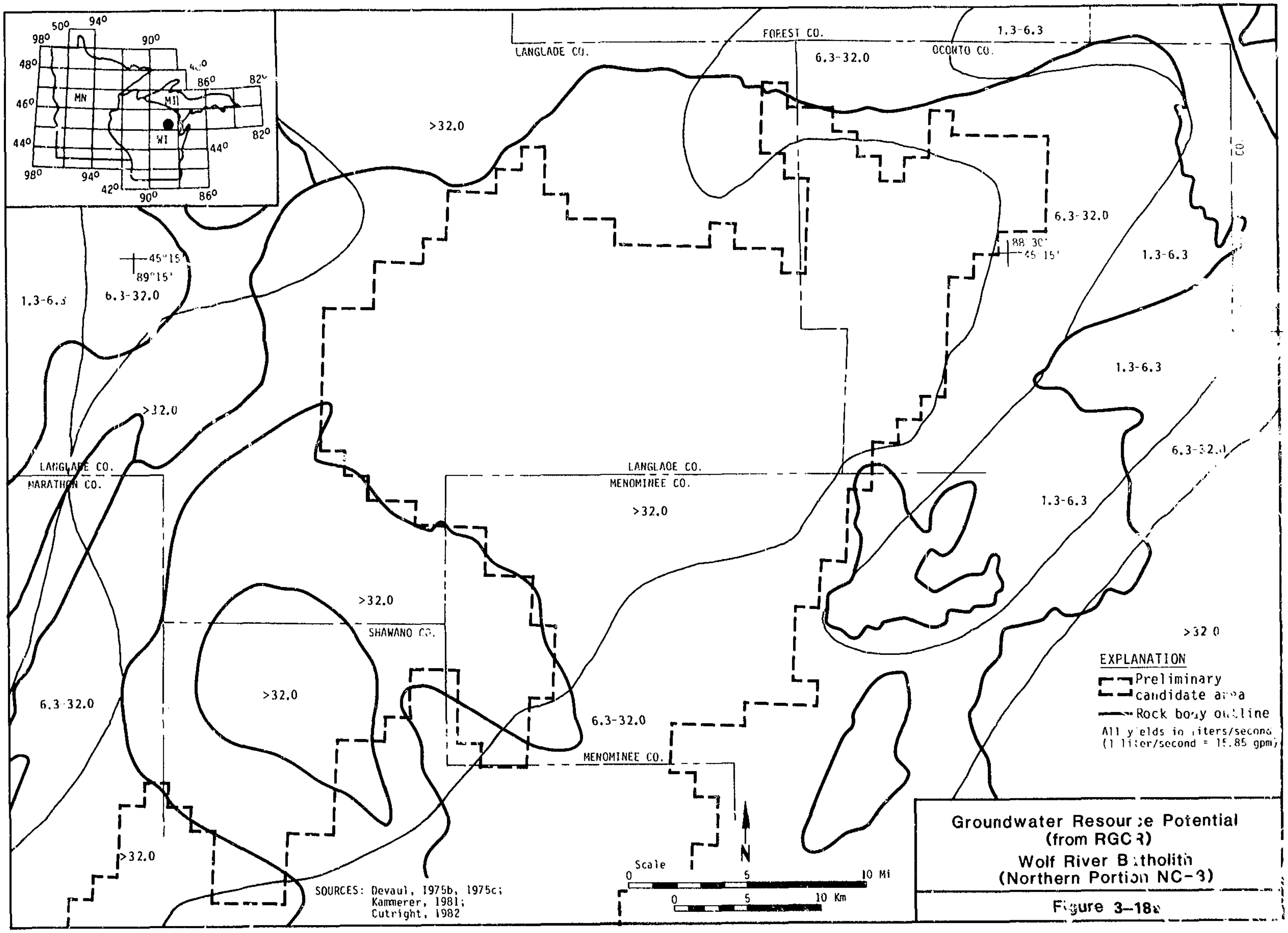
EXPLANATION OF SURFICIAL UNITS

QUATERNARY

Qg	Ground moraine
Qpo	Pitted outwash
Qo	Outwash
Ql	Glacial-lake deposits
(hatched)	Terminal and recessional moraine

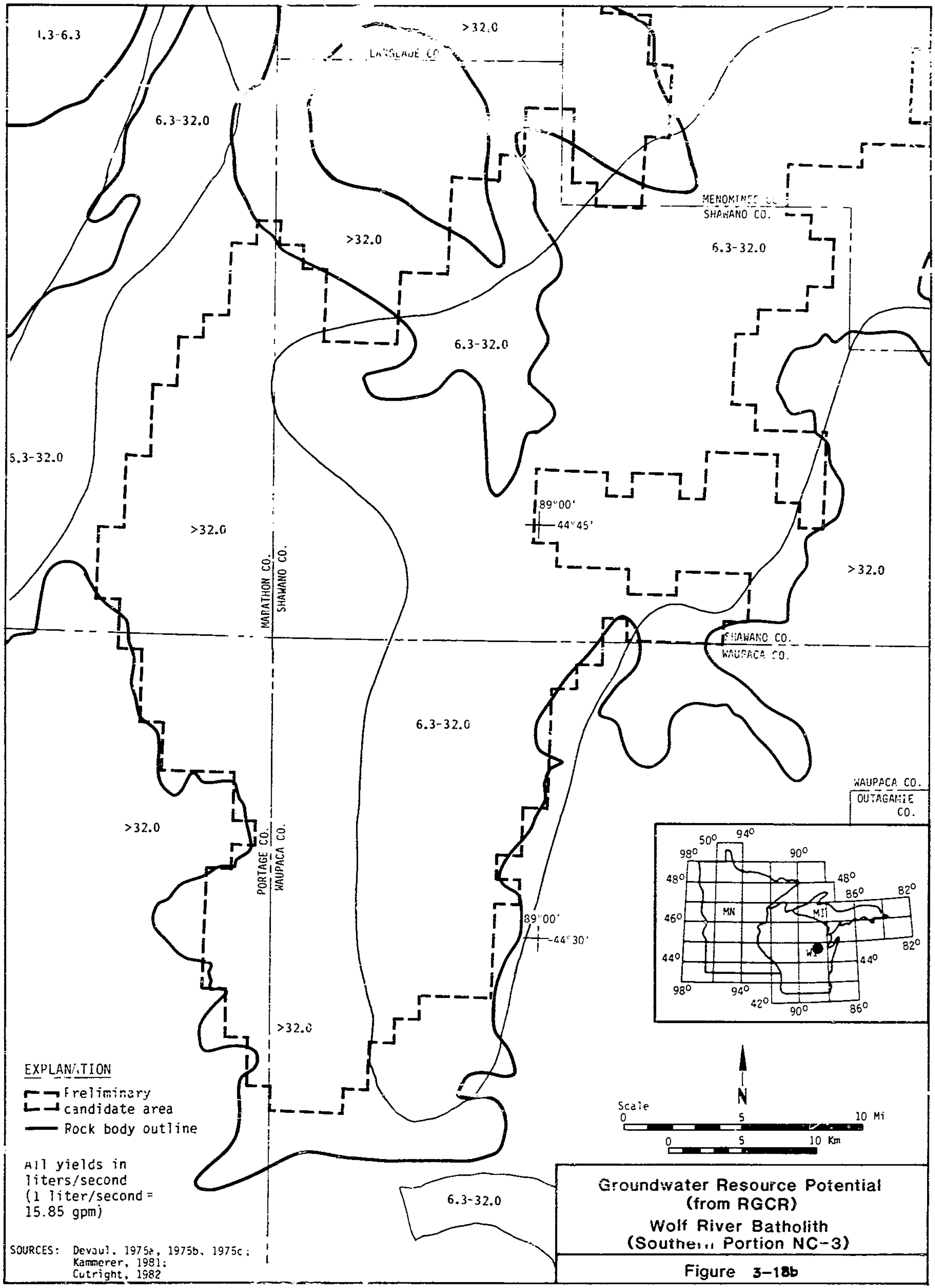
Explanation for Figures 3-17a & 17b Wolf River Batholith (NC-3)

Figure 3-17a & 3-17b Sheet 2



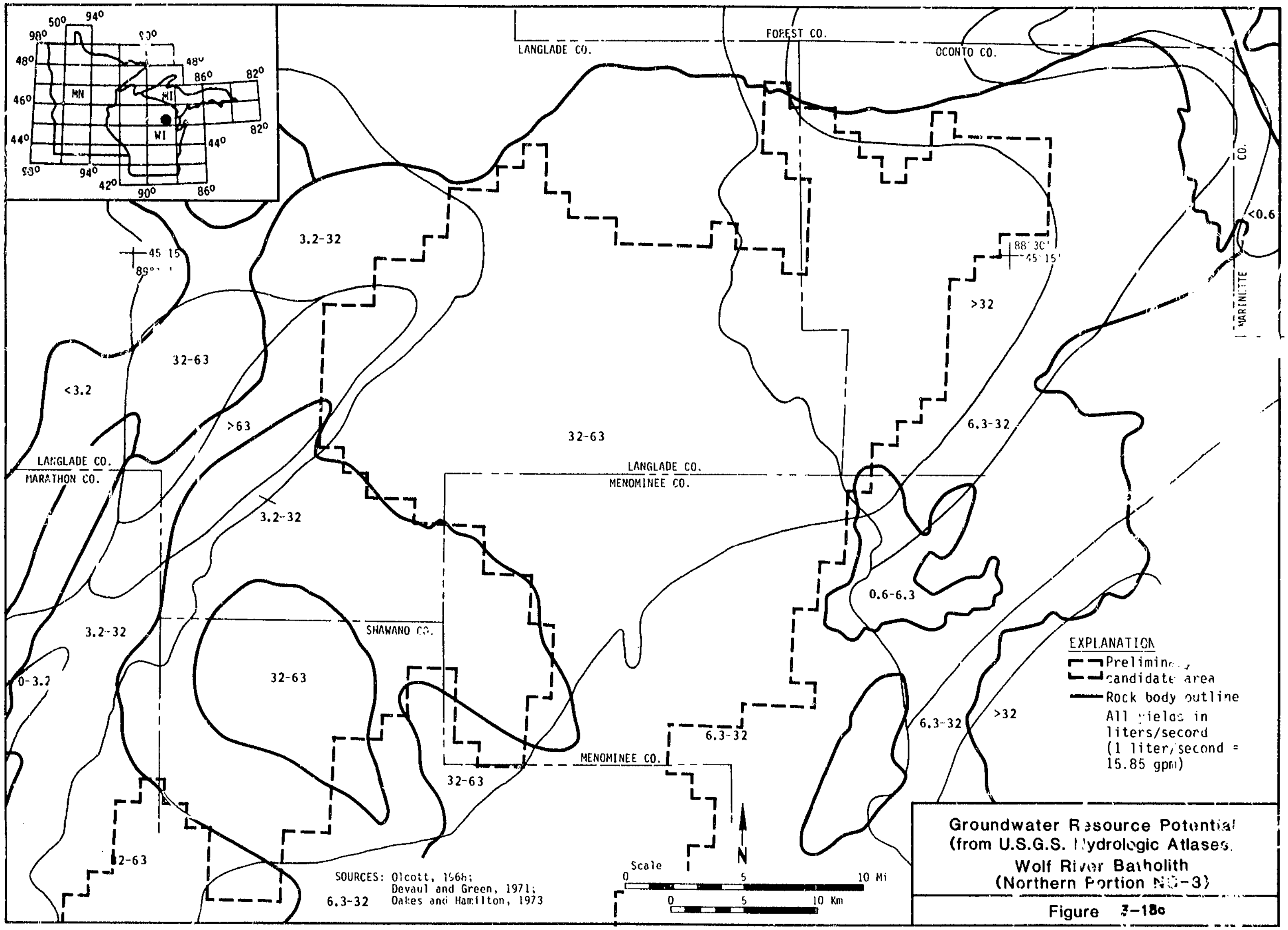
Groundwater Resource Potential
(from RGCR)
Wolf River Batholith
(Northern Portion NC-3)

Figure 3-18a



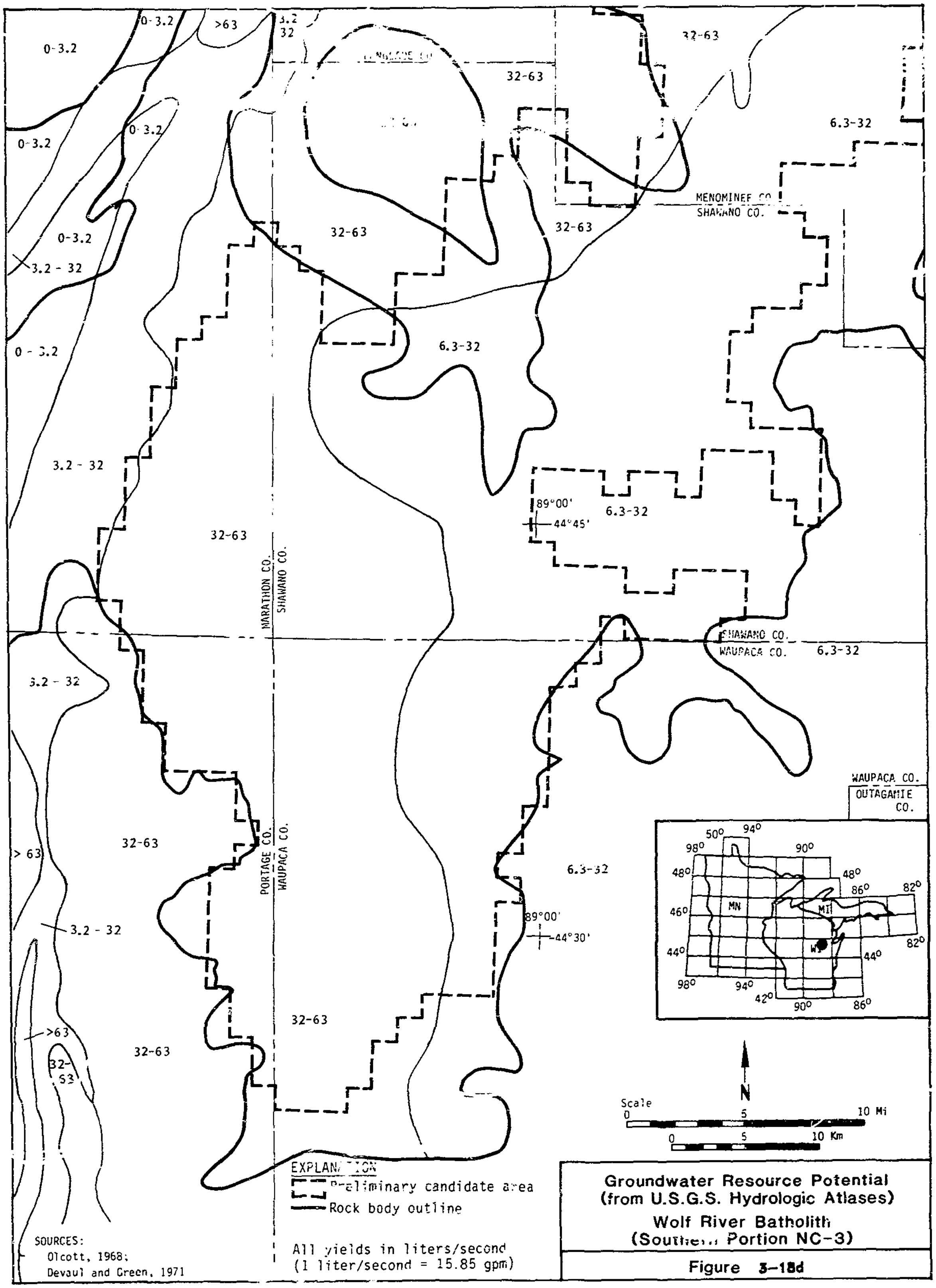
Groundwater Resource Potential (from RGCR)
Wolf River Batholith (Southern Portion NC-3)

Figure 3-18b



Groundwater Resource Potential (from U.S.G.S. Hydrologic Atlases)
Wolf River Batholith (Northern Portion NC-3)

Figure 3-18c



Groundwater Resource Potential
(from U.S.G.S. Hydrologic Atlases)
Wolf River Batholith
(Southern Portion NC-3)

Figure 3-18d

3.2.1.3.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including erosion and deposition and vertical crustal movement, is in Section 3.2.1.1.1.

3.2.1.3.8 Federal Lands. A section of the Wolf National Wild and Scenic River, approximately 3.2 km (2 mi) in length, is located within the northeast quarter of the preliminary candidate area. From the point that the riverway leaves the preliminary candidate area, at its eastern border, the riverway is within 1.6 km (1 mi) of the preliminary candidate area boundary for approximately 8 km (5 mi) to the south. For the next 1.6 km (1 mi) to the south, a portion of the riverway slightly overlaps the preliminary candidate area. The riverway lies between 1.6 and 8 km (1 and 5 mi) east of the preliminary candidate area boundary for an additional 19 km (12 mi). In total, those portions of the riverway lying within the preliminary candidate area occupy approximately 500 ha (1,200 ac) or less than 1% of the preliminary candidate area. In addition, approximately 325 km^2 (125 mi^2) or 32,000 ha (80,000 ac) of the preliminary candidate area's extreme northeast corner are located within the Nicolet National Forest. This area constitutes approximately 11% of the preliminary candidate area. No research natural areas have been identified within this national forest. The features described above are each greater than 130 ha (320 ac) in size and are depicted on Plate 2B of the North Central RECR (DOE, 1985d). There is no evidence in the data base that Federal lands less than 130 ha (320 ac) in size are located in or within 10 km (6 mi) of the preliminary candidate area.

In summary, two Federal lands each greater than 130 ha (320 ac) overlap the preliminary candidate area and cover a total of about 32,500 ha (81,200 ac) or less than 12% of the preliminary candidate area. No additional Federal lands lie within 10 km (6 mi) of the preliminary candidate area (see Figure 3-19).

3.2.1.3.9 State Lands. There are four State lands, each less than 130 ha (320 ac) in size, which lie within the boundary of the preliminary candidate area. These are Keller Whitcomb Creek Woods Scientific and

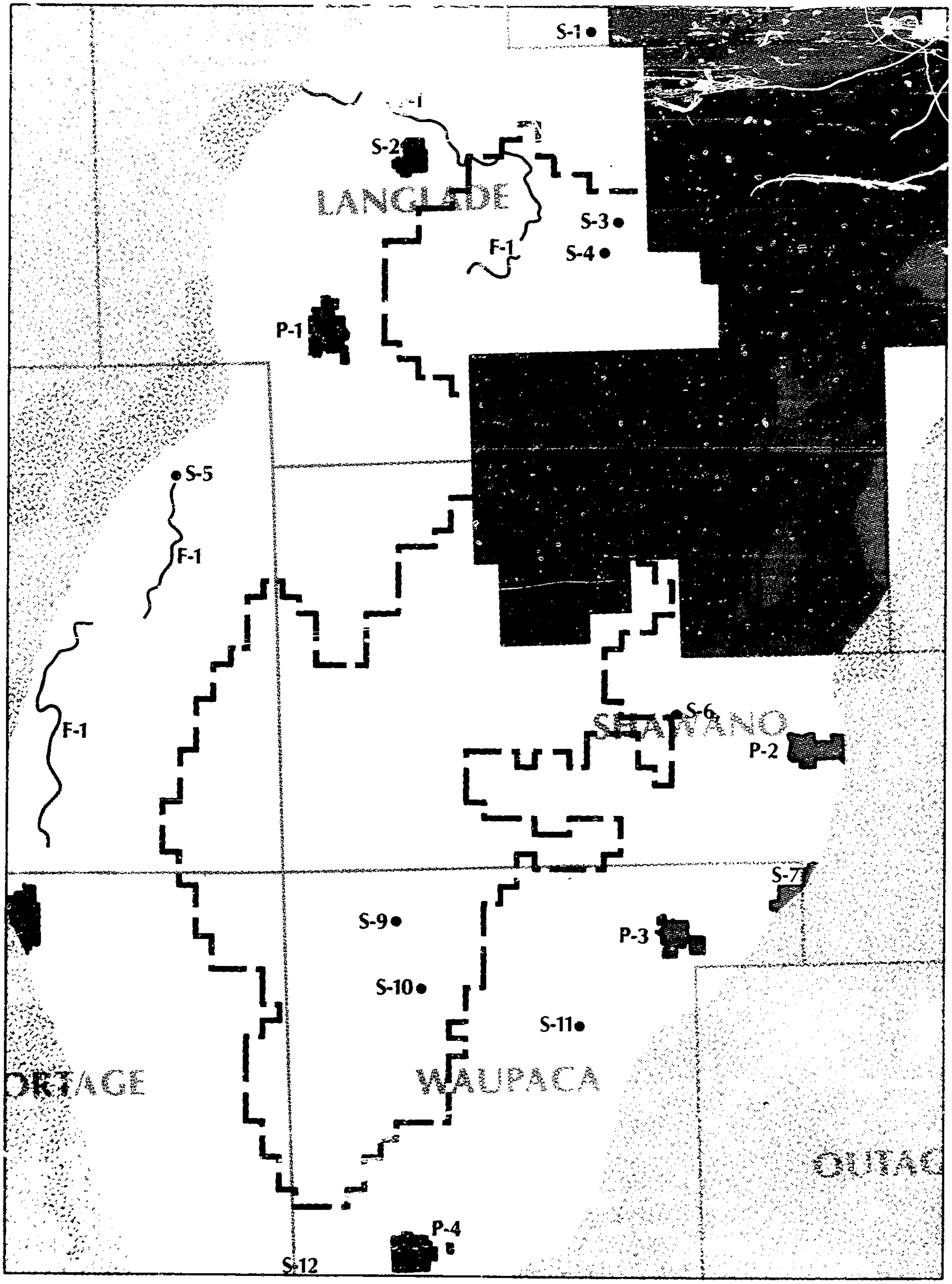


Figure 3–19 Sheet 1

Environmental Features
Wolf River Batholith (NC-3)

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

P Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile

F Federal Lands Greater Than 320 Acres

S State Lands Greater Than 320 Acres

I Federal Indian Reservations

• Federal or State Lands Less Than 320 Acres

F-5 Map Alpha-numeric Codes are Keyed to Environmental Features

Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

0 miles 20

0 kilometers 20

Figure 3-19 Sheet 2

ENVIR[illegible] FEATURES WITHIN 16 KM (10 MI)
[illegible] CANDIDATE AREA NC-3*

Code	Feature
Population Features	
P-1	Antigo Highly Populated Area (HPA)**
P-2	Shawano HPA**
P-3	Clintonville HPA**
P-4	Waupaca HPA**
Federal Lands	
F-1	Ice Age National Scenic Trail
F-2	Nicolet National Forest
F-3	Wolf National Wild and Scenic River
State Lands	
S-1	Bog Brook Wildlife Area (WA)
S-2	Peters Marsh WA
S-3	Oxbow Rapids, Upper Wolf River Scientific and Natural Area (SNA)
S-4	Flora Lake SNA
S-5	Dells of the Eau Claire River SNA
S-6	Jung Hemlock-Beech Forest SNA
S-7	Navarino WA
S-8	Dewey Marsh WA
S-9	Mud Lake SNA
S-10	Keller Whitcomb Creek Woods SNA
S-11	Tellock's Hill Woods SNA
S-12	Hartman Creek State Park
Indian Reservations	
I-1	Potawatomi Indian Reservation
I-2	Menominee Indian Reservation
I-3	Stockbridge-Munsee Indian Reservation

* The accompanying text identifies only those environmental features within 10 km (6 mi) of the preliminary candidate area.

** Area with a population density greater than or equal to 1,000 persons per square mile.

Figure 3-19, Sheet 3

Natural Area (39 ha [... ac]); ... Rapids, Upper Wolf River Scientific and Natural Area (20 ha [... ac]); Flora Lake Scientific and Natural Area (16 ha [40 ac]); and Mud Lake Scientific and Natural Area (63 ha [155 ac]). In total, these areas occupy 138 ha (342 ac) or less than 1% of the preliminary candidate area. The Keller Whitcomb Creek Woods and Mud Lake units are located in the southern half of the preliminary candidate area and the other two units are located in the northern half. Hartman Creek State Park, which is greater than 130 ha (320 ac) in size, is 5.6 km (3.5 mi) southeast of the preliminary candidate area. The Peter's Marsh Wildlife Management Area, which is also greater than 130 ha (320 ac) in size, is located 3.2 km (2 mi) northeast of the preliminary candidate area. There are three State lands, each less than 130 ha (320 ac) in size, within 10 km (6 mi) of the preliminary candidate area: Bog Brook Wildlife Area, located 10 km (6 mi) north; Jung Hemlock-Beech Forest Scientific and Natural Area, which abuts the preliminary candidate area's eastern boundary; and Tellock's Hill Woods Scientific and Natural Area, located 10 km (6 mi) east of the preliminary candidate area. All of the features described above are either depicted on Plate 3B or are listed in Appendix B of the North Central RECR (DOE, 1985d).

In summary, four State scientific and natural areas (each less than 130 ha [320 ac]) are located within the preliminary candidate area and cover a total of 138 ha (342 ac) or less than 1% of the preliminary candidate area. Also, five State lands (two greater than and three less than 130 ha [320 ac]) lie within 10 km (6 mi) of the preliminary candidate area (see Figure 3-19).

3.2.1.3.10 Environmental Compliance. There are no air quality nonattainment areas or Prevention of Significant Deterioration (PSD) Class I Areas located in or within 40 km (25 mi) of the preliminary candidate area (40 CFR 81). Two sites listed on the National Register of Historic Places (NRHP) are located within the preliminary candidate area. Holt and Balcom Logging Camp No. 1 is located in the town of Lakewood in the preliminary candidate area's northwest portion and has State significance (44 FR 7629, 1979). The Lutheran Indian Mission is located in the town of [illegible] on the preliminary candidate area's east-central perimeter, no[illegible] Gresham and has local significance (46 FR 10668, 1981). No proposed NRHP sites are located within the preliminary candidate area. In the regional data base, there are no known existing archaeological sites or districts nor any proposed for designation within the preliminary candidate area. An "Existing Trail - Potentially Certifiable" segment of the Ice Age National Scenic Trail passes through the northwest portion of the preliminary candidate area for approximately 224 km (14 mi) (NPS, 1983).

3.2.1.3.11 Population Density and Distribution. The preliminary candidate area contains no highly populated areas. There are four highly populated areas within 16 km (10 mi) of the preliminary candidate area (Antigo, Clintonville, Shawano, Waupaca) (see Figure 3-19). Antigo, with a population of 8,653, is located 3.2 km (2 mi) west of the preliminary candidate area. Clintonville, with a population of 4,567, and Shawano, with a population of 7,013, are located 6 km (4 mi) and 11 km (7 mi) east of the preliminary candidate area, respectively. Waupaca, with a population of 4,472, is located 5 km (3 mi) south of the preliminary candidate area. The preliminary candidate area contains no areas with population densities greater than or equal to 1,000 persons per square mile. There are four areas with population densities greater than or equal to 1,000 persons per square mile within 16 km (10 mi) of the preliminary candidate area. These include Antigo, Clintonville, Shawano and Waupaca, which are also highly populated areas (see Figure 3-19). Green Bay is located approximately 64 km (40 mi) east of the preliminary candidate area. The average population density of the preliminary candidate area is 21 persons per square mile. The average population density within 80 km (50 mi) of the preliminary candidate area is approximately 60 persons per square mile. Low population density is defined as a density in the general region of the site less than the average population density for the conterminous United States (76 persons per square mile) based on the 1980 census.

3.2.1.3.12 Si[illegible]. There are no DOE-owned lands located within the preliminary candidate area. As mentioned in Section 3.2.1.3.8, the Wolf National Wild and Scenic River and the Nicolet National Forest cover a total of approximately 32,500 ha (81,200 ac) or less than 12% of the preliminary candidate area. Approximately 41,000 ha (102,400 ac) of the preliminary candidate area are located within the Menominee Indian Reservation, and the Stockbridge-Munsee Indian Reservation lies completely within the preliminary candidate area covering 6,400 ha (16,000 ac). These reservations cover approximately 17% of the preliminary candidate area. In addition, the Potawatomi Indian Reservation is located approximately 5 km (3 mi) north of the preliminary candidate area and the Mole Lake Indian Reservation is located approximately 21 km (13 mi) north of the preliminary candidate area (see Figure 3-19 and Plate NC-1B).

3.2.1.3.13 Offsite Installations. No commercial nuclear reactors are located within the preliminary candidate area. The nearest operating commercial nuclear reactors are Kewaunee and Point Beach 1 and 2, all of which are approximately 112 km (70 mi) to the southeast (Michelewicz and Vann, 1983; DOE, 1984c). The nearest commercial nuclear reactor under construction is Byron 2, which is 390 km (200 mi) to the south (Nuclear News, 1985). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.1.3.14 Transportation. The nearest interstate highway is I43 at Green Bay, Wisconsin, which is about 65 km (40 mi) to the southeast of the preliminary candidate area. I90/94 is over 96 km (60 mi) to the south and southwest. U.S. 45 crosses the south central portion while U.S. 10 runs through the extreme southwestern corner. Other nearby U.S. highways are U.S. 51, 8, and 141. U.S. 51, which is 24 km (15 mi) west of the preliminary candidate area, is a major highway in this part of the State. It is a limited-access highway most of the distance between Portage, Wisconsin (junction with I90/94) and Merrill, Wisconsin. About 24 km (15 mi) north of the preliminary candidate area is U.S. 8, which is a major east-west highway across northern Wisconsin. U.S. 141 is approximately 40 km (25 mi) east of the preliminary candidate area. At least eight State highways cross portions of this preliminary candidate area. State Route 29, a principal highway, runs east and west through the central portion of the preliminary candidate area between Shawano and Wausau, Wisconsin. State Route 32 crosses the northeastern tip of the area. Another principal highway, State Route 47, crosses the central portion of the preliminary candidate area between Shawano and Elmhurst, Wisconsin. State Route 49 runs north and south through the western portion of the preliminary candidate area from west of Wittenberg to Waupaca, Wisconsin, at U.S. 10. State Route 52 crosses the northwestern portion of the preliminary candidate area between Antigo and Wabeno, Wisconsin. State Route 55 crosses the northeast portion between Shawano and Crandon, Wisconsin. Highway 64, a principal through highway between Merrill, Antigo, and Marinette, Wisconsin, is the major highway in the northern portion of the preliminary candidate area. State Route 153 crosses the central portion of the preliminary candidate area connecting U.S. 51 near Mosine with U.S. 45 near Wittenberg.

The Soo/Milwaukee railroad mainline between Chicago and Minneapolis crosses the extreme southwestern portion of the preliminary candidate area. This mainline parallels U.S. 10 through this section of Wisconsin. While the transportation network map (Plate NC-6A) shows a mainline about 64 km (40 mi) northeast of the preliminary candidate area, this mainline does not connect with other mainlines in the national network. This line belongs to Chicago and Northwestern and is used to transport iron ore between Iron Mountain and Escanaba, Michigan. Due to the depressed state of the mining industry over the last 4 to 5 years, it is uncertain whether this line is still classified as a mainline. Three branchlines cross the preliminary candidate area. One such line is the Soo/Milwaukee branchline between Appleton, White Lake, and Wisconsin Junction, Wisconsin, where it joins another Soo/Milwaukee branchline between Minneapolis and Sault Ste Marie. In the central portion of the preliminary candidate area, the Chicago and Northwestern has a branchline running between Green Bay and Wausau, Wisconsin. At the extreme southern edge of the preliminary candidate area is the Green Bay and Western branchline which runs east and west across the entire State from Kewanee, on Lake Michigan, to Winona, Minnesota. Historically, several other branchlines have crossed the preliminary candidate area. One such line, which was abandoned approximately 15 years ago, crossed the preliminary candidate area between White Lake and Antigo, Wisconsin. Other lines, now abandoned by the Chicago and Northwestern, roughly paralleled U.S. 45 and State Route 49 across the preliminary candidate area.

Based on the data presented above, access to the preliminary candidate area from both local and regional highway and railway systems appears to be available.

3.2.1.3.15 Preliminary Candidate Area Deferral Analysis. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area NC-3 that could affect DOE's decision to defer further consideration of the area. Based on evaluation of this additional available information, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]
- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]

- low potential ... tectonic deformations suggest that the regional ground-water flow systems should not be significantly affected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]
- absence of historical earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that the frequency of earthquake occurrence within the geologic setting may increase [960.4-2-7(c)(3)]
- the frequency of occurrence or magnitude of earthquakes within the geologic setting are no higher than within the region [960.4-2-7(c)(4)]
- absence of historical earthquakes that, if they recurred, could produce ground motion in excess of reasonable design limits [960.5-2-11(c)(2)]
- absence of evidence, based on correlations of earthquakes with tectonic processes and features within the geologic setting, that the magnitude of earthquakes during repository construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]
- no evidence of subsurface mining or extraction for resources that could affect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence of drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]
- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]
- presence of generally flat terrain [960.5-2-8(b)(1)]
- presence of generally well-drained terrain [960.5-2-8(b)(2)]

- general absence of surface characteristics of surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]
- absence of Federal lands less than 130 ha (320 ac) within and in proximity to (i.e., with 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(3)]
- limited presence of State lands less than 130 ha (320 ac) within (i.e., four) and in proximity to (i.e., three within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(4)]
- a majority of the preliminary candidate area is beyond 16 km [10 mi] from highly populated areas or areas containing more than 1,000 persons per square mile [960.5-2-1(b)(2) and (c)(2)]
- low population density within its boundaries and within 80 km (50 mi) of the preliminary candidate area [960.5-2-1(b)(1)]
- absence of nuclear installations [960.5-2-4(b) and (c)(2)]
- no projected land ownership conflicts over a significant portion (71%) of the preliminary candidate area that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings [960.4-2-8-2(c), 960.5-2-2(c)]
- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2) and (b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)].

The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area NC-3 at this time.

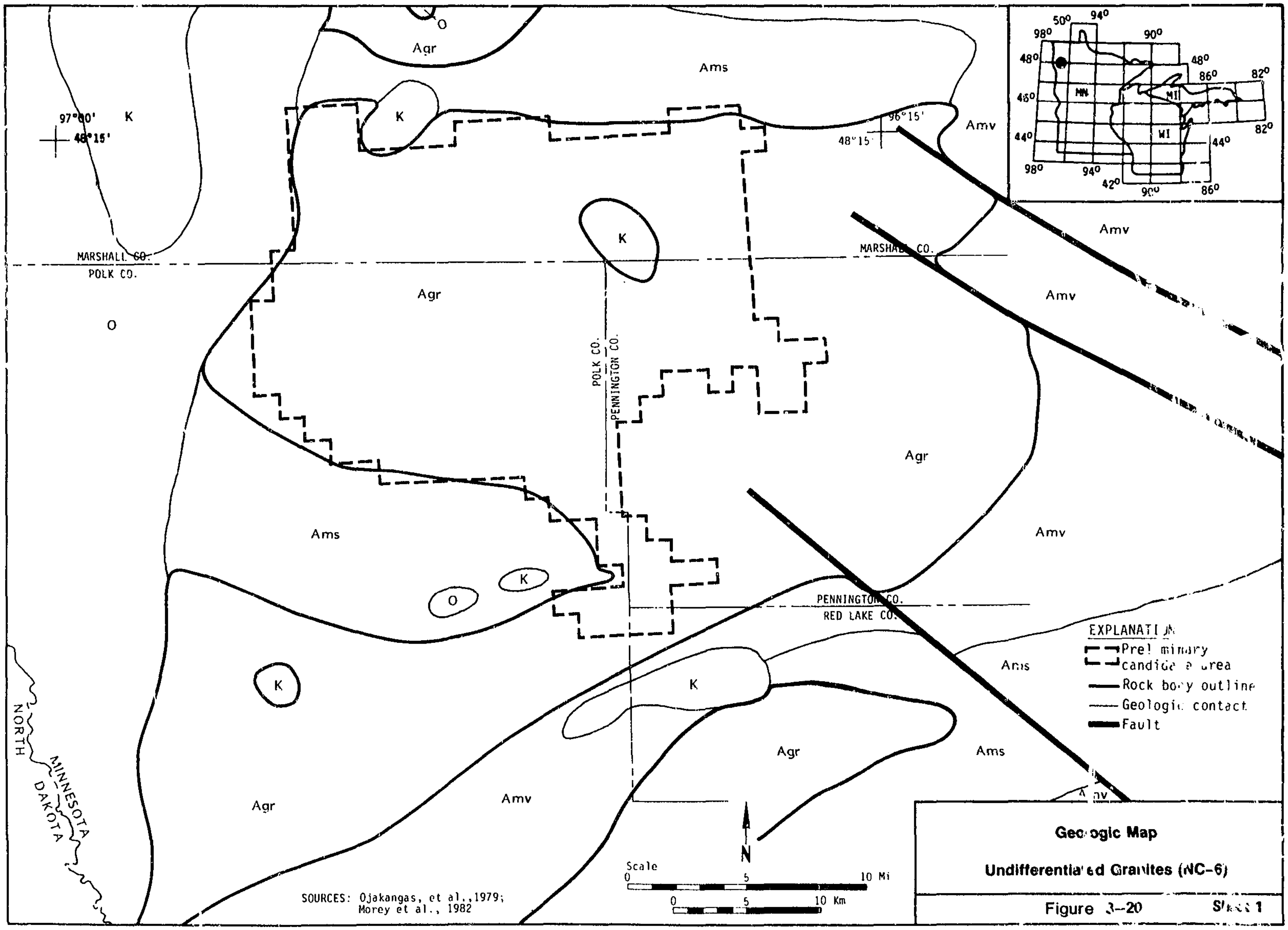
3.2.1.4 Preliminary Candidate Area Description - Undifferentiated Granites (NC-6)

The undifferentiated granites are located within the Lake Agassiz Lowland physiographic province in northern Minnesota. The preliminary candidate area is located in Marshall, Pennington, Polk, and Red Lake Counties at approximately 48°09' N latitude and 96°33' W longitude.

3.2.1.4.1 Host Rock Geometry and Overburden Thickness. The preliminary candidate area shown on Figure 3-20 has an area of approximately 780 km^2 (300 mi^2) and overlies a batholith of undifferentiated granites, the rocks of which are not exposed and the mapped extent of which is inferred from geophysical data (Ojakangas et al., 1979; Morey et al., 1982). The batholith is approximately 100 km (61 mi) long and varies in width from 3 to 55 km (2 to 33 mi). Data on the vertical extent of the batholith are not available; however, the batholith is inferred to extend to a depth of several kilometers (miles) based on the present understanding of the mode of emplacement of batholiths and seismic reflection studies in batholithic terranes. This information suggests that most batholiths are tabular in shape and extend to a depth of 6 to 10 km (4 to 6 mi) (Hamilton and Myers, 1967; Lynn et al., 1981). Furthermore, no postemplacement deformational processes such as large-scale thrust faulting are known to have diminished the vertical extent of the batholith.

There is no exposed bedrock in the preliminary candidate area. Contours of overburden thickness for the northern portion of the preliminary candidate area indicate that a major portion of the area is covered by 91 to 122 m (300 to 400 ft) of overburden (Figure 3-21). Contour data are not available for the southern portion of the preliminary candidate area; however, one drillhole to bedrock penetrated 100 m (328 ft) of overburden.

On the basis of the data presented above and the assumed depth and size of a repository in crystalline rock (see Section 1.5), the



Geologic Map

Undifferentiated Granites (NC-6)

Figure 3-20 Sheet 1

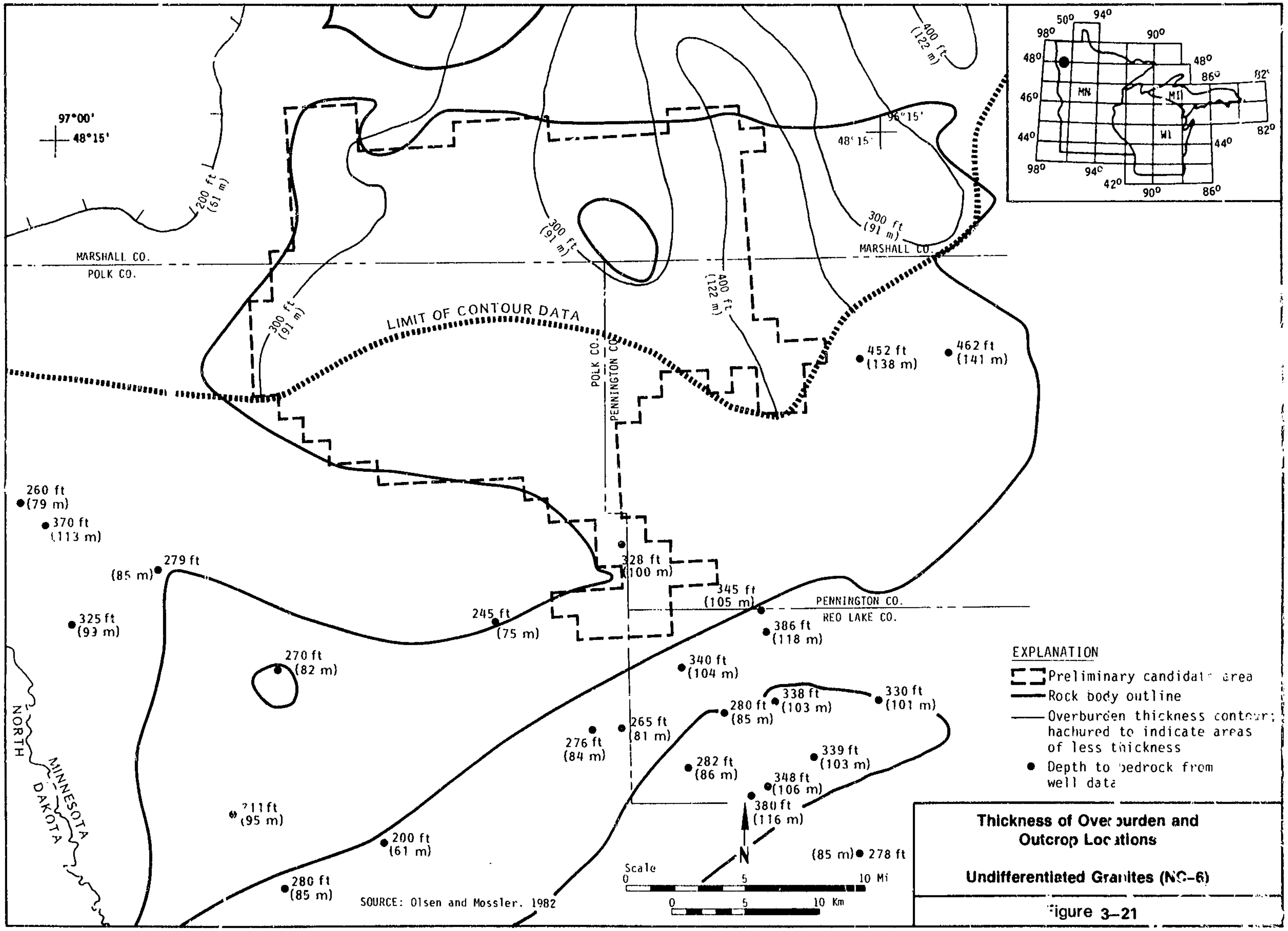
EXPLANATION OF GEOLOGIC UNITS

Age	Unit	Description
CRETACEOUS	K	Sedimentary rocks
ORDOVICIAN	O	Sedimentary rocks
ARCHEAN	Agr	Granitoid rocks
	Ams	Metamorphosed sedimentary and volcaniclastic rocks
	Amv	Metamorphosed mafic-intermediate volcanic rocks

Expanation for
Figure 3-20

Undifferentiated Granites (NC-6)

Figure 3-20 Sheet 2



Thickness of Overburden and Outcrop Locations

Undifferentiated Granites (NC-6)

Figure 3–21

crystalline host rocks of the preliminary candidate area are sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation.

3.2.1.4.2 Lithology and Tectonics. The undifferentiated granites, as inferred from geophysical data, are composed of granitoid rocks of the greenstone-granite terrane (Figure 3-20). These granites are intrusive into mafic to intermediate metavolcanic rocks on the south and east, metasedimentary and metavolcaniclastic rocks on the west and north, and are unconformably overlain by Ordovician limestone, sandstone, siltstone, and shale on the west (Morey, et al., 1982). Several small outliers of Cretaceous shale and sandstone overlie these rocks within the preliminary candidate area (Morey et al., 1982).

The greenstone-granite terrane was deformed and metamorphosed to the greenschist facies, and locally to the upper amphibolite facies during the Algoman orogeny 2,600 to 2,700 million years ago (Morey and Sims, 1976; Sims, 1980). Deformation and metamorphism of the country rock during the Algoman orogeny was virtually synchronous with the emplacement of the granitic rocks and probably resulted from compression caused by the relative upwelling and convergence of the adjacent plutons (Morey and Sims, 1976). Following the intrusion of the granitic plutons, the alternating greenstone and granite belts were displaced by several generations of right-lateral, strike-slip faults (Sims, 1976). Subsequent to the Algoman orogeny, the greenstone-granite terrane has been essentially tectonically stable (Sims et al., 1980). One minor exception was the intrusion of a northwest-trending dike swarm in northern Minnesota about 2,120 million years ago (Southwick and Day, 1983).

There are no mapped faults within the preliminary candidate area (Figure 3-20). Three inferred northwest-trending faults terminate 5.5 to 9.0 km (3.5 to 5.5 mi) to the east and southeast of the preliminary candidate area (Morey et al., 1982). These faults have been inferred on the basis of geoph[illegible] [illegible] are 100 to 230 km (61 to 140 mi) long (Morey et al., 1982). No [illegible]uctural [illegible] exclusive of faults have been reported in the literature for the preliminary candidate area. There is also no evidence of Quaternary activity along these faults or within the geologic setting.

A discussion of recent crustal uplift is presented in the regional geologic setting (Section 3.2.1.1.1.3). There is no evidence to suggest tectonic uplift. The uplift due to glacioisostatic rebound is relatively uniform and occurs at slow rates that will continue to decrease in the future such that this uplift is unlikely to result in any measurable changes in the regional ground-water flow system over the next 10,000 years. There are no in situ stress data available for the vicinity of the preliminary candidate area.

The absence of any igneous activity in and near the preliminary candidate area for the last 1,000 million years and the absence of Quaternary volcanism in the geologic setting (Section 3.2.1.1.1.2) indicate that future igneous activity in the area is highly unlikely.

There is no evidence of igneous activity, folding, faulting, uplift, subsidence, or other tectonic processes within the geologic setting during the Quaternary Period. There appears to be no significant potential for tectonic deformations that could affect the regional ground-water flow system.

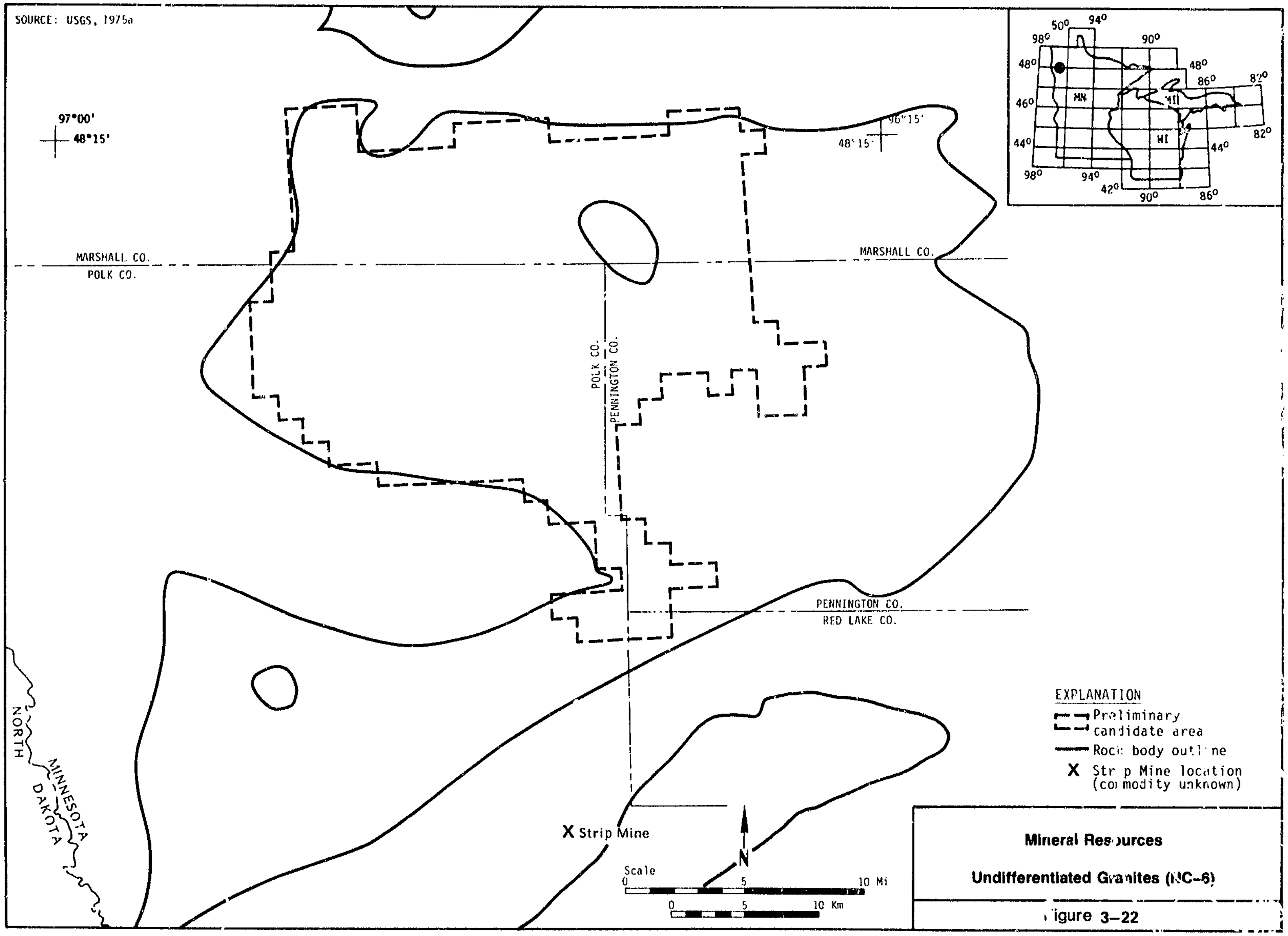
3.2.1.4.3 Seismicity. There are no historical earthquakes reported within the vicinity of the preliminary candidate area and there are no known structures near the preliminary candidate area that might be expected to include seismic activity of greater frequency or intensity than that which is typical of the region. The regional seismicity is discussed in Section 3.2.1.1.1.3.

Considering the low level and magnitude of seismic activity in the region and the absence of active tectonic processes within the geologic setting during the Quaternary Period, it is unlikely that future seismic activity would produce ground motion in excess of reasonable design limits or could affect waste containment or isolation, and it is unlikely that the frequency of occurrence of earthquakes in the preliminary candidate area will increase in the future.

3.2.1.4.4 Mineral Resources. There are no strategic, metallic, or energy-related resources known to occur either in or within 10 km (6 mi) of the preliminary candidate area (Schwartz and Prokopovich, 1966; Walton, 1976; USBM, 1983). A strip mine is shown on the Grand Forks 1:250,000-scale topographic map (USGS, 1975a) and is located approximately 13 km (8 mi) south of the preliminary candidate area (Figure 3-22). Although the commodity is unknown, the open cut nature of the excavation suggests that the deposit is shallow. The current operating status of this deposit is unknown. No deep mines or quarries (greater than 100 m [328 ft] in depth) are located within the preliminary candidate area. The nearest deep mines or quarries are the iron mines in the Mesabi Range, located more than 100 km (62 mi) to the southeast of the preliminary candidate area. Other natural resources within and near the preliminary candidate area (i.e., gravel pits and marl deposits) are shallow and widely available throughout the region.

Based on the data presented in this section, there are no metallic, strategic, or energy-related resources within the preliminary candidate area. There is no evidence of mining to a depth sufficient to affect waste isolation, and no information is currently available to indicate that deep exploration drillholes (greater than 100 m [328 ft] in depth) are present in the preliminary candidate area.

3.2.1.4.5 Topography and Surface Water Characteristics. The topographic relief of the preliminary candidate area is very low, with elevations ranging from 259 to 335 m (850 to 1,100 ft). The preliminary candidate area does not appear to contain large areas of floodplain.



Mineral Resources

Undifferentiated Granites (NC-6)

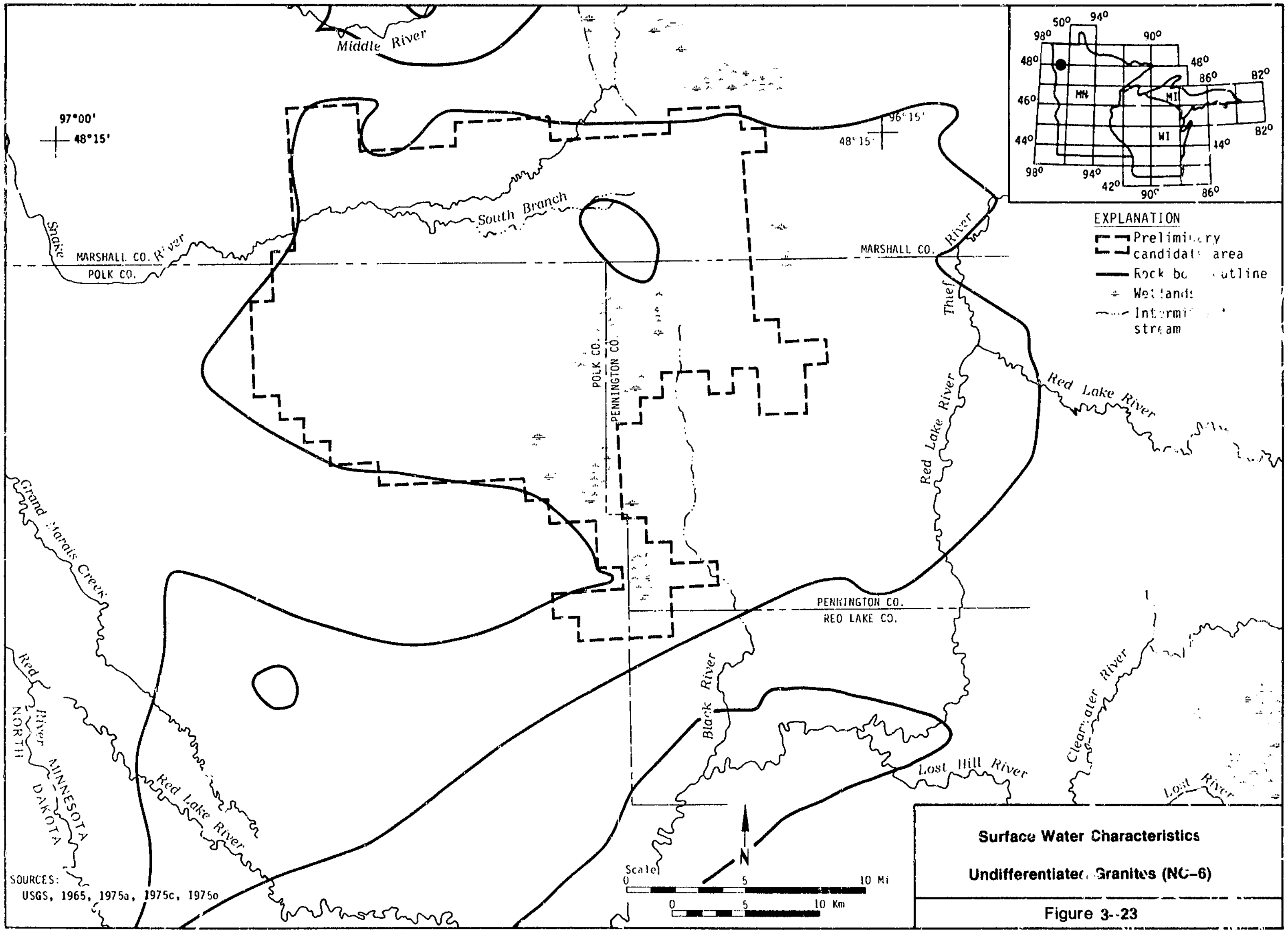
Figure 3-22

Examination of topographic maps indicates that only localized portions of the preliminary candidate area along major drainages and small stream valleys are potentially flood prone. The low relief and slope, and small capacity of stream channels developed in the former Lake Agassiz plain result in more flooding in the western section (Bidwell et al., 1970; Maclay et al., 1965). No reservoirs or impoundments are known to exist in or upstream of the preliminary candidate area.

The undifferentiated granite batholith underlying the preliminary candidate area is drained mainly by the Black and Snake Rivers, which drain south and west, respectively, to discharge to the Red River, which drains toward Canada. As represented by the region-to-area screening data base, the preliminary candidate area is covered by approximately 3% surface water and less than 1% wetland (USGS, 1965; USGS, various dates; Minnesota State Planning Agency, 1984). The locations of lakes, rivers, and swamplands in the preliminary candidate area shown on Figure 3-23 are based on surface water features shown on USGS 1:250,000 Bemidji, Grand Forks, Thief River Falls, and Roseau topographic maps. Major surface water bodies within the preliminary candidate area include the Snake, South Branch of the Snake, and Black Rivers. Other surface water bodies near the preliminary candidate area include the Red Lake River, Middle River, Thief River, Lost Hill River, and numerous other lakes and streams.

The data presented in this section indicate that the relief of the preliminary candidate area is generally low and the terrain is moderately well drained, with scattered small wetlands.

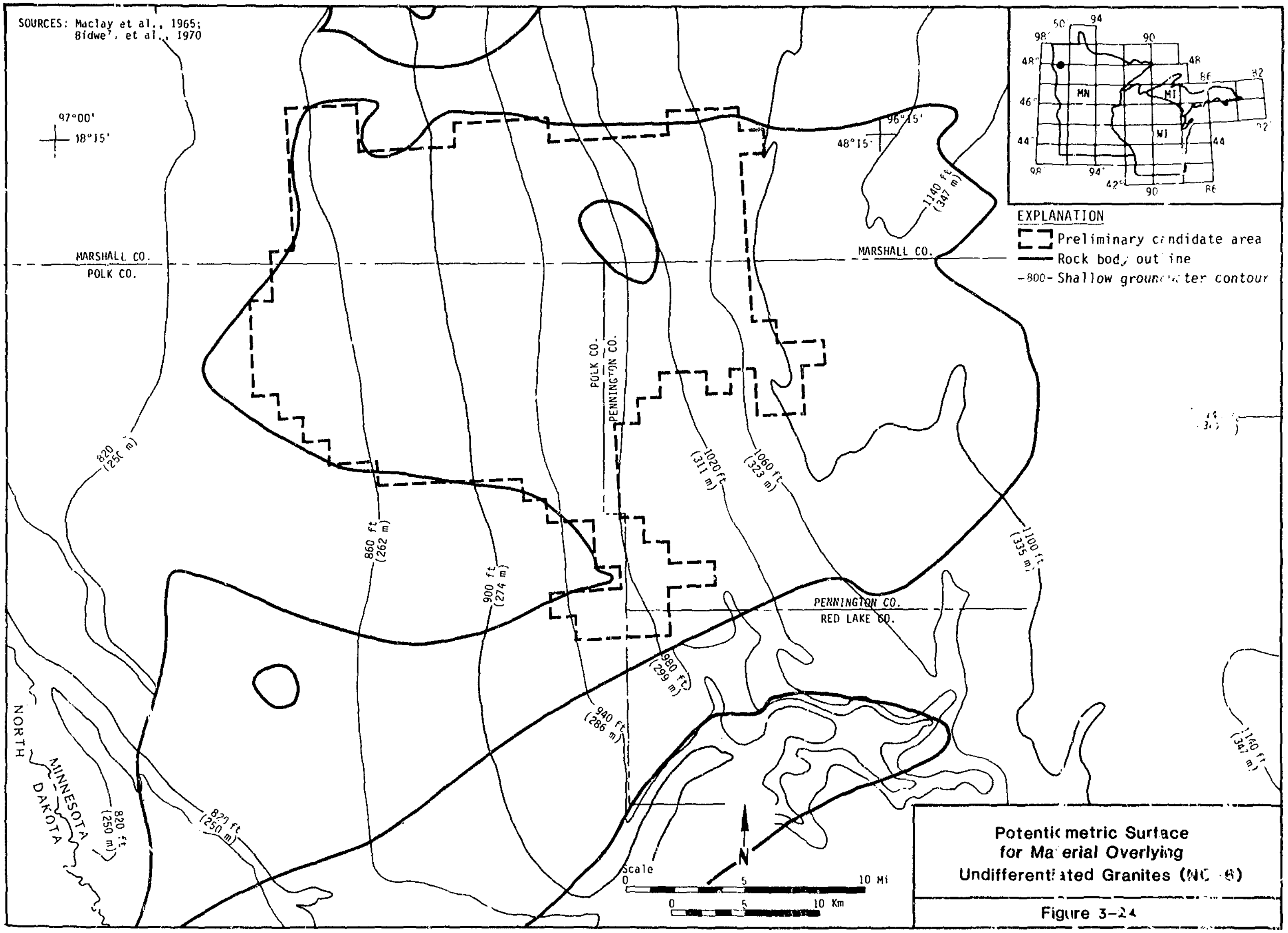
3.2.1.4.6 Ground-Water Resources. The regional hydrology is discussed in Section 3.2.1.1.1.5. Shallow ground-water movement is generally westward toward the Red River. Figure 3-24 shows shallow



Surface Water Characteristics

Undifferentiated Granites (NC-6)

Figure 3-23



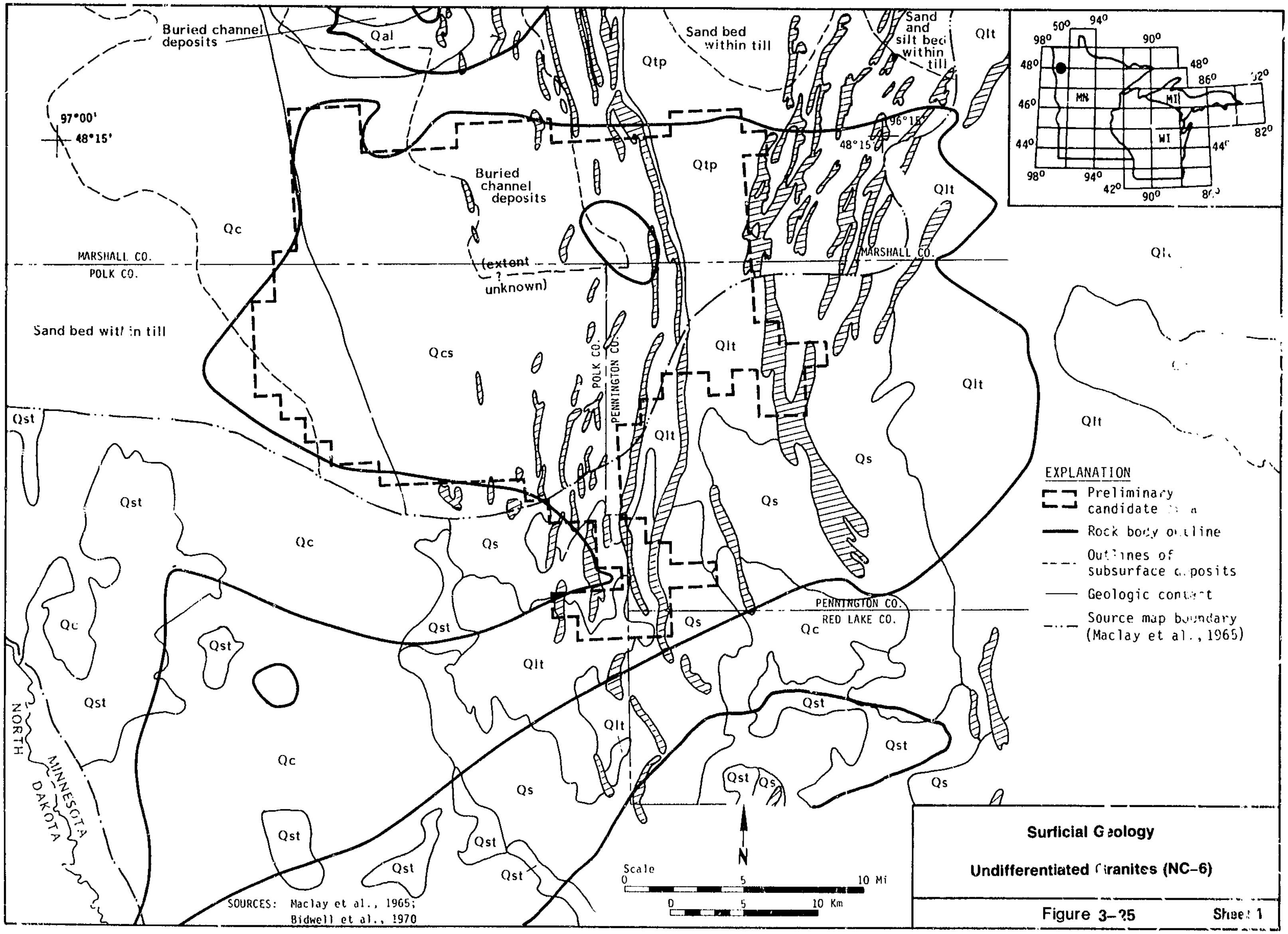
Potentiometric Surface for Material Overlying Undifferentiated Granites (NC-6)

Figure 3-24

ground-water contours reported by Bidwell et al. (1970) and Maclay et al. (1965). Areas that displayed convergence of shallow water-table contours, based on a 30-m (100-ft) contour interval, were considered potential major discharge zones. These generally correspond to locations of major streams and rivers. No major discharge zones have been identified in the preliminary candidate area (DOE, 1985c).

Ground water in and near the preliminary candidate area is primarily obtained from glacial sediments that include: 1) deep-water lake deposits of dense clay and lenses of silt and very fine sand; 2) shallow-water and shoreline deposits of interbedded clay, silt, and fine sand; 3) till consisting of clay, silt, sand, and gravel; 4) beach and bar deposits of fine to coarse sand with lenses of gravel; 5) alluvial and lake bar deposits of predominantly sand and silt with lenses of gravel; 6) buried channel deposits varying from sand and gravel to interbedded sand, silt, and clay; 7) sand beds within till; 8) sand and silt within till; 9) low-permeability glacial lake clay; 10) relatively permeable glacial lake silt; and 11) glacial lake sands (Bidwell et al., 1970; Maclay et al., 1965). The horizontal extent of surficial deposits is shown in Figure 3-25.

Well yields presented in the North Central RGCR (DOE, 1985c) were estimated from maps by Kanivetsky (1978, 1979) and Kanivetsky and Walton (1979), and are shown on Figure 3-26a. Additional detailed well yield information has been reported by Bidwell et al. (1970) and McClay et al. (1965) in USGS Hydrologic Atlases, and is shown on Figure 3-26b. Some estimated well yields shown on these two figures may not agree; however, there is currently no basis for determining which data set is more representative of actual well yields. Both data sets are shown for comparison. The fine-grained lake deposits generally are not a source of water, but may yield less than 0.06 L/s (1 gpm) to a large-diameter well. The beach ridge deposits may yield greater than 1.3 L/s (20 gpm)


Buried channel deposits
Qal
Sand bed within till
Qtp
Sand and silt bed within till
Qlt
97°00'
48°15'
96°15'
48°15'
Buried channel deposits
Qc
MARSHALL CO.
POLK CO.
(extent ? unknown)
MARSHALL CO.
Sand bed within till
Qcs
POLK CO.
PENNINGTON CO.
Qlt
Qst
Qs
Qc
Qst
Qst
Qst
NORTH DAKOTA
MINNESOTA
PENNINGTON CO.
RED LAKE CO.
Qc
Qs
Qst
SOURCES: Maclay et al., 1965; Bidwell et al., 1970
Scale
0 5 10 Mi
0 5 10 Km
N
EXPLANATION
Preliminary candidate area
Rock body outline
Outlines of subsurface deposits
Geologic contact
Source map boundary (Maclay et al., 1965)
MN
MI
WI
Surficial Geology
Undifferentiated Granites (NC-6)
Figure 3-25
Sheet 1

EXPLANATION OF SURFICIAL UNITS

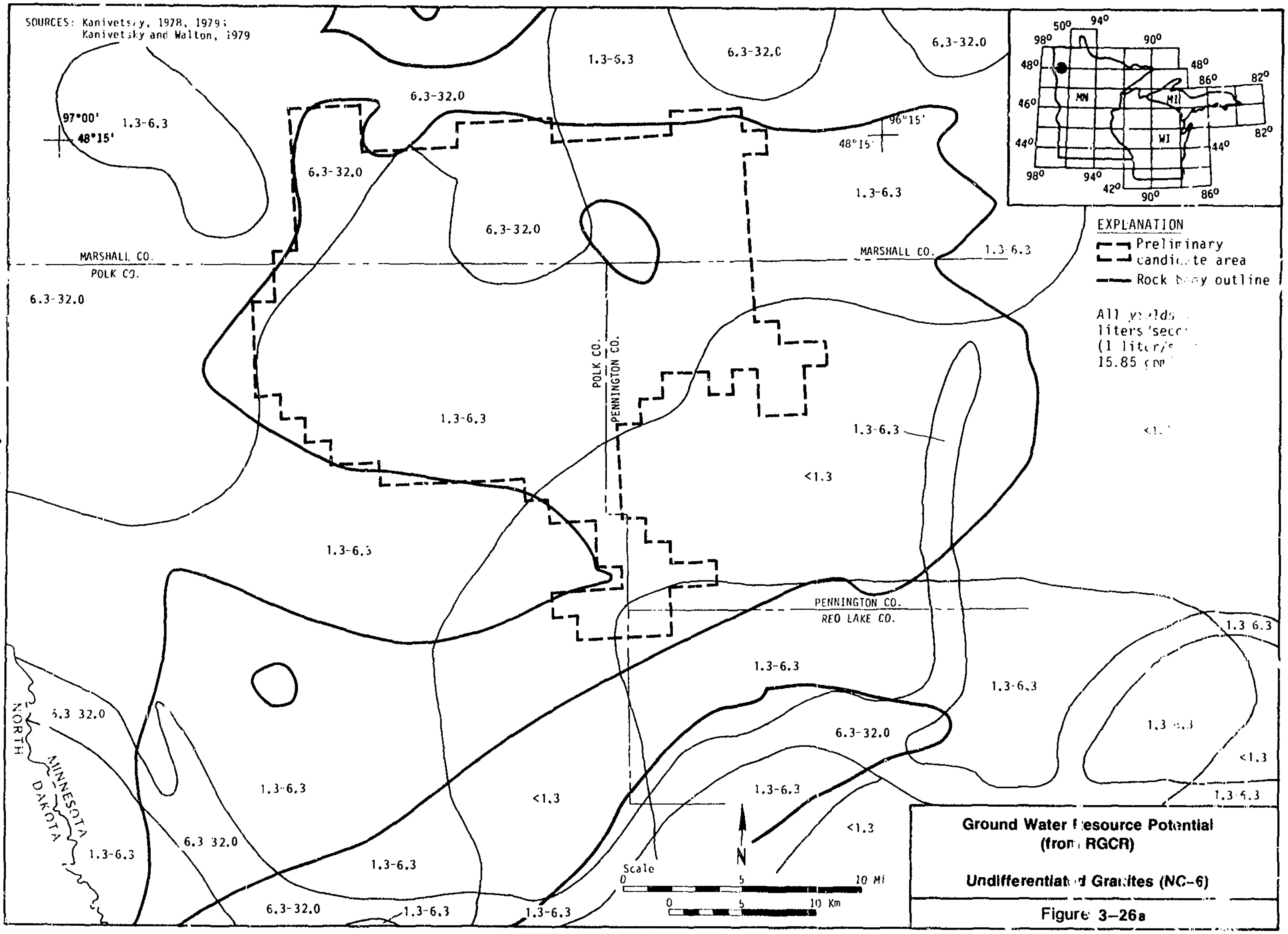
QUATERNARY

Qtp	Till
Qlt	Lake-washed till
Qs	Sand
Qc	Clay
Qst	Silt
	Sand and gravel (beach deposits)

Expanation for Figure 3-25

Undifferentiated Granites (NC-6)

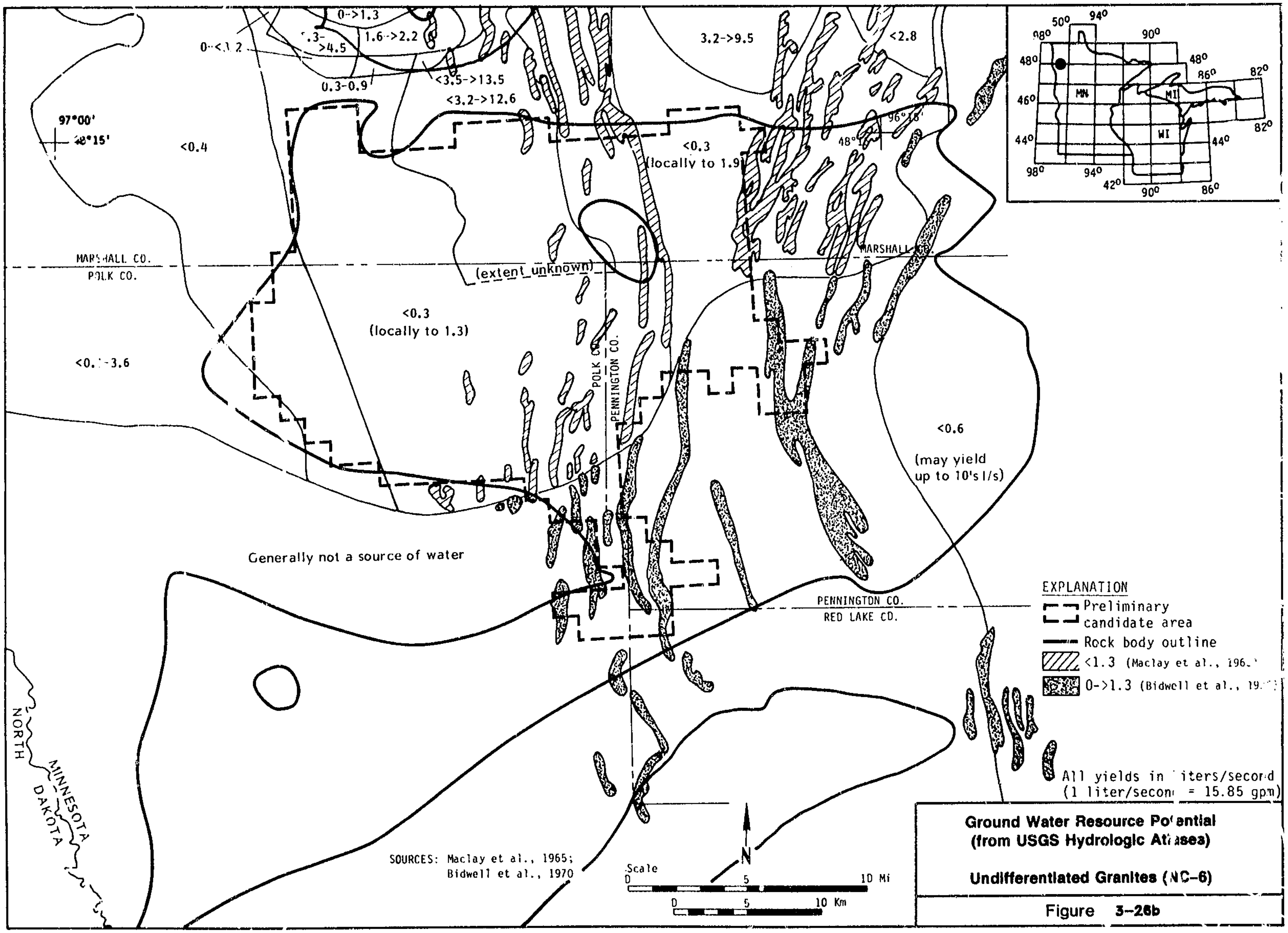
Figure 3-25 Sheet 2



Ground Water Resource Potential (from RGCR)

Undifferentiated Granites (NC-6)

Figure 3-26a



Ground Water Resource Potential (from USGS Hydrologic Atlases)

Undifferentiated Granites (NC-6)

Figure 3-26b

in thicker sections. [illegible] generally yields less than 0.6 L/s (10 gpm), but lenses of [illegible] and gravel may yield up to 10 L/s (150 gpm).

The data indicate that relatively shallow Quaternary aquifers that contain potable ground water are present within the preliminary candidate area. Two deep wells (i.e., greater than 100 m [328 ft] in depth) have been reported in the literature. However, local ground-water conditions in the deeper crystalline rock are currently unknown.

3.2.1.4.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including erosion and deposition and vertical crustal movement, is in Section 3.2.1.1.1.1.

3.2.1.4.8. Federal Lands. No Federal lands of greater than 130 ha (320 ac) in size are located in or within 10 km (6 mi) of the preliminary candidate area. Federal lands greater than 130 ha (320 ac) in size, which are located in the Minnesota portion of the region, are depicted on Plate 2A of the North Central RECR (DOE, 1985d). In addition, there is no evidence in the data base that Federal lands less than 130 ha (320 ac) in size are located in or within 10 km (6 mi) of the preliminary candidate area.

3.2.1.4.9 State Lands. The Pembina Wildlife Management Area overlaps approximately 36 km^2 (14 mi^2) or 3,626 ha (8,960 ac) of the preliminary candidate area, and the Sanders Wildlife Management Area occupies 33 ha (80 ac) within the preliminary candidate area. In total, these two areas occupy 3,659 ha (9,040 ac) or approximately 5% of the preliminary candidate area. There are four wildlife management areas, each greater than 130 ha (320 ac) in size, located within 10 km (6 mi) of the preliminary candidate area: Rosewood, 0.8 km (0.5 mi) east; Moran, 6.5 km (4 mi) southeast; Huot, 8.8 km (5.5 mi) southeast; and Higinbotham, 6.5 km (4 mi) east. In addition, there are three wildlife management areas, each less than 130 ha (320 ac) in size, located within

10 km (6 mi) of the preliminary candidate area. The Old Crossing Treaty State Wayside, also less than 130 ha (320 ac) in size, is located approximately 10 km (6 mi) south of the preliminary candidate area boundary. Three unnamed parcels of State forest lands, each greater than 130 ha (320 ac), are located within 1.6 km (1 mi) of the preliminary candidate area. All of the features described above are depicted on Plates 3A or 4A or are listed in Appendix B of the North Central RECR (DOE, 1985d).

In summary, two State wildlife management areas (one greater than and one less than 130 ha [320 ac]) are located within the preliminary candidate area and cover a total of approximately 3,659 ha (9,040 ac) or 5% of the preliminary candidate area. Also, eleven State lands (seven greater than and four less than 130 ha [320 ac]) are located within 10 km (6 mi) of the preliminary candidate area (see Figure 3-27).

3.2.1.4.10 Environmental Compliance. There are no nonattainment areas or Prevention of Significant Deterioration (PSD) Class I Areas in or within 40 km (25 mi) of the preliminary candidate area (40 CFR 81). No sites listed on the National Register of Historic Places (NRHP) and no proposed NRHP sites are located with the preliminary candidate area. In the regional data base, there are no known existing archaeological sites or districts nor any proposed for designation within the preliminary candidate area. No National Trails are located in or within 40 km (25 mi) of the preliminary candidate area.

3.2.1.4.11 Population Density and Distribution. The preliminary candidate area contains no highly populated areas. However, there is one highly populated area, Thief River Falls, within 16 km (10 mi) of the preliminary candidate area. Thief River Falls is located 10.5 km (6.5 mi) east of the preliminary candidate area and has a population of 9,105 (see Figure 3-27). The preliminary candidate area contains one area, Warren, with a population density greater than or equal to 1,000 persons per square mile. Warren, with a population of 2,105, is located

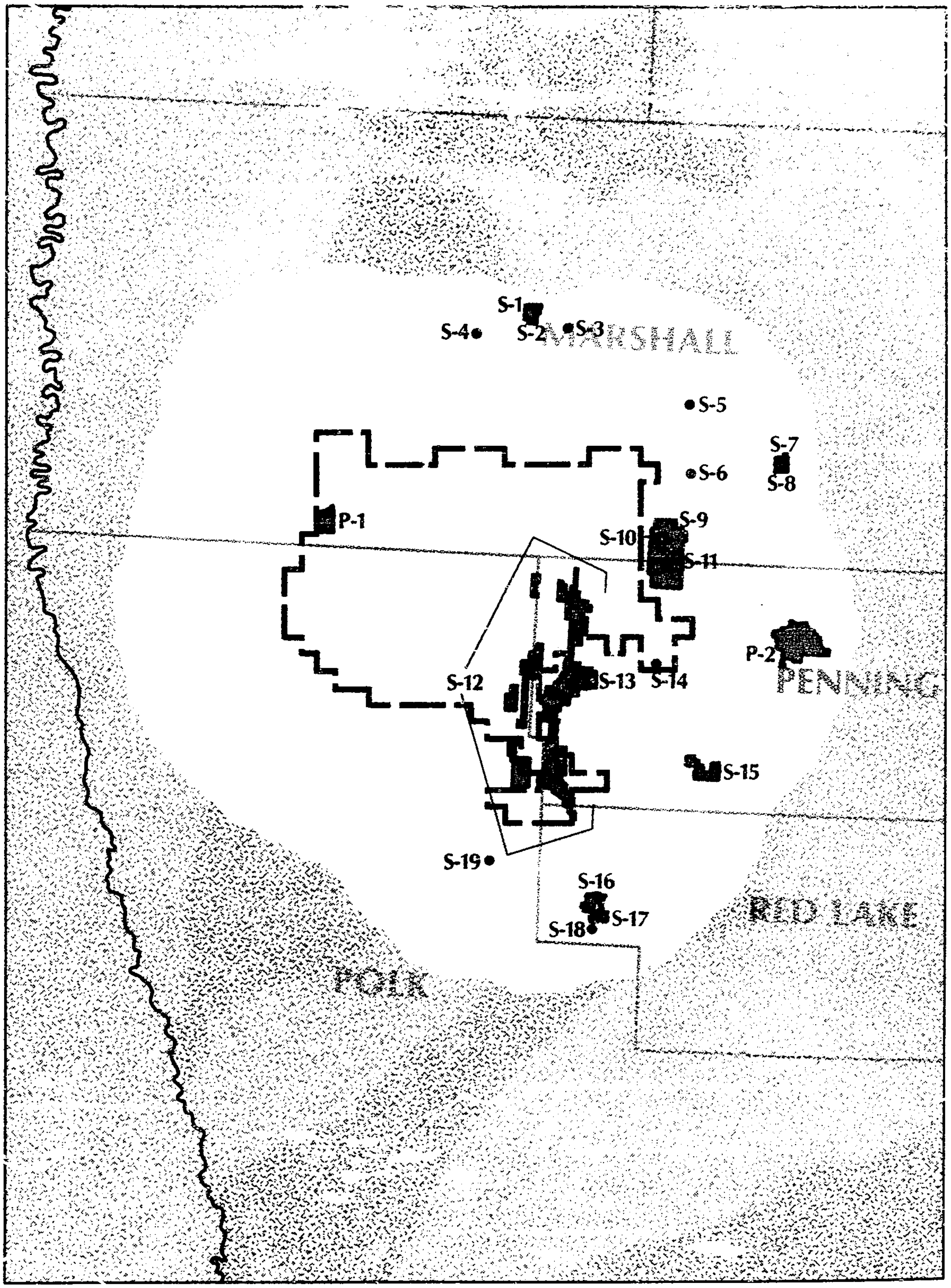


Figure 3–27 Sheet 1

Environmental Features
Undifferentiated Granites (NC-6)

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

P	Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile
F	Federal Lands Greater Than 320 Acres
S	State Lands Greater Than 320 Acres
I	Federal Indian Reservations
●	Federal or State Lands Less Than 320 Acres
F-5	Map Alpha-numeric Codes are Keyed to Environmental Features

Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

0 miles 20

0 kilometers 20

Figure 3-27 Sheet 2

ENVIRONMENTAL FEATURES WITHIN 16 KM (10 MI) OF PRELIMINARY CANDIDATE AREA NC-6*

Code	Feature
Population Features	
P-1	Warren**
P-2	Thief River Falls Highly Populated Area**
Federal Lands	
None	
State Lands	
S-1	Wright Wildlife Management Area (WMA)
S-2	Unnamed State Forest Parcel (SFO)
S-3	Adolf Elseth Memorial WMA
S-4	Old Mill State Park
S-5	New Folden WMA
S-6	New Solum WMA
S-7	Excel WMA
S-8	SFO
S-9	Rosewood WMA
S-10	SFO
S-11	SFO
S-12	Pembina WMA
S-13	SFO
S-14	Sanders WMA
S-15	Higinbotham WMA
S-16	Moran WMA
S-17	Huot WMA
S-18	Old Crossing Treaty State Wayside
S-19	Belgium WMA
Indian Reservations	
None	

* The accompanying text identifies only those environmental features within 10 km (6 mi) of the preliminary candidate area.

** Area with a population density of greater than or equal to 1,000 persons per square mile.

Figure 3-27, Sheet 3

in the northwestern portion of the preliminary candidate area. There is one area with a population density greater than or equal to 1,000 persons per square mile within 16 km (10 mi) of the preliminary candidate area. This area is Thief River Falls, which is also a highly populated area (see Figure 3-27). Grand Forks, North Dakota is located approximately 24 km (15 mi) southwest of the preliminary candidate area. The average population density of the preliminary candidate area is 12 persons per square mile. The average population density within 80 km (50 mi) of the preliminary candidate area is approximately 16 persons per square mile. Low population density is defined as a density in the general region of the site less than the average population density for the conterminous United States (76 persons per square mile) based on the 1980 census.

3.2.1.4.12 <u>Site Ownership</u>. There are no Federal or DOE-owned lands located within the preliminary candidate area. The Red Lake Indian Reservation is located 53 km (33 mi) east of the preliminary candidate area, and the White Earth Indian Reservation is located 53 km (33 mi) southeast of the preliminary candidate area (see Plate NC-1A).

3.2.1.4.13 <u>Offsite Installations</u>. No commercial nuclear reactors are located within the preliminary candidate area. The nearest operating commercial nuclear reactor is Monticello which is approximately 350 km (219 mi) to the southeast (Michelewicz and Vann, 1983; DOE, 1984c). The nearest commercial nuclear reactor under construction is Byron 2, which is 890 km (500 mi) to the southeast (Nuclear News, 1985). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.1.4.14 <u>Transportation</u>. The nearest interstate highway to the preliminary candidate area is I29 in North Dakota which is about 25 km (16 mi) to the west. U.S. 75 passes through the western portion of the preliminary candidate area. U.S. 59 runs approximately 4.8 km (3 mi) to the east. U.S. 2, which is a four-lane divided highway, is about 19 km (12 mi) from the southern portion of the preliminary candidate area. State Route 1 is the only State highway that crosses the preliminary candidate area. This is a principal State highway which intersects U.S. 59 at Thief River Falls, U.S. 75 at Warren, and continues on to I29 in North Dakota.

The Burlington Northern Minneapolis to Winnipeg mainline crosses the preliminary candidate area. A mainline, which is part of the Soo/Milwaukee is located approximately 4.8 km (3 mi) east of the preliminary candidate area. The Soo/Milwaukee has a branchline which crosses the northern portion of the preliminary candidate area in an east-west direction. This branchline originates at the Soo/Milwaukee mainline described above.

Based on the data presented above, access appears to be available to both local and regional road and rail systems.

3.2.1.4.15 Preliminary Candidate Area Deferral Analysis. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area NC-6 that could affect DOE's decision to defer further consideration of the area. Based on evaluation of this additional available information, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1 000 ft) below ground surface [960.4-2-5(b)(1)]

- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]
- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]
- low potential for tectonic deformations suggest that the regional ground-water flow systems should not be significantly affected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]
- absence of historical earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that the frequency of earthquake occurrence within the geologic setting may increase [960.4-2-7(c)(3)]
- the frequency of occurrence or magnitude of earthquakes within the geologic setting are no higher than within the region [960.4-2-7(c)(4)]
- absence of historical earthquakes that, if they recurred, could produce ground motion in excess of reasonable design limits [960.5-2-11(c)(2)]
- absence of evidence, based on correlations of earthquakes with tectonic processes and features within the geologic setting, that the magnitude of earthquakes during repository construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]
- no evidence of subsurface mining or extraction for resources that could affect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence or drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]

- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]
- presence of generally flat terrain [960.5-2-8(b)(1)]
- presence of generally well-drained terrain [960.5-2-8(b)(2)]
- general absence of surface characteristics or surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]
- absence of Federal lands less than 130 ha (320 ac) within and in proximity to (i.e., within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(3)]
- limited presence of State lands less than 130 ha (320 ac) with (i.e., 1) and in proximity to (i.e., 4 within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(4)]
- low population density within its boundaries and within 80 km (50 mi) of the preliminary candidate area [960.5-2-1(b)(1)]
- absence of nuclear installations [960.5-2-4(b) and (c)(2)]
- no projected land ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings [960.4-2-8-2(c), 960.5-2-2(c)]
- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2), 960.5-2-7(b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)]

- a majority (approximately 50%) of the preliminary candidate area is within 16 km (10 mi) of highly populated areas or areas containing more than 1,000 persons per square mile [960.5-2-1(c)(2)].

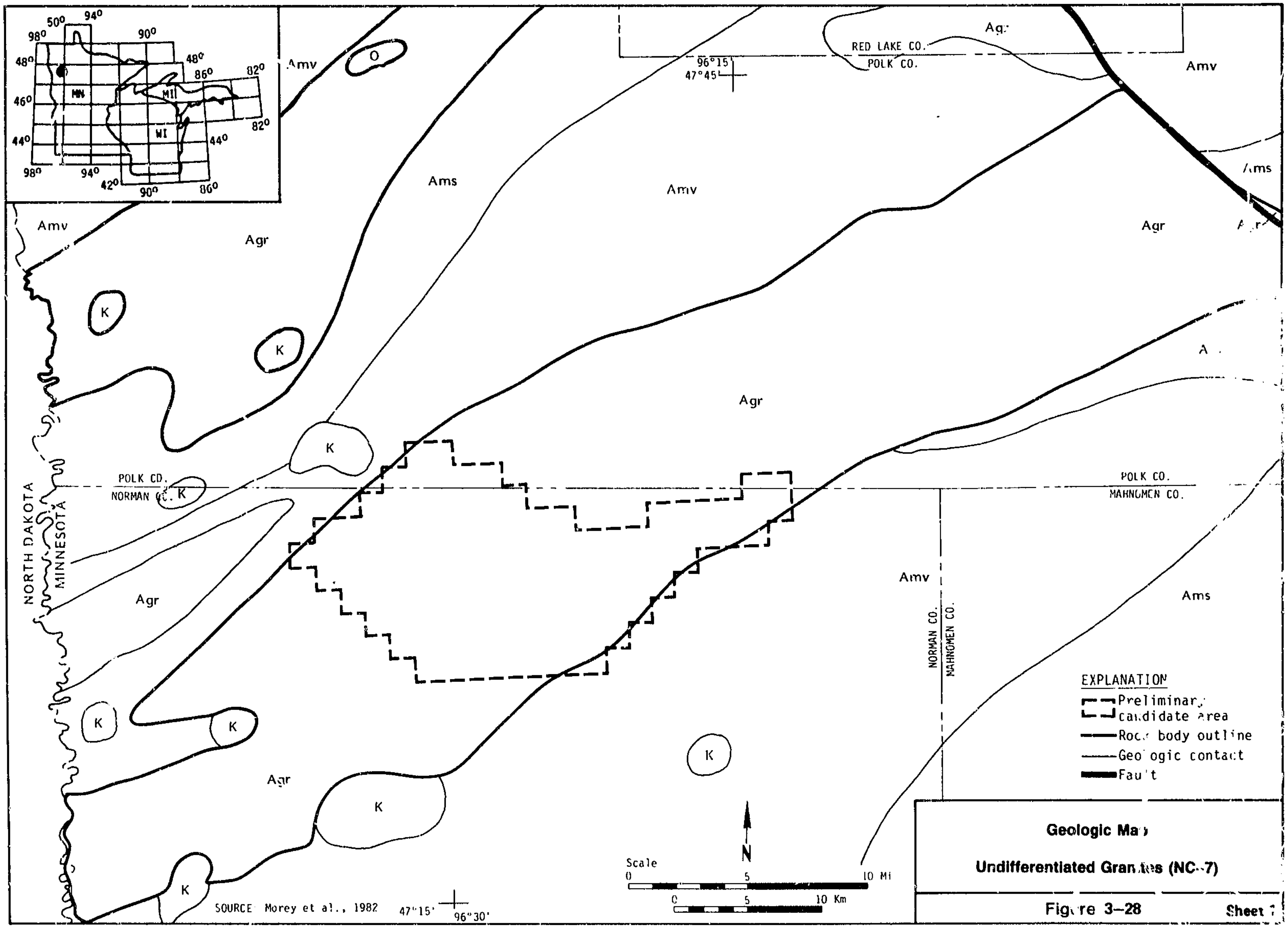
The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area NC-6 at this time.

3.2.1.5 Preliminary Candidate Area Description - Undifferentiated Granites (NC-7)

These undifferentiated granites are located within the Lake Agassiz Lowland and the Central Minnesota Moraine Complex Upland physiographic province in northern Minnesota. The preliminary candidate area is located in Norman and Polk Counties at approximately 47°26' N latitude and 96°28' W longitude.

3.2.1.5.1 Host Rock Geometry and Overburden Thickness. The preliminary candidate area shown on Figure 3-28 has an area of approximately 294 km^2 (113 mi^2) and overlies a batholith of undifferentiated granites, the rocks of which are not exposed and the mapped extent of which is inferred largely from geophysical data (Ojakangas et al., 1979; Morey et al., 1982). The batholith is approximately 110 km (67 mi) long and varies in width from 4 to 18 km (2 to 11 mi). Data on the vertical extent of the batholith are not available, however the batholith is inferred to extend to depths of several kilometers (miles) based on the present understanding of the mode of emplacement of batholiths and seismic reflection studies in batholithic terranes. This information suggests that most batholiths are tabular in shape and extend to a depth of 6 to 10 km (4 to 6 mi) (Hamilton and Myers; 1967; Lynn et al., 1981). Furthermore, no postemplacement deformational processes such as large-scale thrust faulting are known to have diminished the vertical extent of the batholith.

There is no exposed bedrock in the preliminary candidate area. Contours of overburden thickness are not available for the preliminary candidate area; however, there is one drillhole to bedrock in the preliminary candidate area that penetrates 93 m (306 ft) of overburden (Figure 3-29). A number of drillholes near the preliminary candidate area penetrated between 96 and 126 m (316 to 412 ft) of overburden.



Geologic Map

Undifferentiated Granites (NC-7)

Figure 3–28

EXPLANATION OF GEOLOGIC UNITS

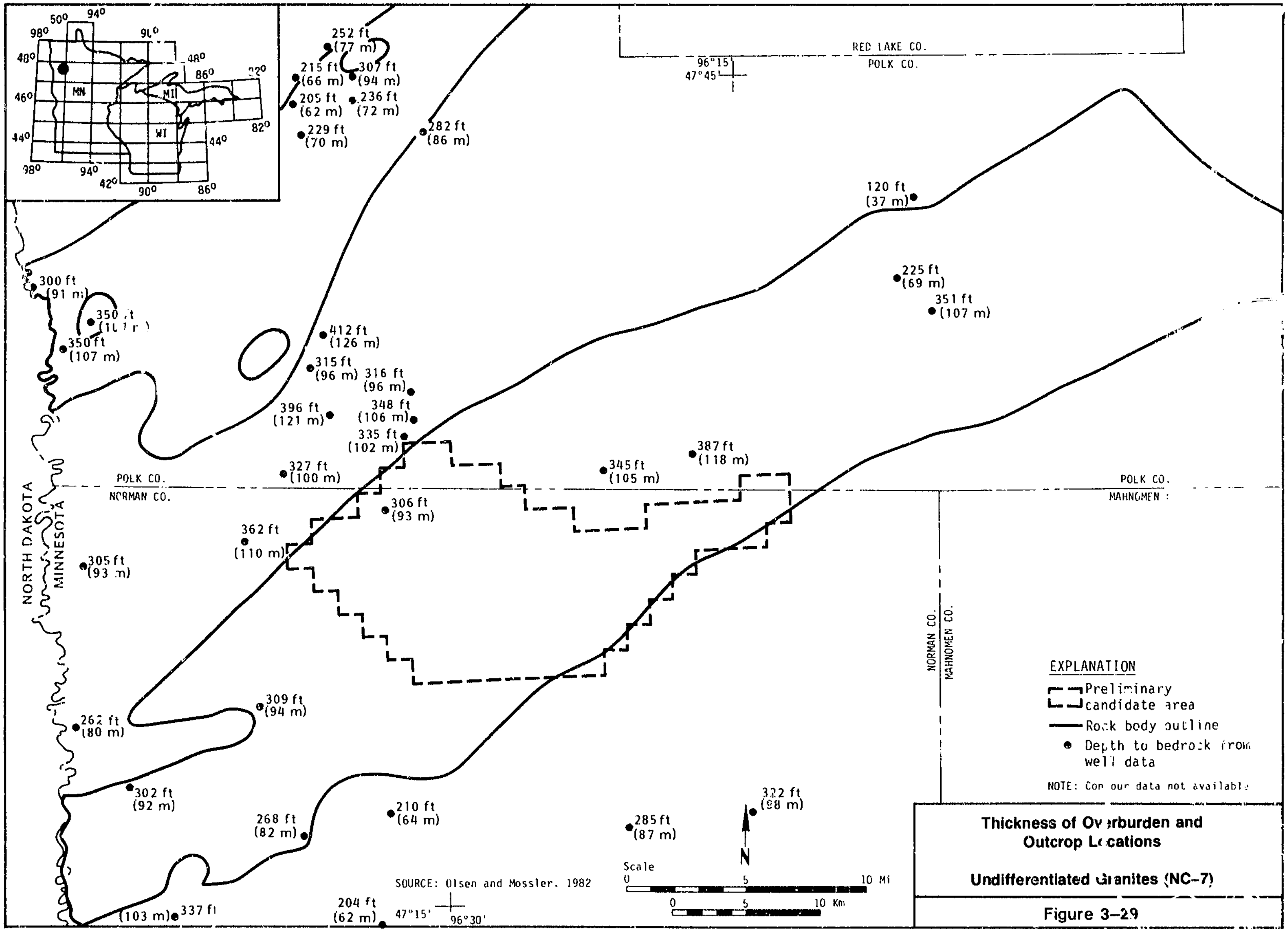
CRETACEOUS

CRETACEOUS	K	Sedimentary rocks
ARCHEAN	Agr	Granitoid rocks
ARCHEAN	Ams	Metamorphosed sedimentary and volcaniclastic rocks
ARCHEAN	Amv	Metamorphosed mafic-intermediate volcanic rocks

Explanation for Figure 3-28

Undifferentiated Granites (NC-7)

Figure 3-28 Sheet 2



Thickness of Overburden and Outcrop Locations

Undifferentiated Granites (NC-7)

Figure 3–29

On the basis of the data presented above and the assumed depth and size of a repository in crystalline rock (see Section 1.5), the crystalline host rocks of the preliminary candidate area are sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation.

3.2.1.5.2 Lithology and Tectonics. The undifferentiated granites, as inferred from geophysical data, are composed of granitoid rocks of the greenstone-granite terrane (Figure 3-28). These rocks are intrusive into mafic to intermediate metavolcanic rocks except on the east where they are intrusive into metasedimentary and metavolcaniclastic rocks (Morey et al., 1982). Several small outliers of Cretaceous shale and sandstone overlie these rocks to the west of the preliminary candidate area (Morey et al., 1982).

The greenstone-granite terrane was deformed and metamorphosed to the greenschist facies, and locally to the upper amphibolite facies during the Algoman orogeny 2,600 to 2,700 million years ago (Morey and Sims, 1976; Sims, 1980). Deformation and metamorphism of the country rock during the Algoman orogeny was virtually synchronous with the emplacement of the granitic rocks and probably resulted from compression caused by the relative upwelling and convergence of the adjacent plutons (Morey and Sims, 1976). Following the intrusion of the granitic plutons, the alternating greenstone and granite belts were displaced by several generations of right-lateral, strike-slip faults (Sims, 1976). Subsequent to the Algoman orogeny, the greenstone-granite terrane has been essentially tectonically stable (Sims et al., 1980). One minor exception was the intrusion of a northwest-trending dike swarm in northern Minnesota about 2,120 million years ago (Southwick and Day, 1983).

There are no mapped faults within the preliminary candidate area (Figure 3-28). Approximately 35 km (22 mi) northeast of the preliminary candidate area is a 160-km (99-mi) long northwest-trending, geophysically inferred fault that appears to displace the rock body in a right-lateral sense (Morey et al., 1982). No structural features exclusive of faults have been reported in the literature for the preliminary candidate area. There is also no evidence of Quaternary activity along these faults or within the geologic setting.

A discussion of recent crustal uplift is presented in the regional geologic setting (Section 3.2.1.1.1.3). There is no evidence to suggest tectonic uplift. The uplift due to glacioisostatic rebound is relatively uniform and occurs at slow rates that will continue to decrease in the future such that this uplift is unlikely to result in any measurable changes in the regional ground-water flow system over the next 10,000 years. There are no in situ stress data available for the vicinity of the preliminary candidate area.

The absence of any igneous activity in and near the preliminary candidate area for the last 1,000 million years and the absence of Quaternary volcanism in the geologic setting (Section 3.2.1.1.1.2) indicate that future igneous activity in the area is highly unlikely.

There is no evidence of igneous activity, folding, faulting, uplift, subsidence, or other tectonic processes within the geologic setting during the Quaternary Period. There appears to be no significant potential for tectonic deformations that could affect the regional ground-water flow system.

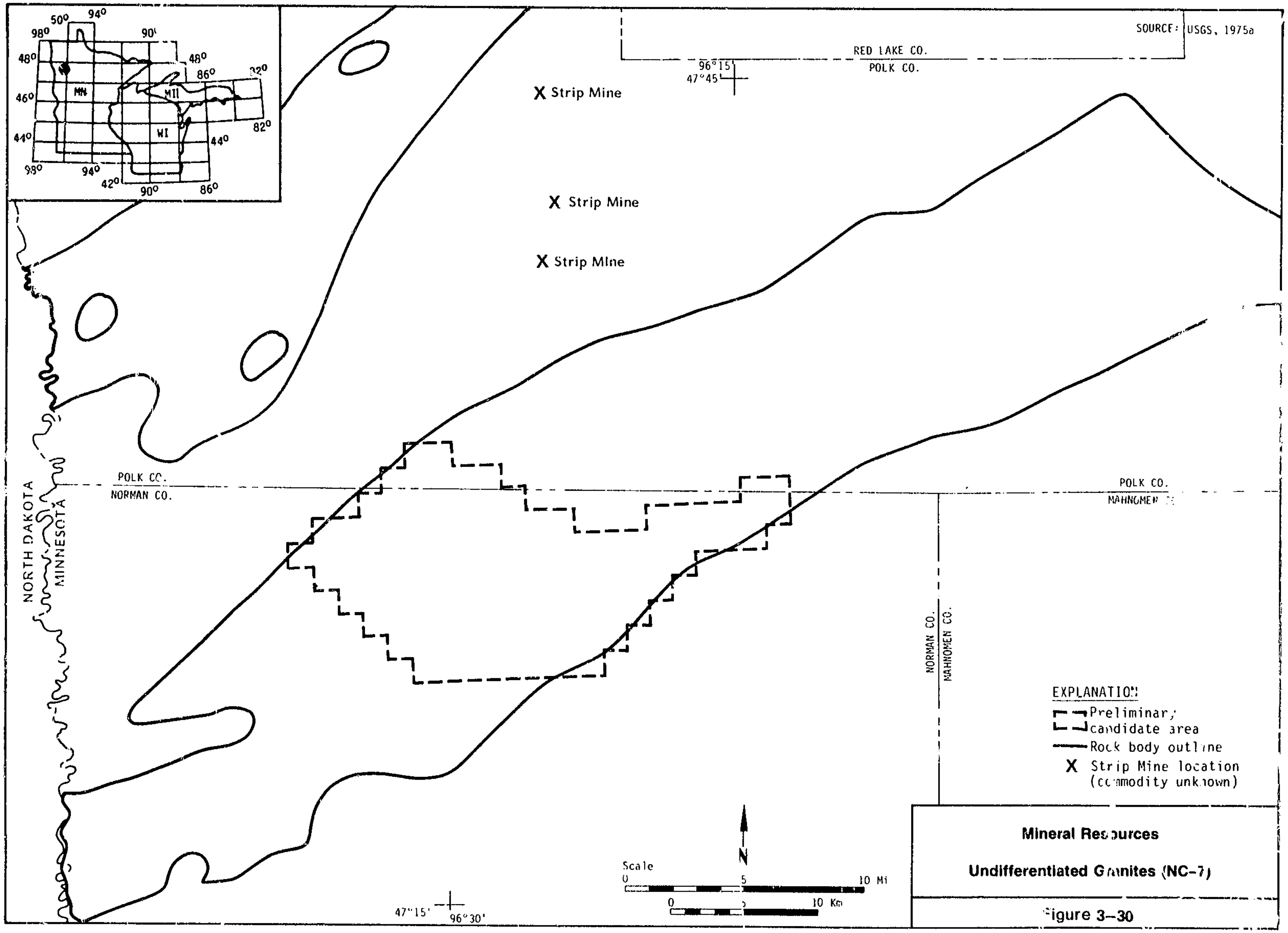
3.2.1.5.3 <u>Seismicity</u>. There are no historical earthquakes reported within the vicinity of the preliminary candidate area. There are no known structures near the preliminary candidate area that might be expected to induce seismic activity of greater frequency or intensity than that which is typical of the region. The regional seismicity is discussed in Section 3.2.1.1.1.3.

Considering the low le[illegible] and magnitude of seismic activity in the region and the absence of active tectonic processes within the geologic setting during the Quaternary Period, it is unlikely that seismic activity would produce ground motion in excess of reasonable design limits or could affect waste containment or isolation and it is unlikely that the frequency of occurrence of earthquakes in the preliminary candidate area will increase in the future.

3.2.1.5.4 Mineral Resources. There are no strategic, metallic, or energy-related resources known to occur either in or within 10 km (6 mi) of the preliminary candidate area (Schwartz and Prokopovich, 1966; Walton, 1976; USBM, 1983). Three strip mines for unidentified commodities are shown on the Grand Forks 1:250,000-scale topographic map (USGS, 1975a) and are located approximately 14, 18, and 26 km (9, 11, and 16 mi), respectively, north of the preliminary candidate area (Figure 3-30). Although the commodities are unknown, the open cut nature of the excavations suggests that the resources are shallow. The current operating status of these deposits is unknown. No deep mines or quarries (greater than 100 m [328 ft] in depth) are located within the preliminary candidate area. The nearest deep mines or quarries are the iron mines in the Mesabi Range, located more than 100 km (62 mi) east of the preliminary candidate area. Other natural resources within and near the preliminary candidate area (i.e., gravel pits and marl deposits) are shallow and widely available throughout the region.

Based on the data presented in this section, there are no metallic, strategic, or energy-related resources within the preliminary candidate area. There is no evidence of mining to a depth sufficient to affect waste isolation and no information is currently available to indicate that deep exploration drillholes (greater than 100 m [328 ft] in depth) are present in the preliminary candidate area.

3.2.1.5.5 Topography and Surface Water Characteristics The topographic relief of the preliminary candidate area is very low, with



Mineral Resources

Undifferentiated Granites (NC-7)

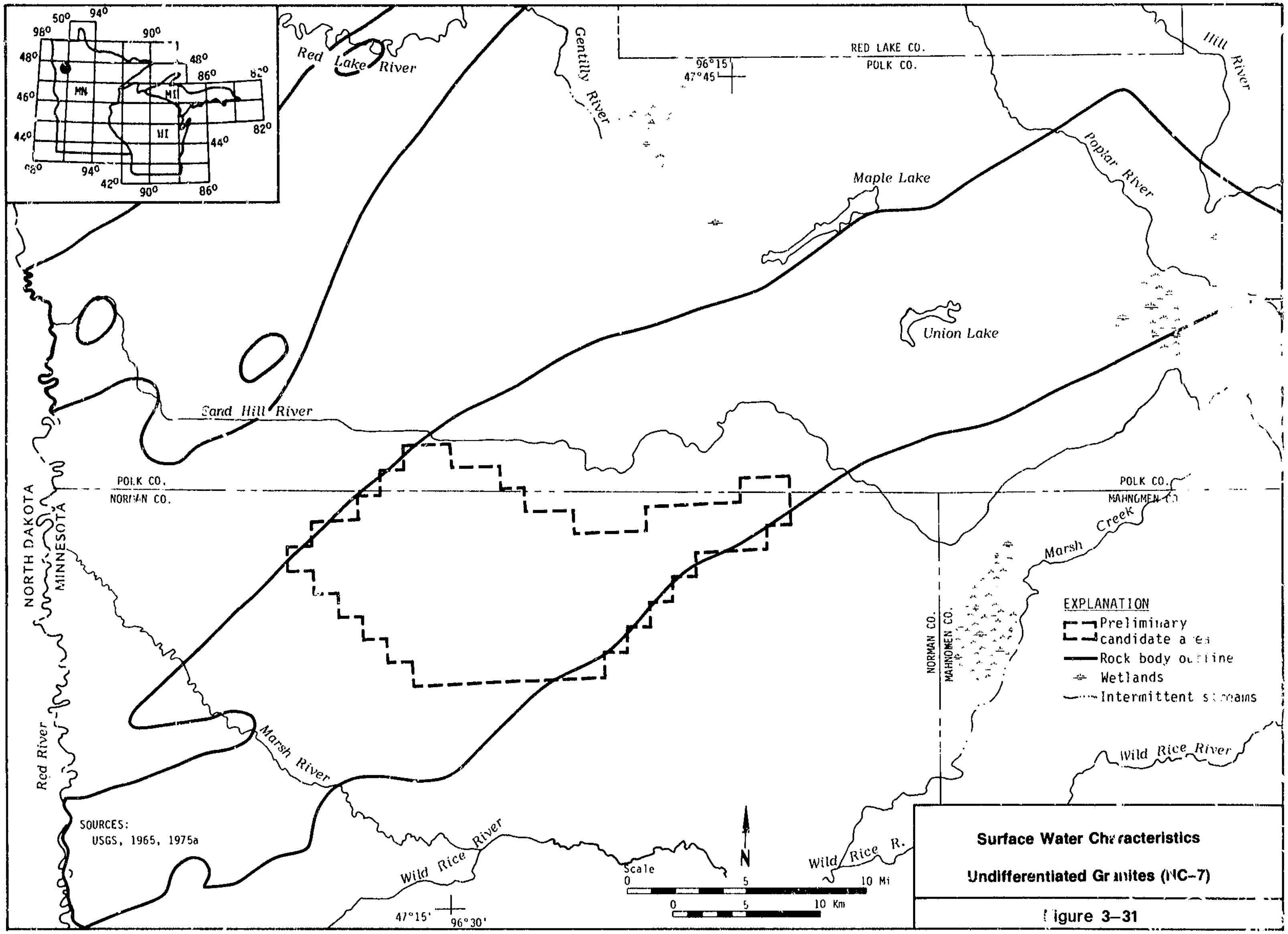
Figure 3-30

elevations ranging from [illegible] 350 m (900 to 1,150 ft). The preliminary candidate area does not appear to contain large areas of floodplain. Examination of topographic maps indicates that only localized portions of the preliminary candidate area along major drainages and small stream valleys are potentially flood prone. The low relief, slope, and small capacity of stream channels developed in the former Lake Agassiz plain result in more flooding in the western portion (Bidwell et al., 1970; Winter et al., 1970). No reservoirs or impoundments are known to exist in or upstream of the preliminary candidate area.

The undifferentiated granites underlying the preliminary candidate area are drained mainly by the Sand Hill River, which drains west to the Red River; the Red River drains to Canada. As represented by the region-to-area screening data base, the preliminary candidate area has no surface water cover and contains no wetland (USGS, 1965; USGS, various dates; Minnesota State Planning Agency, 1984). The locations of lakes, rivers, and marshlands near the preliminary candidate area shown on Figure 3-31 are based on surface water features shown on USGS 1:250,000 Bemidji and Grand Forks topographic maps. Surface water bodies near the preliminary candidate area include the Sand Hill River, Marsh River, Wild Rice River, Union Lake, and Maple Lake, as well as numerous small lakes and intermittent streams.

The data presented in this section indicate that the relief of the preliminary candidate area is generally low and the terrain is generally well drained.

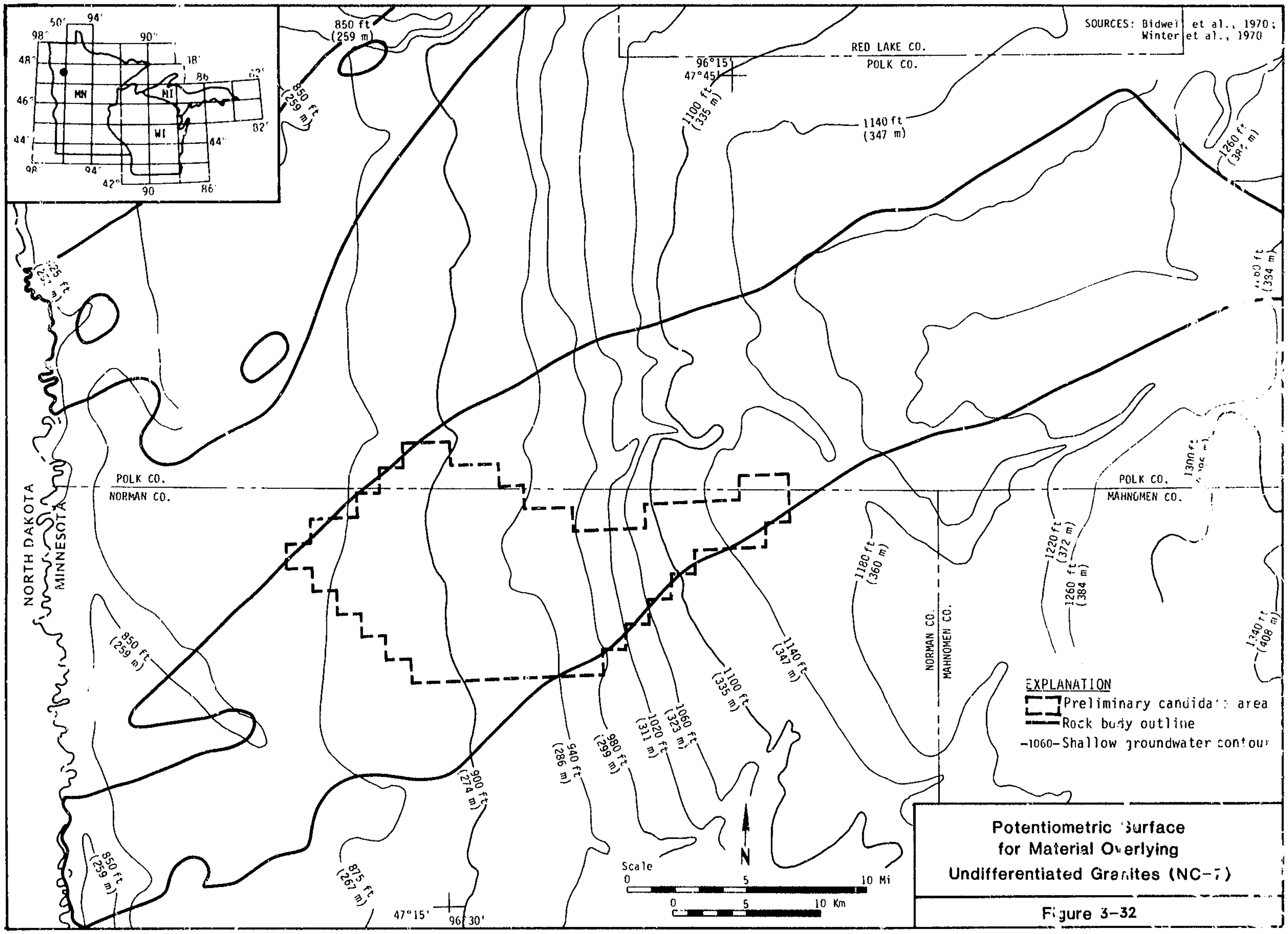
3.2.1.5.6 Ground-Water Resources. The regional hydrology is discussed in Section 3.2.1.1.1.5. Shallow ground-water movement is generally westward toward the Red River. Figure 3-32 shows shallow ground-water contours reported by Bidwell et al., (1970) and Winter et al., (1970). Areas that displayed convergence of shallow water-table contours, based on a 30-m (100-ft) contour interval, were considered



Surface Water Characteristics

Undifferentiated Granites (NC-7)

Figure 3–31



Potentiometric Surface for Material Overlying Undifferentiated Granites (NC-7)

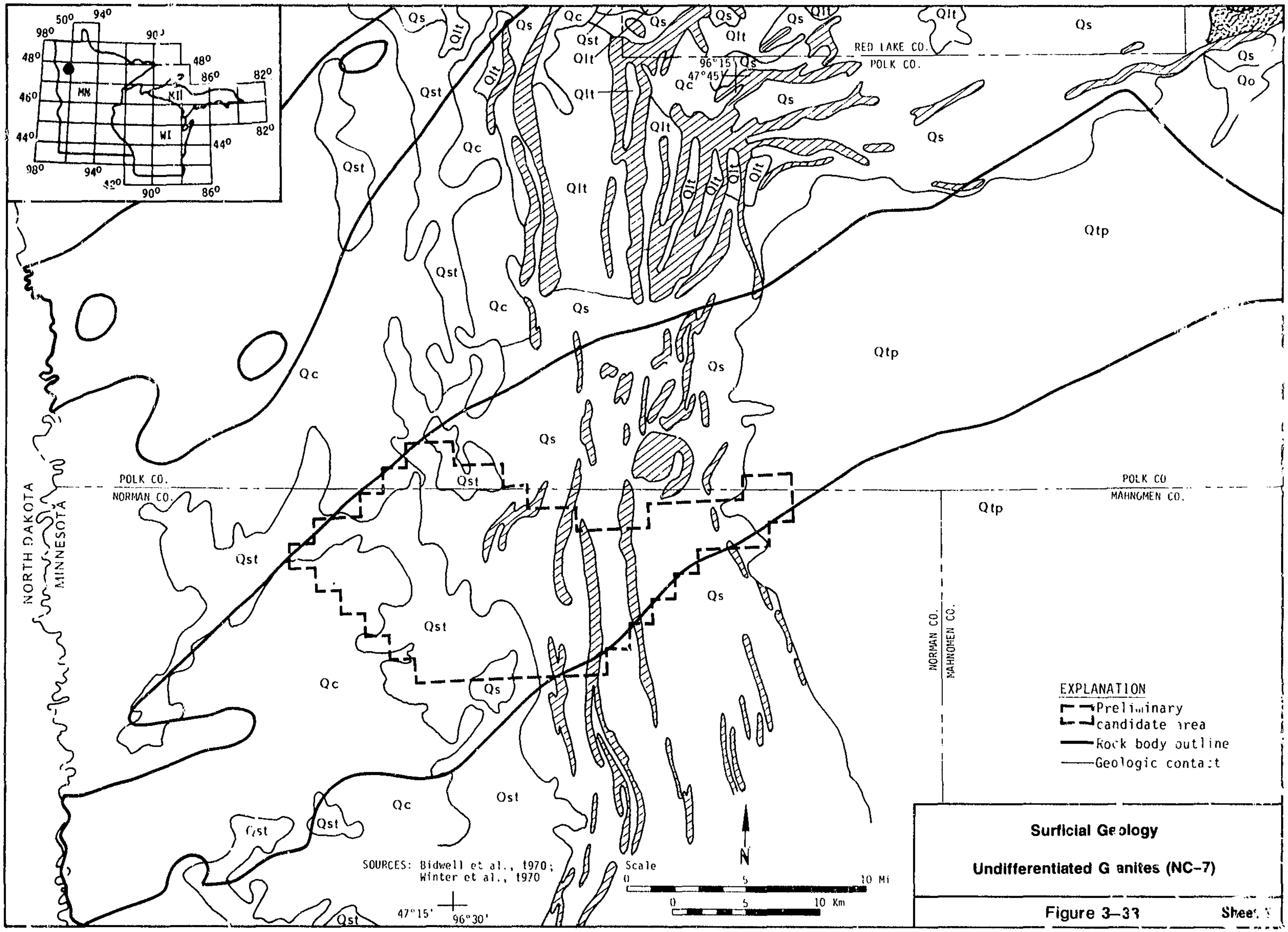
Figure 3-32

potential major discharge zones. These generally correspond to locations of major streams and rivers. No major discharge zones have been identified in the preliminary candidate area (DOE, 1985c).

Ground water in and near the preliminary candidate area is primarily obtained from glacial sediments that include: 1) beach deposits of fine sand to medium gravel; 2) lake-washed till comprised of sandy, clay-silt loam containing fine to medium gravel and scattered boulders; 3) clay, consisting of a dense, uniform, low-permeability glacial lake clay; 4) silt, consisting of a uniform, fairly permeable glacial lake silt; and 5) sand, consisting of very fine to fine grained uniform glacial lake sands (Bidwell et al., 1970; Winter et al., 1970). The horizontal extent of surficial deposits is shown in Figure 3-33.

Well yields presented in the North Central RGCR (DOE, 1985c) were estimated from maps by Kanivetsky (1978, 1979) and Kanivetsky and Walton (1979) and are shown in Figure 3-34a. Additional detailed well yield information has been reported by Bidwell et al. (1970) and Winter et al. (1970) in USGS Hydrologic Atlases, and is shown in Figure 3-34b. Some estimated well yields shown on these two figures may not agree; however, there is currently no basis for determining which data set is more representative of actual well yields. Both data sets are shown for comparison. The fine-grained lake deposits generally are not a source of water, but may yield less than 0.06 L/s (1 gpm) to a large-diameter dug well. The beach ridge deposits may yield greater than 1.3 L/s (20 gpm) in thicker sections. The till generally yields less than 0.6 L/s (10 gpm); but lenses of sand may yield 0.3 to 16 L/s (5 to 250 gpm).

The data indicate that relatively shallow Quaternary aquifers that contain potable ground water are present within the preliminary candidate area. No deep wells (i.e., greater than 100 m [328 ft] in depth) have



Surficial Geology

Undifferentiated Granites (NC-7)

Figure 3–33 Sheet

EXPLANATION OF SURFICIAL UNITS

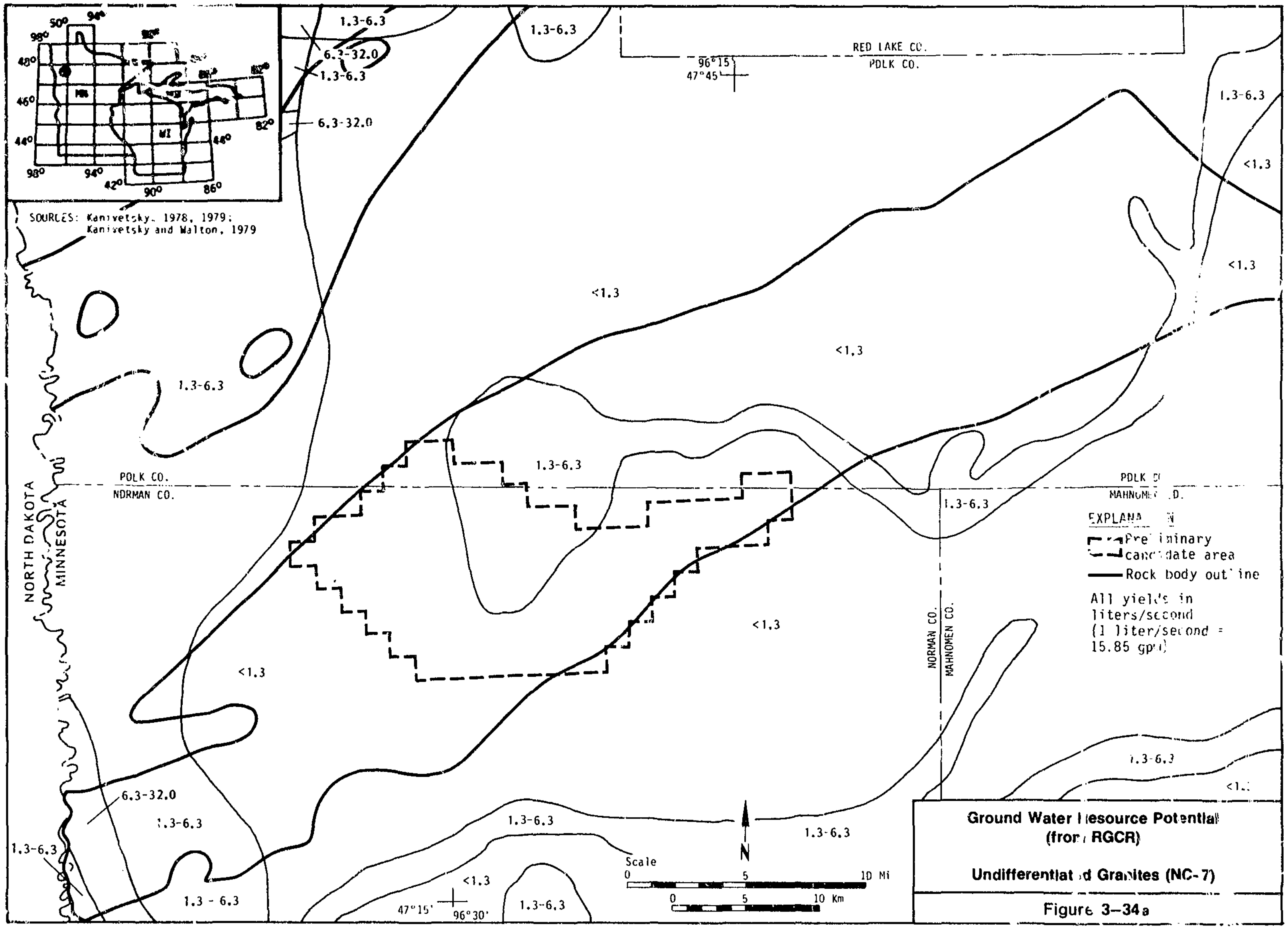
QUATERNARY

Qtp	Till
Qlt	Lake-washed till
Qs	Sand
Qc	Clay
Qst	Silt
Qo	Outwash
(diagonal hatch)	Sand and gravel (beach deposits)
(stipple)	Peat

Explanation for Figure 3-33

Undifferentiated Granites (NC-7)

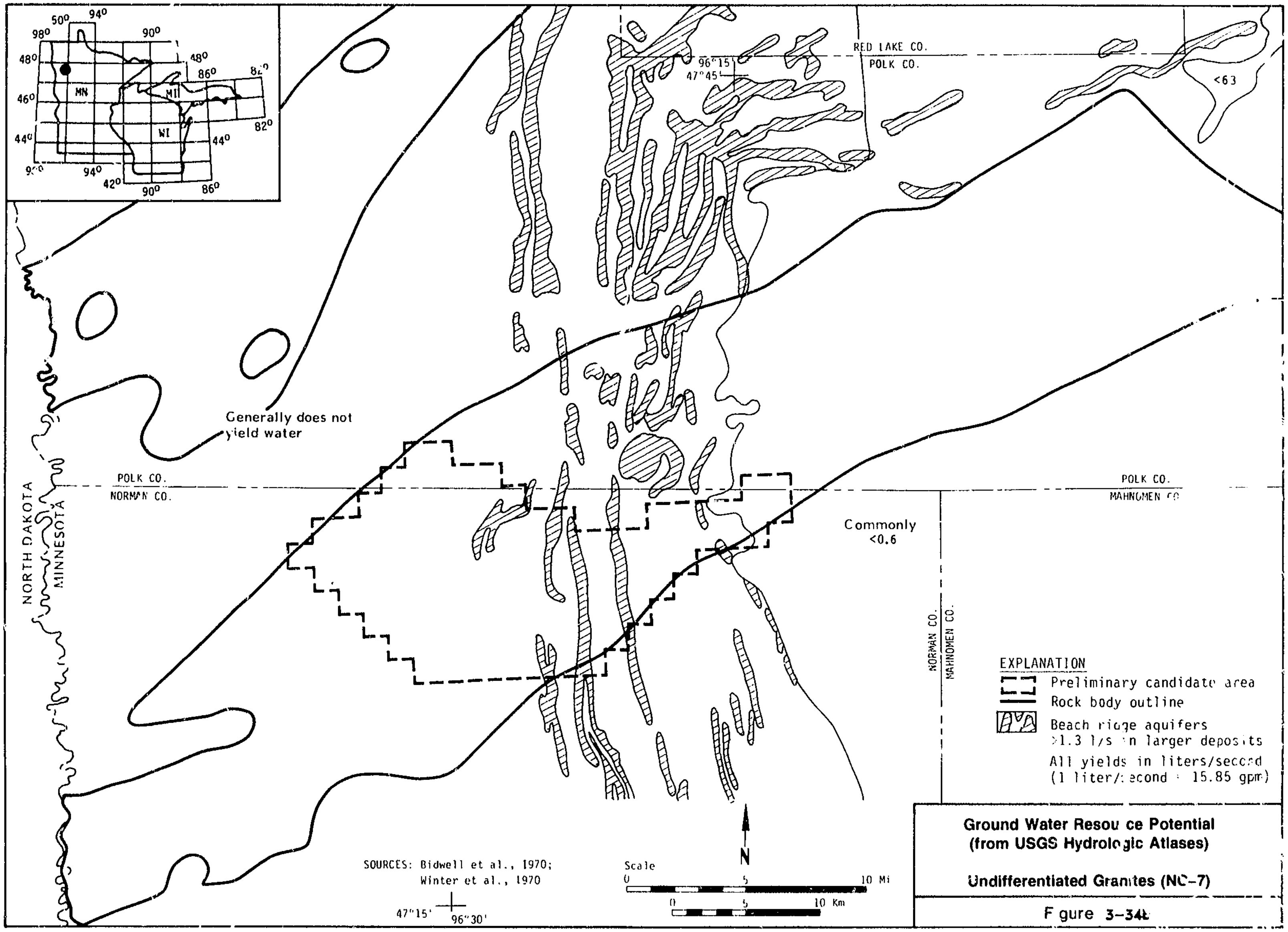
Figure 3-33 **Sheet 2**



Ground Water Resource Potential (from RGCR)

Undifferentiated Granites (NC-7)

Figure 3–34a



Ground Water Resource Potential (from USGS Hydrologic Atlases)

Undifferentiated Granites (NC-7)

Figure 3-34b

been reported in the literature to be present in the preliminary candidate area. The [illegible] ground water conditions in the deeper crystalline rock are currently unknown.

3.2.1.5.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including erosion and deposition and vertical crustal movement, is in Section 3.2.1.1.1.1.

3.2.1.5.8. Federal Lands. There are no Federal lands within the preliminary candidate area boundary. One waterfowl production area, greater than 130 ha (320 ac) in size, is located 8.5 km (5.2 mi) north of the preliminary candidate area. There are seven waterfowl production areas, which are each less than 130 ha (320 ac) in size, within 10 km (6 mi) of the preliminary candidate area. These features are either depicted on Plate 3 or are in Appendix A of the North Central RECR (DOE, 1985d) (see also Figure 3-35).

3.2.1.5.9 State Lands. The Agassiz-Olson Wildlife Management Area overlaps 526 ha (1,300 ac) or less than 2% of the preliminary candidate area in the north central portion. Three wildlife management areas, each greater than 130 ha (320 ac) in size, are located within 10 km (6 mi) of the preliminary candidate area boundary: Ranum, 0.8 km (0.5 mi) east; Liberty, 4 km (2.5 mi) north; and Chicoq, 8 km (5 mi) north. In addition, there are three wildlife management areas of less than 130 ha (320 ac) in size within 10 km (6 mi) of the preliminary candidate area boundary. The Agassiz Dunes Scientific and Natural Area, which is greater than 130 ha (320 ac) in size, abuts the northern boundary of the preliminary candidate area. All of the features discussed above are either depicted on Plate 4A or are in Appendix B of the North Central RECR (DOE, 1985d).

In summary, one State wildlife management area lies within the preliminary candidate area and covers a total of 526 ha (1,300 ac) or less than 2% of the preliminary candidate area, and seven State lands (four greater than and three less than 130 ha or 320 ac) are located within 10 km (6 mi) of the preliminary candidate area (see Figure 3-35).

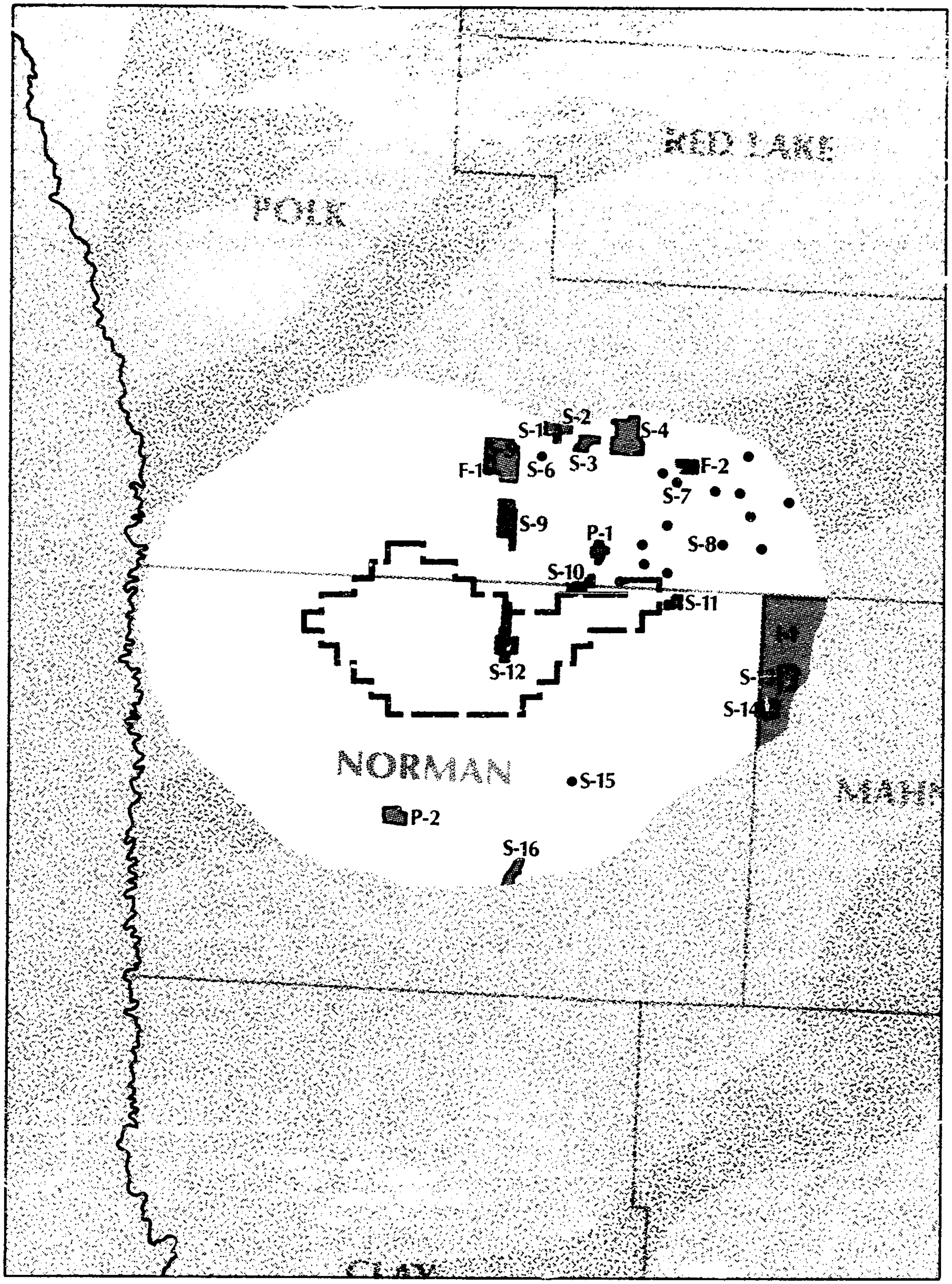


Figure 3—35 Sheet 1

Environmental Features
Undifferentiated Granites (NC-7)

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

P Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile

F Federal Lands Greater Than 320 Acres

S State Lands Greater Than 320 Acres

I Federal Indian Reservations

Federal or State Lands Less Than 320 Acres

F-5 Map Alpha-numeric Codes are Keyed to Environmental Features

Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

0 miles 20

0 kilometers 20

Figure 3-35 Sheet 2

ENVIRONMENTAL FEATURES WITHIN 16 KM (10 MI) OF PRELIMINARY CANDIDATE AREA NC-7*

Code	Feature
Population Features	
P-1	Fertile**
P-2	Ada**
Federal Lands***	
F-1	Waterfowl Production Area (WPA)
F-2	WPA
State Lands	
S-1	Burnham Wildlife Management Area (WMA)
S-2	Trail WMA
S-3	Godfrey WMA
S-4	Maple Meadows WMA
S-5	Chicoq WMA
S-6	Floan Prairie Scientific and Natural Area (SNA)
S-7	Woodside WMA
S-8	Rindahl WMA
S-9	Liberty WMA
S-10	Agassiz Dunes SNA
S-11	Ranum WMA
S-12	Agassiz-Olson WMA
S-13	Bejou WMA
S-14	Dittmer WMA
S-15	Ida WMA
S-16	Rockwell WMA
Indian Reservations	
I-1	White Earth Indian Reservation

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* The accompanying text identifies only those environmental features within 10 km (6 mi) of the preliminary candidate area.

** Area with a population density greater than or equal to 1,000 persons per square mile.

*** Waterfowl production areas less than 130 ha (320 ac) are displayed as dots on the map but are not coded due to lack of space.

Figure 3-35, Sheet 3

3.2.1.5.10 Environmental Compliance. There are no nonattainment areas or Prevention of Significant Deterioration (PSD) Class I Areas in or within 40 km (25 mi) of the preliminary candidate area (40 CFR 81). No sites listed on the National Register of Historic Places (NRHP), no proposed NRHP sites, and no National Trails are located within the preliminary candidate area. No National Trails are located within 40 km (25 mi) of the preliminary candidate area. In the regional data base, there are no known existing archeological sites or districts nor any proposed for designation within the preliminary candidate area.

3.2.1.5.11 Population Density and Distribution. There are no highly populated areas in or within 16 km (10 mi) of the preliminary candidate area. The highly populated areas located in Minnesota are depicted on Plate 5A of the North Central RECR (DOE, 1985d). The preliminary candidate area does not contain any areas with population densities greater than or equal to 1,000 persons per square mile. There are two areas with population densities greater than or equal to 1,000 persons per square mile within 16 km (10 mi) of the preliminary candidate area. Ada, with a population of 1,971, is located 8 km (5 mi) south of the preliminary candidate area, and Fertile, with a population of 869, is located 2 km (1.5 mi) north of the preliminary candidate area (see Figure 3-35). Fargo, North Dakota, is located 61 km (38 mi) southwest of the preliminary candidate area. The average population density of the preliminary candidate area is 4 persons per square mile. The average population density within 80 km (50 mi) of the preliminary candidate area is approximately 29 persons per square mile. Low population density is defined as a density in the general region of the site less than the average population density for the conterminous United States (76 persons per square mile) based on the 1980 census.

3.2.1.5.12 Site Ownership. There are no Federal or DOE-owned lands located within the preliminary candidate area. The White Earth Indian Reservation is located 11 km (7 mi) east of the preliminary candidate area (see Figure 3-35).

3.2.1.5.13 Offsite installations. No commercial nuclear reactors are located within the preliminary candidate area. The nearest operating commercial nuclear reactor is Monticello which is approximately 295 km (185 mi) southeast of the preliminary candidate area (Michelewicz and Vann, 1983; DOE, 1984c). The nearest commercial nuclear reactor under construction is Byron 2, which is 800 km (500 mi) to the southeast (Nuclear News, 1985). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.1.5.14 Transportation. The nearest interstate highway is I29 in North Dakota which is about 24 km (15 mi) west of the preliminary candidate area. I94 is approximately 64 km (40 mi) south of the preliminary candidate area. The preliminary candidate area is surrounded by four U.S. highways which are U.S. 2, 10, 59, and 75. U.S. 2 is a four-lane divided highway which runs east and west between Bemidji, Minnesota, and Grand Forks, North Dakota. This highway is 24 km (15 mi) north of the preliminary candidate area. U.S. 59 is a north-south highway which is approximately 16 km (10 mi) from the eastern edge of the preliminary candidate area. U.S. 75 also runs north-south and is located about 13 km (8 mi) west of the preliminary candidate area. U.S. 10, another four-lane divided highway, is approximately 56 km (35 mi) south of the preliminary candidate area. Two State highways cross portions of the preliminary candidate area. State Route 9 crosses the western portion of the preliminary candidate area south of Crookston, Minnesota. State Route 32 is also a north-south highway which crosses the eastern section of the preliminary candidate area.

The Soo/Milwaukee mainline between Minneapolis and Winnipeg is a north-south line which parallels U.S. 59 about 16 km (10 mi) from the eastern edge of the preliminary candidate area. The Burlington Northern mainline between Duluth and Grand Forks, North Dakota, passes about 24 km (15 mi) north of the preliminary candidate area. The Burlington Northern has a branchline which traverses the preliminary candidate area. This branchline parallels State Route 9 crossing the western portion of the preliminary candidate area. Another Burlington Northern branchline terminates at Fertile, Minnesota, which is about 1.6 km (1 mi) from the northeastern part of the preliminary candidate area. This line once continued south from Fertile paralleling State Route 32 to the Minneapolis-Fargo mainline.

Based on the data presented above, access to the preliminary candidate area from both local and regional highways and railway systems appears to be available.

3.2.1.5.15 Preliminary Candidate Area Deferral Analysis. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area NC-7 that could affect DOE's decision to defer further consideration of the area. Based on evaluation of this additional available information, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]
- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]
- low potential for tectonic deformations suggest that the regional ground-water flow systems should not be significantly affected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]

preliminary candidate area. Another Burlington Northern branchline terminates at Fertile, Minnesota, which is about 1.6 km (1 mi) from the northeastern part of the preliminary candidate area. This line once continued south from Fertile paralleling State Route 32 to the Minneapolis-Fargo mainline.

Based on the data presented above, access to the preliminary candidate area from both local and regional highways and railway systems appears to be available.

3.2.1.5.15 Preliminary Candidate Area Deferral Analysis. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area NC-7 that could affect DOE's decision to defer further consideration of the area. Based on additional available information and in the absence of further evaluation, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]
- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]
- low potential for tectonic deformations suggest that the regional ground water flow systems should not be significantly affected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]

- absence of historical earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that the frequency of earthquake occurrence within the geologic setting may increase [960.4-2-7(c)(3)]
- the frequency of occurrence or magnitude of earthquakes within the geologic setting are no higher than within the region [960.4-2-7(c)(4)]
- absence of historical earthquakes that, if they recurred, could provide ground motion in excess of reasonable design limits [960.5-2-11(c)(2)]
- absence of evidence, based on correlations of earthquakes with tectonic processes and features within the geologic setting, that the magnitude of earthquakes during repository construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]
- no evidence of subsurface mining or extraction for resources that could affect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence of drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]
- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]
- presence of generally flat terrain [960.5-2-8(b)(1)]
- presence of generally well-drained terrain [960.5-2-8(b)(2)]
- general absence of surface characteristics or surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]

- absence of Federal lands less than 130 ha (320 ac) within the preliminary candidate area and limited presence in proximity to (i.e., 7 within 10 km [6 mi]) the preliminary candidate area [960.5-2-5(c)(3)]
- absence of State lands less than 130 ha (320 ac) within the preliminary candidate area and limited presence in proximity to (i.e., 3 within 10 km [6 mi]) the preliminary candidate area [960.5-2-5(c)(4)]
- absence of highly populated areas in or within 16 km (10 mi) of the preliminary candidate area [960.5-2-1(b)(2)]
- low population density within its boundaries and within 80 km (50 mi) of the preliminary candidate area [960.5-2-1(b)(1)]
- absence of nuclear installations [960.5-2-4(b) and (c)(2)]
- no projected land ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings [960.4-2-8-2(c), 960.5-2-2(c)]
- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2 and (b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)]
- presence of areas containing more than 1,000 persons per square mile within 16 km (10 mi) of the preliminary candidate area (i.e. a majority of the preliminary candidate area is within 16 km [10 mi] of population features) [960.5-2-1(c)(2)].

The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area NC-7 at this time.

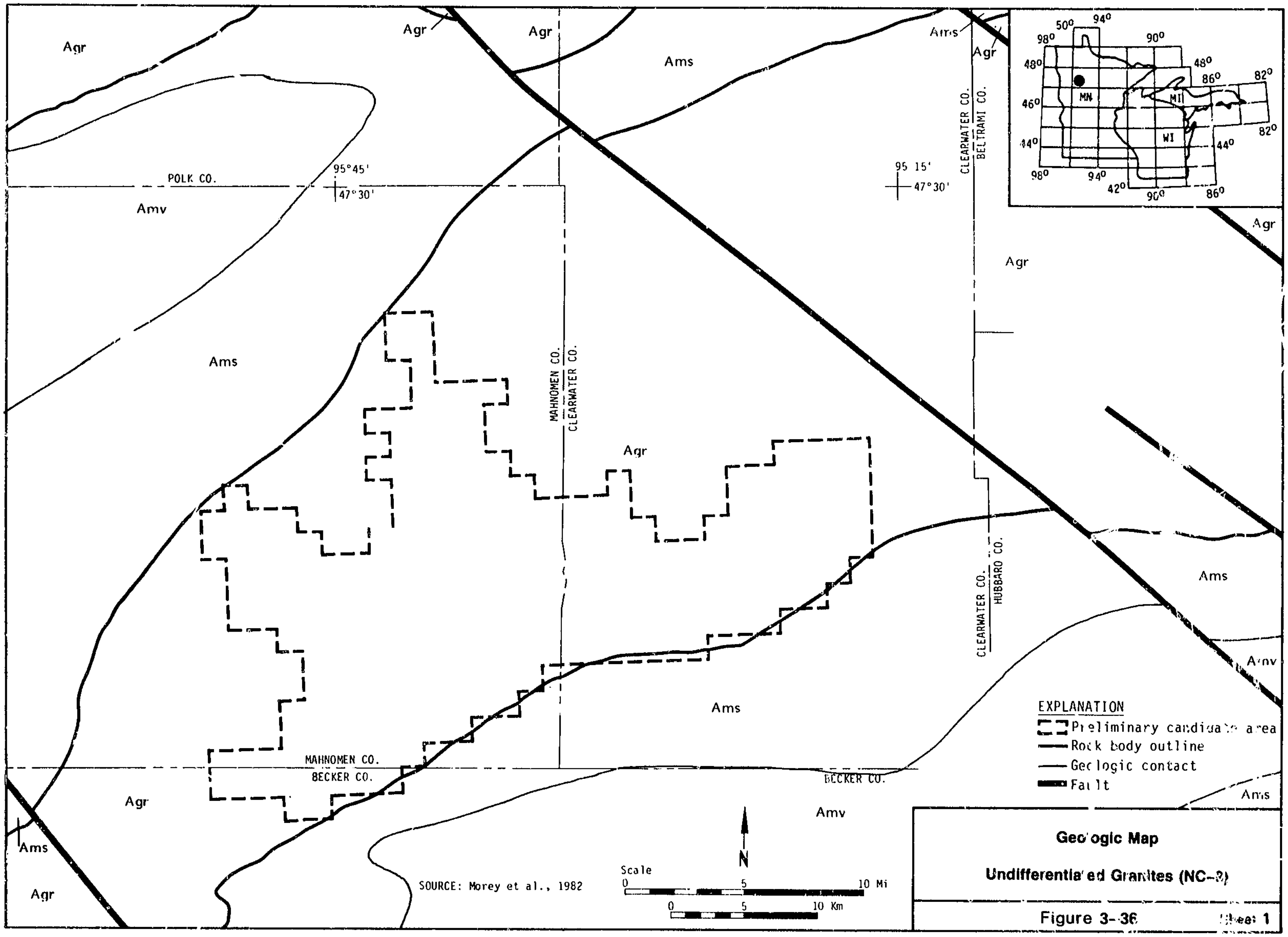
3.2.1.6 Preliminary Candidate Area Description - Undifferentiated Granites ([illegible])

These undifferentiated granites are located within the Central Minnesota Moraine Complex Upland physiographic province in northern Minnesota. The preliminary candidate area is located in Clearwater, Mahnomen, and Becker Counties at approximately 47°17' N latitude and 96°37' W longitude.

3.2.1.6.1 Host Rock Geometry and Overburden Thickness. The preliminary candidate area shown on Figure 3-36 has an area of approximately 647 km^2 (249 mi^2) and overlies a batholith of undifferentiated granites, which are not exposed and the mapped extent of which is largely inferred from geophysical data (Ojakangas et al., 1979; Morey et al., 1982). The batholith is approximately 260 km (158 mi) long and varies in width from 3 to 37 km (2 to 22 mi).

Data on the vertical extent of the batholith are not available, however, the batholith is inferred to extend to a depth of several kilometers (miles) based on the present understanding of the mode of emplacement of batholiths and seismic reflection studies in batholithic terranes. This information suggests that most batholiths are tabular in shape and extend to a depth of 6 to 10 km (4 to 6 mi) (Hamilton and Myers, 1967; Lynn et al., 1981). Furthermore, no postemplacement deformational processes such as large-scale thrust faulting are known to have diminished the vertical extent of the batholith.

There is no exposed bedrock in the preliminary candidate area. Contours of overburden thickness and depth to bedrock from drillhole data are not available for the preliminary candidate area. However, the closest drillhole, located approximately 26 km (16 mi) west of the preliminary candidate area, penetrated 98 m (322 ft) of overburden, and other drillholes in the vicinity penetrated between 96 m and 139 m



Geologic Map

Undifferentiated Granites (NC-3)

Figure 3-36 Sheet 1

EXPLANATION OF GEOLOGIC UNITS

ARCHEAN

Agr	Granitoid rocks
Ams	Metamorphosed sedimentary and volcanoclastic rocks
Amv	Metamorphosed mafic-intermediate volcanic rocks

Explanation for Figure 3-36

Undifferentiated Granites (NC-9)

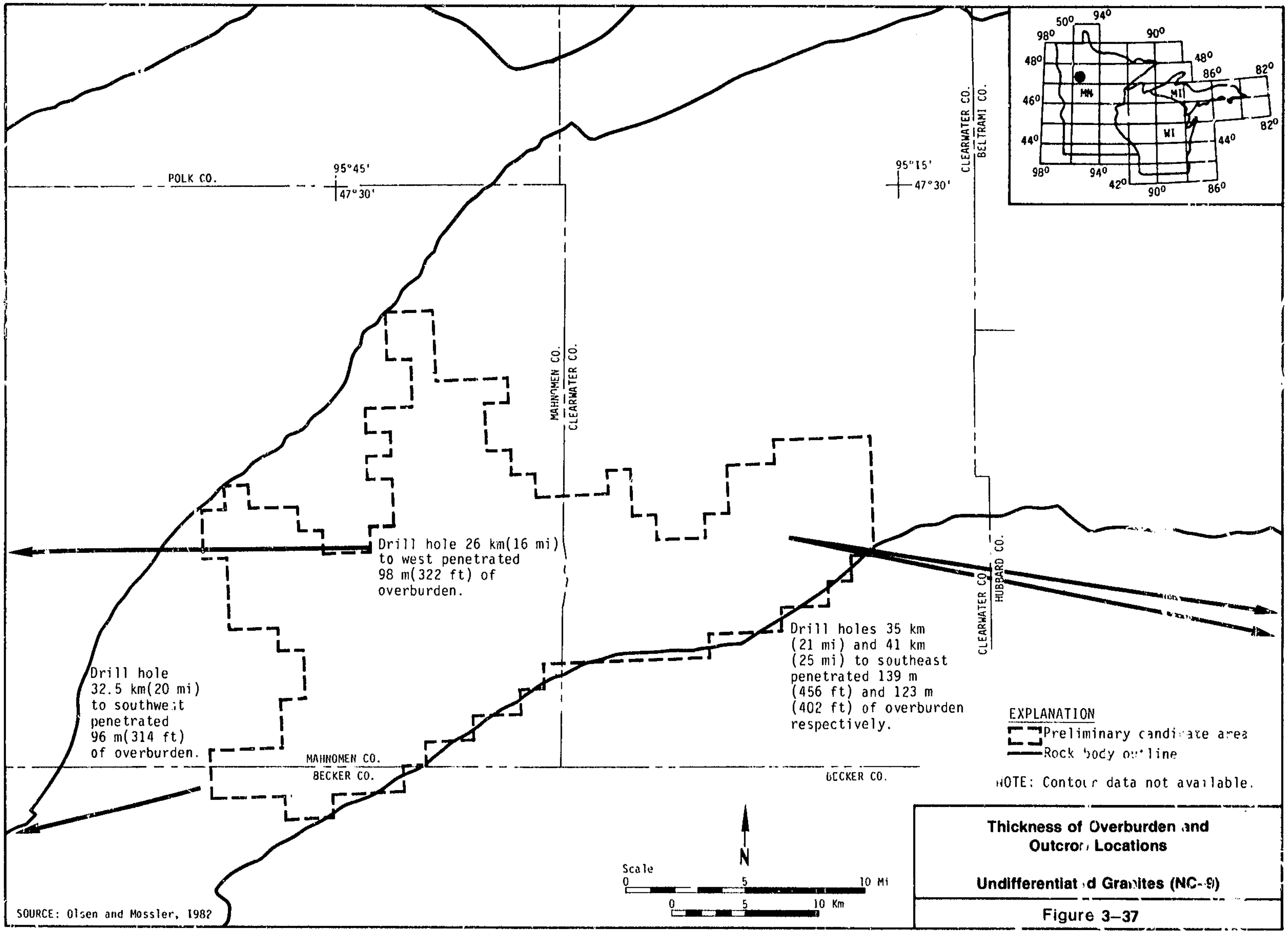
Figure 3-36 **Sheet 2**

(314 to 456 ft) of overburden (Figure 3-37). Winter et al. (1970) reported that overburden in the preliminary candidate area is greater than 115 m (350 ft) thick.

On the basis of the data presented above and the assumed depth and size of a repository in crystalline rock (see Section 1.5), the crystalline rocks of the preliminary candidate area are sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation.

3.2.1.6.2 <u>Lithology and Tectonics</u>. The undifferentiated granites, as inferred from geophysical data, are composed of granitoid rocks of the Archean greenstone-granite terrane (Figure 3-36) (Morey et al., 1982). These rocks are intrusive into metasedimentary and metavolcaniclastic within the vicinity of the preliminary candidate area.

The greenstone-granite terrane was deformed and metamorphosed to the greenschist facies, and locally to the upper amphibolite facies during the Algoman orogeny 2,600 to 2,700 million years ago (Morey and Sims, 1976; Sims, 1980). Deformation and metamorphism of the country rock during the Algoman orogeny was virtually synchronous with the emplacement of the granitic rocks and probably resulted from compression caused by the relative upwelling and convergence of the adjacent plutons (Morey and Sims, 1976). Following the intrusion of the granitic plutons, the alternating greenstone and granite belts were displaced by several generations of right-lateral, strike-slip faults (Sims, 1976). Subsequent to the Algoman orogeny, the greenstone-granite terrane has been essentially tectonically stable (Sims, et al., 1980). One minor exception was the intrusion of a northwest-trending dike swarm in northern Minnesota about 2,120 million years ago (Southwick and Day, 1983).



Thickness of Overburden and Outcrop Locations

Undifferentiated Granites (NC-9)

Figure 3–37

There are no mapped [illegible]s within the preliminary candidate area (Figure 3-36). Approximately 4 km (3 mi) northeast of the preliminary candidate area is a 160-km (98-mi) long inferred fault and approximately 10 km (6 mi) southwest of the preliminary candidate area is a 130-km (79-mi) long inferred fault (Morey et al., 1982). Both of these faults trend northwesterly and have been inferred on the basis of geophysical data (Morey et al., 1982). There is also no evidence of Quaternary activity along these faults or within the geologic setting. No structural features exclusive of faults have been reported in the literature for the preliminary candidate area.

A discussion of recent crustal uplift is presented in the regional geologic setting in (Section 3.2.1.1.1.3). There is no evidence to suggest tectonic uplift. The uplift due to glacioisostatic rebound is relatively uniform and occurs at slow rates that will continue to decrease in the future such that this uplift is unlikely to result in any measurable changes in the regional ground-water flow system over the next 10,000 years. There are no in situ stress data available for the vicinity of the preliminary candidate area.

The absence of any igneous activity in and near the preliminary candidate area for the last 1,000 million years and the absence of Quaternary volcanism in the geologic setting (Section 3.2.1.1.1.2) indicate that future igneous activity in the area is highly unlikely.

There is no evidence of igneous activity, folding, faulting, uplift, subsidence, or other tectonic processes within the geologic setting during the Quaternary Period. There appears to be no significant potential for tectonic deformations that could affect the regional ground-water flow system.

3.2.1.6.3 Seismicity. There are no historical earthquakes within the vicinity of the preliminary candidate area. There are no known geologic structures near the preliminary candidate area that might be expected to induce seismic activity of greater frequency or intensity than that which is typical of the region. The regional seismicity is discussed in Section 3.2.1.1.1.3.

Considering the low level and magnitude of seismic activity in the region and the absence of active tectonic processes within the geologic setting during the Quaternary Period, it is unlikely that seismic activity would produce ground motion in excess of reasonable design limits or could affect waste containment or isolation, and it is unlikely that the frequency of occurrence of earthquakes in the area will increase in the future.

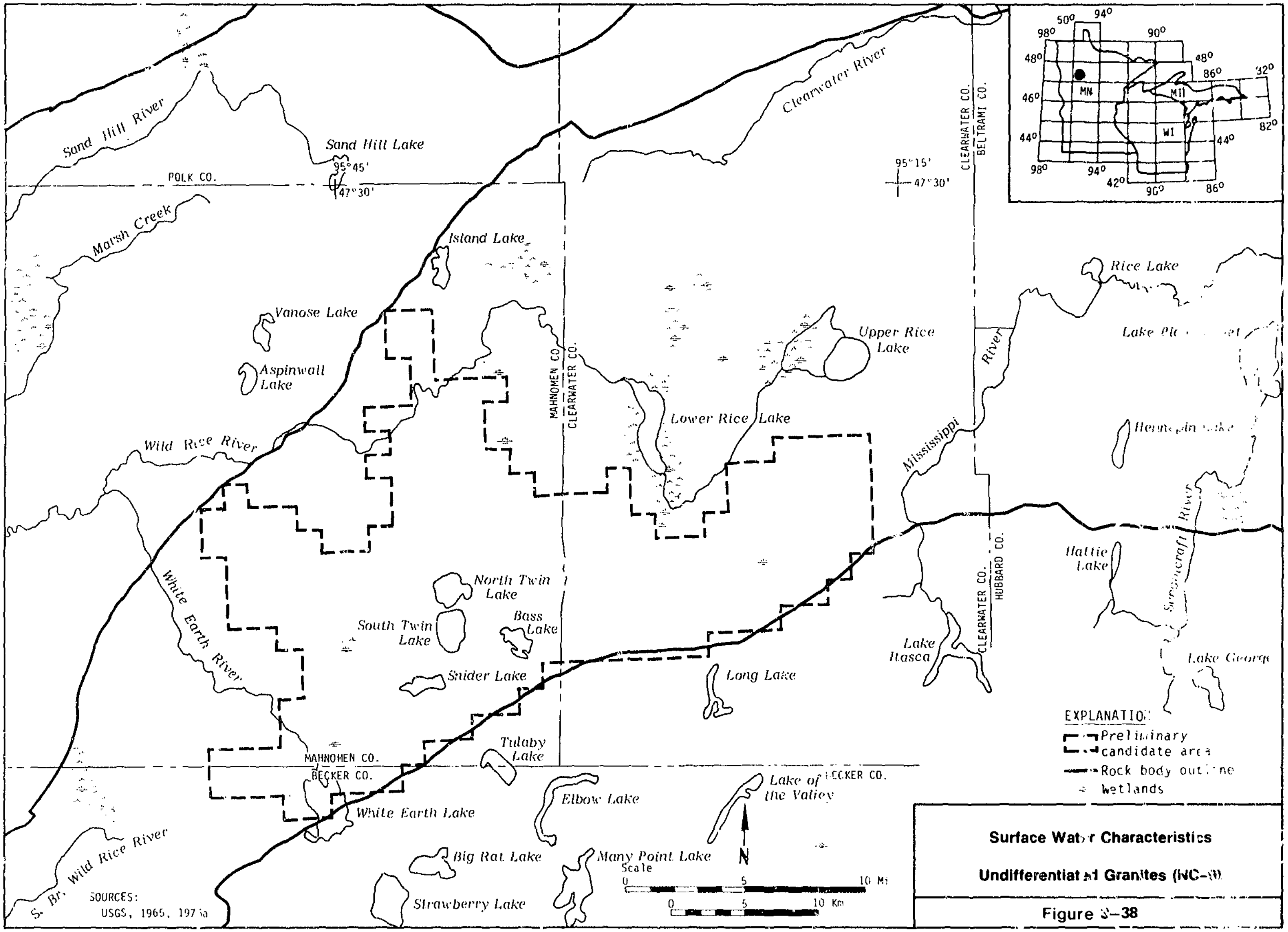
3.2.1.6.4 Mineral Resources. There are no strategic, metallic, or energy-related mineral resources known to occur either in or within 10 km (6 mi) of the preliminary candidate area (Schwartz and Prokopovich, 1966; Walton, 1976; USBM, 1983). No deep mines or quarries (greater than 100 m [328 ft] in depth) are located within the preliminary candidate area. The nearest deep mines or quarries are the iron mines in the Mesabi Range, located more than 100 km (62 mi) east of the preliminary candidate area. Other natural resources within and near the preliminary candidate area (i.e., quarries, gravel pits, and marl deposits) are shallow and widely available throughout the region.

Based on the data presented in this section, there are no metallic, strategic, or energy-related resources within the preliminary candidate area. There is no evidence for mining to a depth sufficient to affect waste isolation, and no information is currently available to indicate that deep exploration drillholes (greater than 100 m [328 ft] in depth) are present in the preliminary candidate area.

3.2.1.6.5 Topography and Surface Water Characteristics. The topographic relief of the preliminary candidate area is low, with elevations ranging from 390 to 621 m (1,280 to 2,040 ft). The southern portion of the preliminary candidate area contains low hills with elevations ranging from 457 to 621 m (1,500 to 2,040 ft). The preliminary candidate area does not appear to contain large areas of floodplain. Examination of topographic maps indicates that only localized portions of the preliminary candidate area along major drainages and small stream valleys are potentially flood prone. No reservoirs or impoundments are known to exist in or upstream of the preliminary candidate area.

The preliminary candidate area is drained mainly by the Wild Rice and White Earth Rivers, which drain west to the Red River; the Red River drains to Canada. As represented by the region-to-area screening data base, the preliminary candidate area is covered by approximately 6% surface water and less than 1% wetland (USGS, 1965; USGS, various dates; Minnesota State Planning Agency, 1984). The locations of lakes, rivers, and marshlands in the preliminary candidate area shown on Figure 3-38 are based on surface water features shown on USGS 1:250,000 Bemidji and Grand Forks topographic maps. Major surface water bodies within the preliminary candidate area include the Wild Rice and White Earth Rivers, North and South Twin Lakes, White Earth Lake, Bass Lake, and Snider Lake. Other surface water bodies near the preliminary candidate area include Marsh Creek, Mississippi River, Upper and Lower Rice Lake, Island Lake, Lake Itasca, Tulaby Lake, Big Rat Lake, Strawberry Lake, Elbow Lake, Long Lake, Vanose Lake, and Aspinwall Lake, as well as numerous other lakes and streams.

The data presented in this section indicate that the relief of the preliminary candidate area is generally low and the terrain is well drained.



Surface Water Characteristics

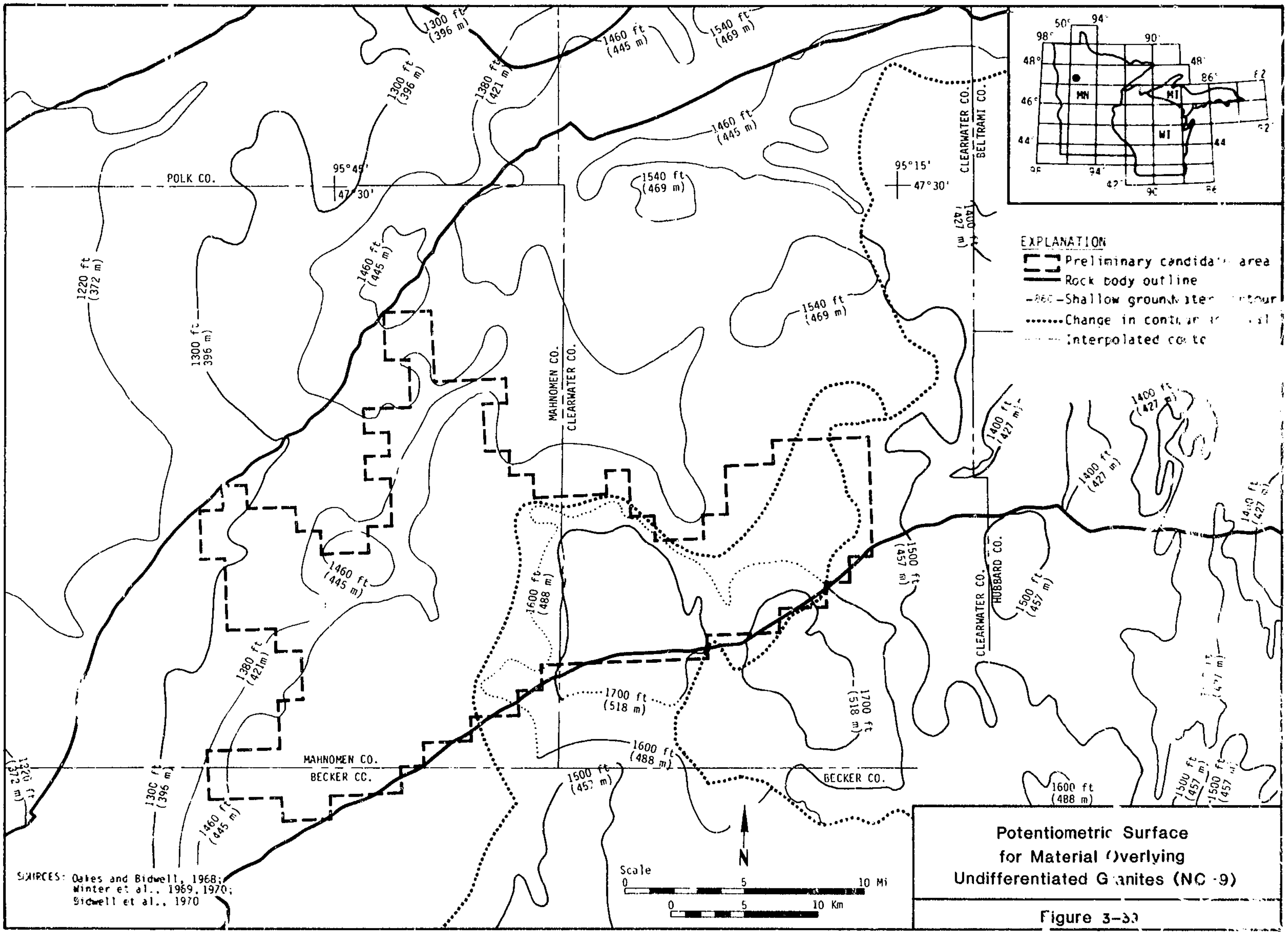
Undifferentiated Granites (NC-[illegible])

Figure 3–38

3.2.1.6.6 Ground-Water Resources. The regional hydrology is discussed in Section 3.2.1.1.1.5. Shallow ground-water movement is generally westward toward the Red River. Figure 3-39 shows shallow ground-water contours reported by Oakes and Bidwell (1968), Bidwell et al. (1970), Winter et al. (1969), and Winter et al. (1970). Areas that displayed convergence of shallow water-table contours, based on a 30-m (100-ft) contour interval, were considered potential major discharge zones. These generally correspond to locations of major streams and rivers. No major discharge zones have been identified in the preliminary candidate area (DOE, 1985c).

Ground water in and near the preliminary candidate area is primarily obtained from glacial sediments that are characterized by till plains and outwash sand and gravel, with some localized peat and end moraine deposits (Oakes and Bidwell, 1968; Winter et al., 1969; Winter et al., 1970; Bidwell et al., 1970). The horizontal extent of surficial deposits is shown on Figure 3-40.

Well yields presented in the North Central RGCR (DOE, 1985c) were estimated from maps by Kanivetsky (1978, 1979) and Kanivetsky and Walton (1979) and are shown on Figure 3-41a. Additional detailed well yield information has been reported by Oakes and Bidwell (1968), Bidwell et al. (1970), and Winter et al. (1969, 1970), in USGS Hydrologic Atlases, and is shown on Figure 3-41b. Some estimated well yields shown on these two figures may not agree; however, there is currently no basis for determining which data set is more representative of actual well yields. Both data sets are shown for comparison. The outwash aquifers yield from 0.6 to greater than 32 L/s (10 to greater than 500 gpm) and up to 63 L/s (1,000 gpm) locally (Bidwell et al., 1970; Winter et al., 1969). Oakes and Bidwell (1968) report wells yielding in excess of 126 L/s (2,000 gpm) in outwash sands. Well yields from the till are



Potentiometric Surface for Material Overlying Undifferentiated Granites (NC-9)

Figure 3-

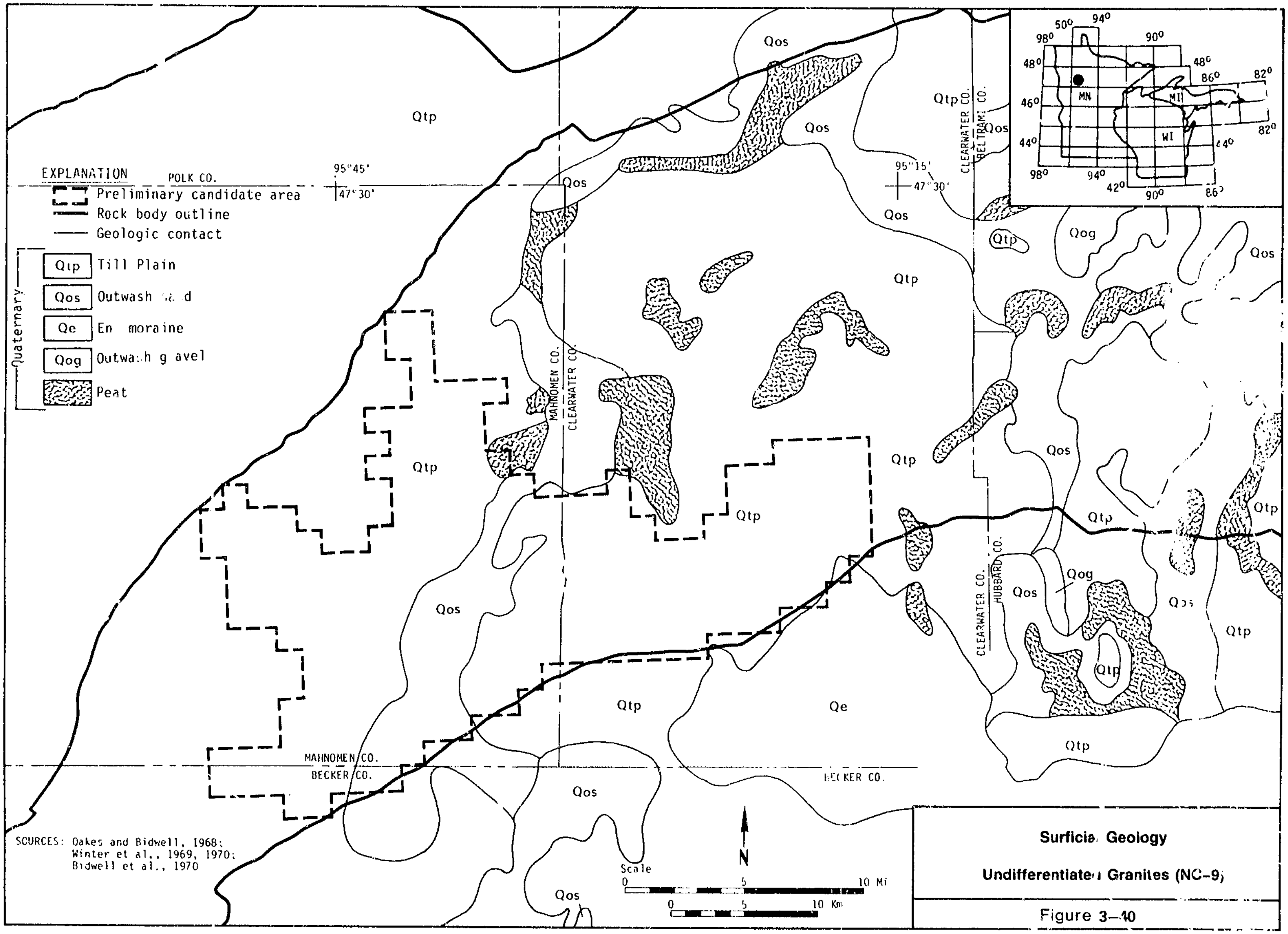
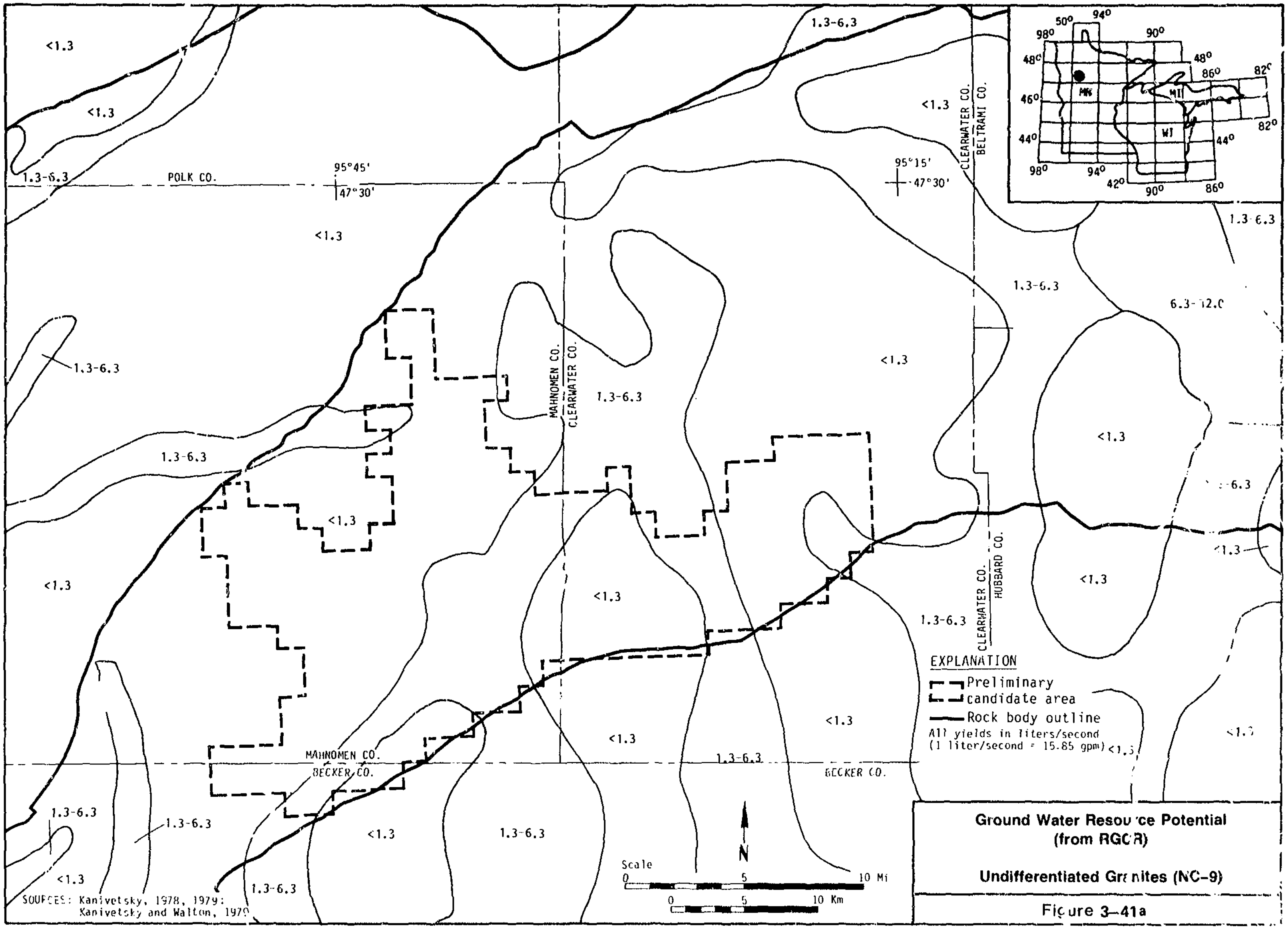

EXPLANATION
Preliminary candidate area
Rock body outline
Geologic contact
Qtp Till Plain
Qos Outwash sand
Qe End moraine
Qog Outwash gravel
Peat
Quaternary
POLK CO.
MAHNOMEN CO.
CLEARWATER CO.
BELTRAMI CO.
HUBBARD CO.
BECKER CO.
95°45'
47°30'
95°15'
SOURCES: Oakes and Bidwell, 1968; Winter et al., 1969, 1970; Bidwell et al., 1970
Scale
0 5 10 Mi
0 5 10 Km
N
MN
MI
WI
Surficial Geology
Undifferentiated Granites (NC-9)

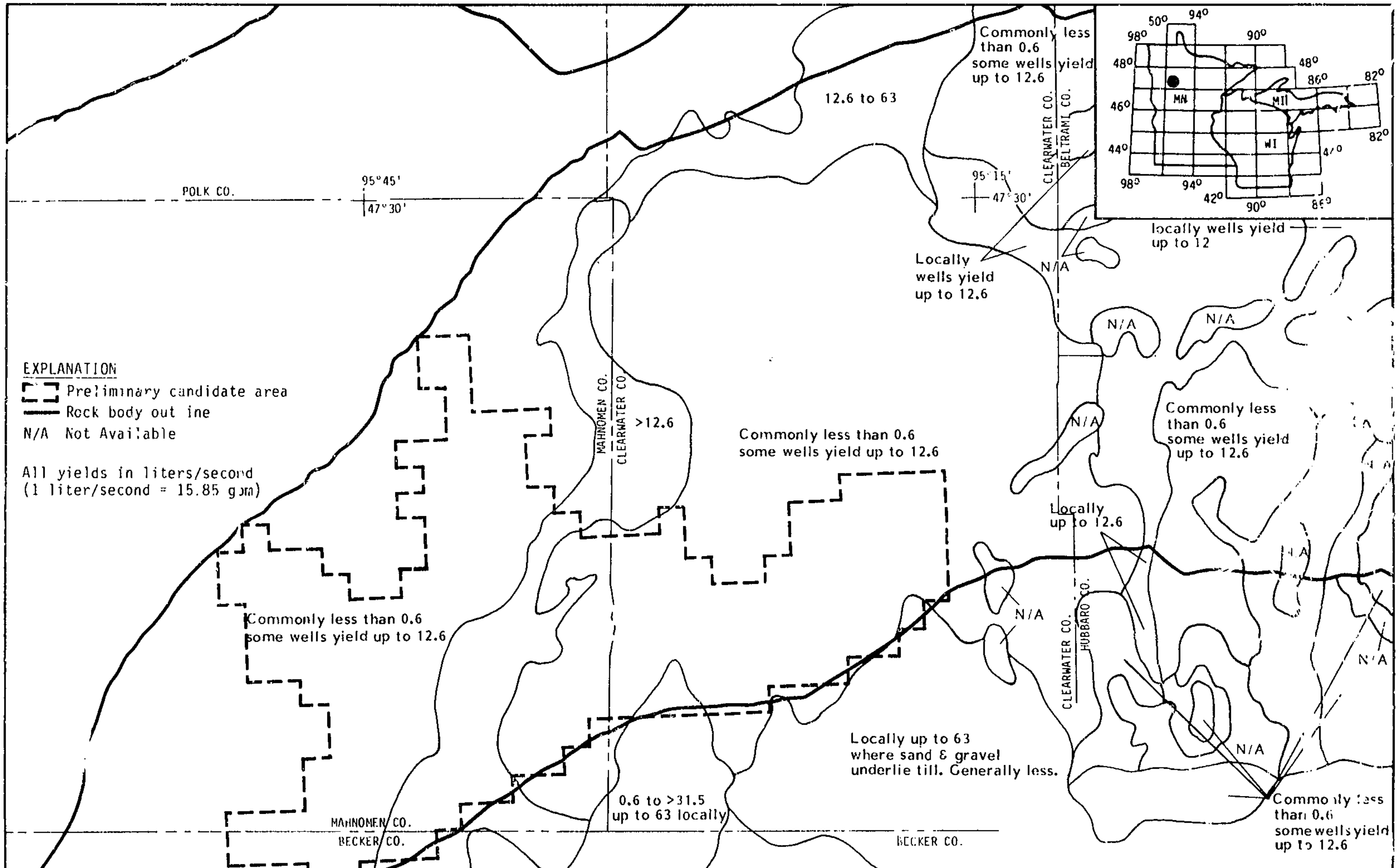
Figure 3-40



Ground Water Resource Potential (from RGCR)

Undifferentiated Granites (NC-9)

Figure 3-41a



Ground Water Resource Potential (from USGS Hydrologic Atlases)

Undifferentiated Granites (NC-9)

Figure 3-41b

reported to be commonly [illegible] than 0.6 L/s (10 gpm) and locally up to 13 L/s (200 gpm) (Winter et al., 1970; Bidwell et al., 1970). In some areas, sand and gravel aquifers may underlie the till, yielding up to 32 L/s (500 gpm) (Oakes and Bidwell, 1968). Locally, this formation can yield up to 63 L/s (1,000 gpm), but yields are generally much less where underlying sand and gravel is not present.

The data indicate that relatively shallow Quaternary aquifers that contain potable ground water are present within the preliminary candidate area. No deep wells (i.e., greater than 100 m [328 ft] in depth) have been reported in the literature to be present in the preliminary candidate area. Consequently, local ground water conditions in the deeper crystalline rock are currently unknown.

3.2.1.6.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including erosion and deposition and vertical crustal movement is in Section 3.2.1.1.1.1.

3.2.1.6.8 Federal Lands. Three Federal waterfowl production areas, each greater than 130 ha (320 ac) in size, and eight waterfowl production areas, each less than 130 ha (320 ac) in size, lie within the western third of the preliminary candidate area. These lands cover a total of 1,376 ha (3,400 ac) or approximately 2% of the preliminary candidate area. The Tamarac National Wildlife Refuge and the Tamarac National Wilderness Area, each greater than 130 ha (320 ac) in size, are both 8 km (5 mi) south of the preliminary candidate area. Additionally, there are 12 waterfowl production areas, each greater than 130 ha (320 ac)in size, within 10 km (6 mi) of the preliminary candidate area's western boundary. Also, there are 40 waterfowl production areas, each less than 130 ha (320 ac)in size, within 10 km (6 mi) of the preliminary candidate area's western boundary. All of these features are depicted on Plate 2A of the North Central RECR or are discussed in Appendix A of that report (DOE, 1985d).

In summary, eleven Fe[illegible] waterfowl production areas (three greater than and eight less than 130 ha [320 ac]) are located within the preliminary candidate area and cover a total of 1,376 ha (3,400 ac) or approximately 2% of the preliminary candidate area. There are 54 Federal lands (14 greater than and 40 less than 130 ha or 320 ac) located within 10 km (6 mi) of the preliminary candidate area (see Figure 3-42).

3.2.1.6.9 State Lands. The Budde Meadows Wildlife Management Area, covering 316 ha (780 ac), lies entirely within the preliminary candidate area. In addition, there are five wildlife management areas, each less than 130 ha (320 ac) in size, within the preliminary candidate area: Clearwater VS 27, 11 ha (27 ac); Clearwater VS 28, 6 ha (14 ac); Clearwater VS 29, 14 ha (35 ac); Clearwater VS 31, 16 ha (40 ac); and Clearwater VS 32, 14 ha (35 ac). Also, approximately 17,800 ha (44,000 ac) or 28% of the preliminary candidate area is overlapped by the White Earth State Forest. Little Elbow Lake State Park partially overlaps the preliminary candidate area along the southern boundary. This park occupies 388 ha (960 ac) within the preliminary candidate area. Itasca State Park, which is greater than 130 ha (320 ac) in size, is located 1.6 km (1 mi) southeast of the preliminary candidate area. Additionally, there are eight wildlife management areas, each greater than 130 ha (320 ac) in size, within 10 km (6 mi) of the preliminary candidate area: Lower Rice Lake, Upper Rice Lake, Beaulieu, Ogema Springs, Spring Creek, Waubun, Vanose, and Rush. Thirty wildlife management areas, each less than 130 ha (320 ac) in size, are located within 10 km (6 mi) of the preliminary candidate area boundary. Iron Springs Bog Scientific and Natural Area and Itasca Wilderness Area Scientific and Natural Area, each greater than 130 ha (320 ac) in size, are located 2.4 km (1.5 mi) and 5 km (3 mi) east of the preliminary candiate candidate area, respectively, and the Mississippi Headwaters Wild and Scenic River, which is also greater than 130 ha (320 ac) in size, is 3.2 km (2.0 mi) east of the preliminary candidate area. The Mississippi Headwaters State Forest is located 3.2 km (2 mi) east of the

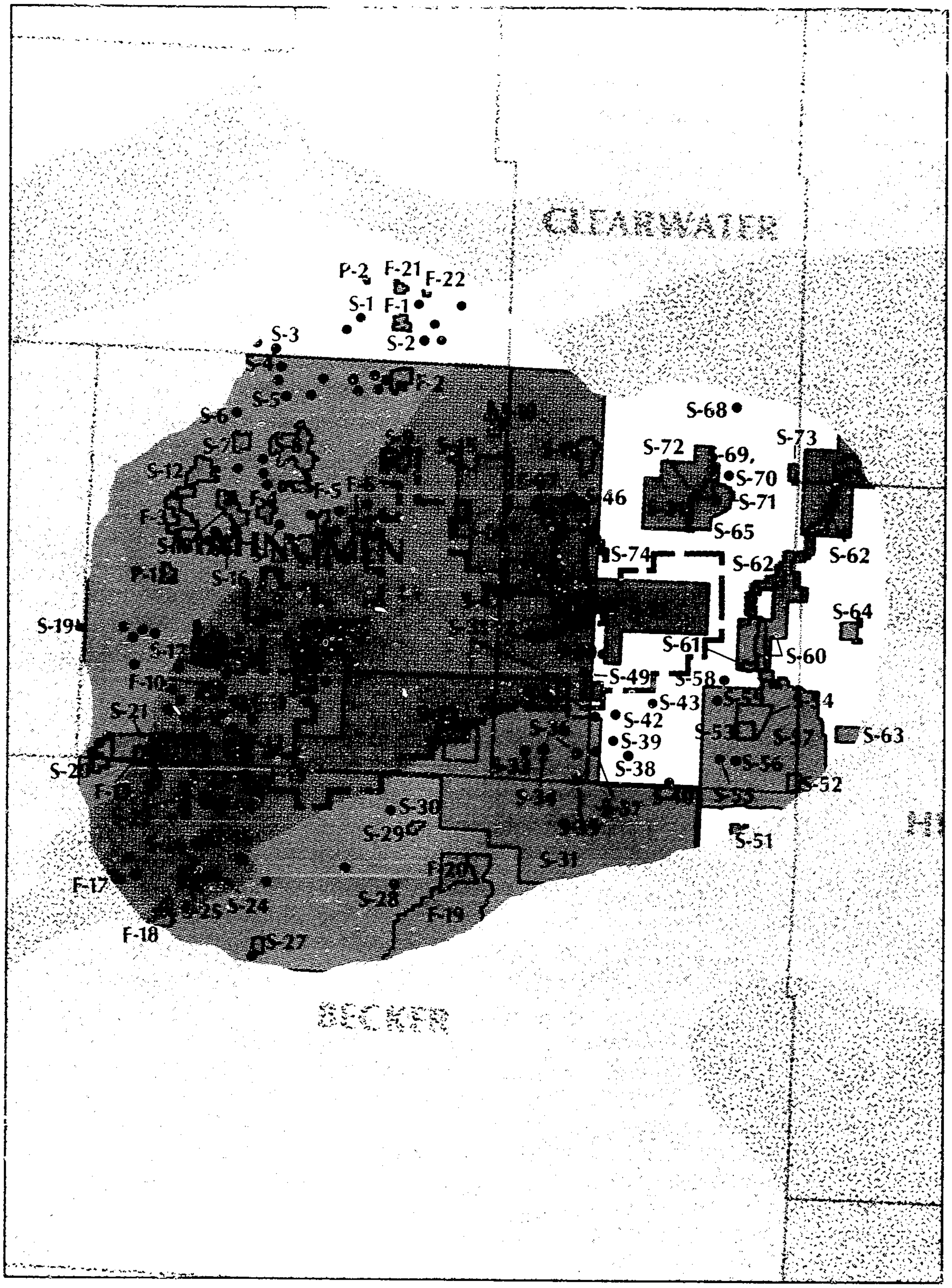


Figure 3–42 Sheet 1

Environmental Features
Undifferentiated Granites (NC-9)

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

- **P** Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile
- **F** Federal Lands Greater Than 320 Acres
- **S** State Lands Greater Than 320 Acres
- **I** Federal Indian Reservations
- ● Federal or State Lands Less Than 320 Acres
- **F-5** Map Alpha-numeric Codes are Keyed to Environmental Features

Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

0 miles 20

0 kilometers 20

Figure 3—42 Sheet 2

ENV... ...ES WITHIN 16 KM (10 MI)
... PR... ...NARY CANDIDATE AREA NC-9*

Code	Feature
Population Features	
P-1	Mahnomen**
P-2	Fosston**
Federal Lands* **	
F-1	Waterfowl Production Area (WPA)
F-2	WPA
F-3	WPA
F-4	WPA
F-5	WPA
F-6	WPA
F-7	WPA
F-8	WPA
F-9	WPA
F-10	WPA
F-11	WPA
F-12	WPA
F-13	WPA
F-14	WPA
F-15	WPA
F-16	WPA
F-17	WPA
F-18	WPA
F-19	Tamarac National Wildlife Refuge
F-20	Tamarac National Wilderness Area
F-21	WPA
F-22	WPA
State Lands	
S-1	Hovland Wildlife Management Area (WMA)
S-2	Lengby WMA
S-3	Rosebud WMA
S-4	Killian WMA
S-5	Foot WMA
S-6	Mahgre WMA
S-7	Gregory WMA
S-8	Vanose WMA
S-9	Budde Meadows WMA
S-10	Unnamed State Forest Parcel (SFO)
S-11	SFO
S-12	Wambach WMA

Figure 3-42, Sheet 3

EN[illegible] FEATURES WITHIN 16 KM (10 MI)
[illegible]ARY CANDIDATE AREA NC-9[illegible]

Code	Feature
State Lands	
S-13	Rush WMA
S-14	Beaulieu WMA
S-15	Warren WMA
S-16	Mah Soo WMA
S-17	Santwire WMA
S-18	Bluestem WMA
S-19	Faith WMA
S-20	Coburn WMA
S-21	Waubun WMA
S-22	Spring Creek WMA
S-23	Moccasin WMA
S-24	Riparia WMA
S-25	Ogema Springs WMA
S-26	SFO
S-27	Callaway WMA
S-28	Teiken-Dalve WMA
S-29	SFO
S-30	White Earth WMA
S-31	White Earth State Forest
S-32	Little Elbow Lake State Park
S-33	Clearwater VS 25 WMA
S-34	Clearwater VS 23 WMA
S-35	Clearwater VS 26 WMA
S-36	Clearwater VS 24 WMA
S-37	Clearwater VS 17 WMA
S-38	Clearwater VS 16 WMA
S-39	Clearwater VS 15 WMA
S-40	Clearwater VS 18 WMA
S-41	Clearwater VS 13 WMA
S-42	Clearwater VS 14 WMA
S-43	Clearwater VS 12 WMA
S-44	Lower Rice Lake WMA
S-45	SFO
S-46	SFO
S-47	Clearwater VS 27 & 28 WMA
S-48	Clearwater VS 29 WMA
S-49	Clearwater VS 32 WMA
S-50	Clearwater VS 31 WMA
S-51	SFO
S-52	SFO
S-53	SFO
S-54	Itasca Wilderness Area SNA
S-55	Clearwater VS 3 WMA

Figure 3-42, sheet 4

ENVIRONMENTAL FEATURES WITHIN 16 KM (10 MI) OF PRELIMINARY CANDIDATE AREA NC-9[illegible]

Code	Feature
State Lands - Continued	
S-56	Clearwater VS 4 WMA
S-57	Itasca State Park
S-58	Clearwater VS 1 WMA
S-59	Clearwater VS 2 WMA
S-60	Mississippi Headwaters State Forest
S-61	Iron Springs Bog SNA
S-62	Mississippi Headwaters Wild and Scenic River
S-63	Paul Bunyan State Forest
S-64	SFO
S-65	Upper Rice Lake WMA
S-66	Clearwater VS 34 WMA
S-67	Perch Lake WMA
S-68	Clearwater VS 6 WMA
S-69	Clearwater VS 7 WMA
S-70	Clearwater VS 20 WMA
S-71	Clearwater VS 5 WMA
S-72	Clearwater VS 19 WMA
S-73	SFO
S-74	SFO
Indian Reservations	
I-1	White Earth Indian Reservation

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* The accompanying text identifies only those environmental features within 10 km (6 mi) of the preliminary candidate area.

** Area with a population density greater than or equal 1,000 persons per square mile.

*** Waterfowl production areas less than 130 ha (320 ac) are displayed as dots on the map but are not coded due to lack of space.

Figure 3-42, sheet 5

preliminary candidate area, and eight parcels of unnamed State forest land are located within 10 km (6 mi) of the preliminary candidate area boundary. These State forest lands are each greater than 130 ha (320 ac) in size. All the features described above are either depicted on Plates 3A or 4A of the North Central RECR or are listed in Appendix B of that report (DOE, 1985d).

In summary, eight State lands (three greater than and five less than 130 ha or 320 ac) are located within or overlap the preliminary candidate area and cover a total of approximately 18,565 ha (45,891 ac) or 29% of the preliminary candidate area. Fifty-one State lands (21 greater than and 30 less than 130 ha or 320 ac) are located within 10 km (6 mi) of the preliminary candidate area (see Figure 3-42).

3.2.1.6.10 Environmental Compliance. There are no nonattainment areas or Prevention of Significant Deterioration (PSD) Class I Areas in or within 40 km (25 mi) of the preliminary candidate area (40 CFR 81). No sites listed on the National Register of Historic Places (NRHP) and no proposed NRHP sites are located within the preliminary candidate area. In the regional data base, there are no known existing archaeological sites or districts nor any proposed for designation within the preliminary candidate area. No existing designated National Trails are located in or within 40 km (25 mi) of the preliminary candidate area. However, the potential range of a future segment of the North Country National Scenic Trail is located within 5 km (3 mi) southeast of the preliminary candidate area. According to the National Park Service's planning document for the trail, the future segment of the trail is classified as having "High Potential Opportunity for the North Country National Scenic Trail Route and Recommended Side Trails" (NPS, 1982). In addition, an existing trail which lies within 4 km (2.5 mi) of the preliminary candidate area's southern boundary is classified in the plan as "Existing Trail Eligible for Certification as Official North Country National Scenic Trail Route".

3.2.1.6.11 Population Density and Distribution. There are no highly populated areas in or within 16 km (10 mi) of the preliminary candidate area. The highly populated areas located in Minnesota are depicted on Plate 5A of the North Central RECR (DOE, 1985a). The preliminary candidate area does not contain any areas with population densities greater than or equal to 1,000 persons per square mile. There are two areas with populations densities greater than or equal to 1,000 persons per square mile within 16 km (10 mi) of the preliminary candidate area. Fosston, with a population of 1,599 is located 16 km (10 mi) northwest of the preliminary candidate area, and Mahnomen, with a population of 1,283, is located 6 km (4 mi) west of the preliminary candidate area (see Figure 3-42). Fargo, North Dakota, is located 82 km (51 mi) southwest of the the preliminary candidate area. The average population density of the preliminary candidate area is 6 persons per square mile. The average population density within 80 km (50 mi) of the preliminary candidate area is approximately 18 persons per square mile. Low population density is defined as a density in the general region of the site less than the average population density for the conterminous United States (76 persons per square mile) based on the 1980 census.

3.2.1.6.12 Site Ownership. There are no DOE-owned lands located within the preliminary candidate area. As mentioned in Section 3.2.1.6.8, eight Federal waterfowl production areas lie within the preliminary candidate area and cover a total of 1,376 ha (3,400 ac) or approximately 2% of the preliminary candidate area. The White Earth Indian Reservation overlaps 43,200 ha (106,240 ac) or 66% of the western portion of the preliminary candidate area (see Figure 3-42).

3.2.1.6.13 Offsite Installations. No commercial nuclear reactors are located within the preliminary candidate area. The nearest operating commercial nuclear reactor is Monticello which is approximately 246 km (154 mi) southeast of the preliminary candidate area (Michelewicz and Vann, 1983; DOE, 1984c). The nearest commercial nuclear reactor under construction is Byron 2, which is 760 km (475 mi) to the southeast

(Nuclear News, 1985). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.1.6.14 Transportation. Interstate 94 is the nearest interstate highway to the preliminary candidate area and is approximately 72 km (45 mi) southwest of the area. The only other nearby interstate highway is I29 in North Dakota, which is approximately 80 km (50 mi) west of the preliminary candidate area. Nearby U.S. highways are U.S. 59 which is about 3.2 km (2 mi) west and U.S. 71, about 13 km (8 mi) to the east. U.S. 2, a four-lane divided highway, comes to within 13 km (8 mi) of the northern boundary. Three State highways cross portions of the preliminary candidate area: State Routes 92, 113, and 200. State Route 92 runs through the extreme northeastern part intersecting U.S. 2 at Bagley, Minnesota. State Route 113 is an east-west highway across the southern part of the preliminary candidate area connecting U.S. 59 at Waurin with U.S. 71 north of Park Rapids, Minnesota. State Route 200, which is approximately 16 km (10 mi) north and parallels State Route 113, also crosses this area.

There are two mainlines in the vicinity of the preliminary candidate area. The Soo/Milwaukee mainline between Minneapolis and Winnipeg runs near the western edge of the preliminary candidate area (4.8 km [3 mi]). The Burlington Northern Duluth to Grand Forks mainline is about 8 km (5 mi) north of the preliminary candidate area. There are no branchline railroads near the preliminary candidate area.

Based on the data presented above, access to the preliminary candidate area from both local and regional highway and railway systems appears to be available.

3.2.1.6.15 Preliminary Candidate Area Deferral Analysis. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area NC-9 that could affect DOE's decision to defer further consideration of the area. Based on evaluation of this additional available information, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]
- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]
- low potential for tectonic deformations suggests that the regional ground-water flow systems should not be significantly affected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]
- absence of historical earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that the frequency of earthquake occurrence within the geologic setting may increase [960.4-2-7(c)(3)]

- the frequency of occurrence or magnitude of earthquakes within the geologic setting are no higher than within the region [960.4-2-7(c)(4)]
- absence of historical earthquakes that, if they recurred, could provide ground motion in excess of reasonable design limits [960.5-2-11(c)(2)]
- absence of evidence, based on correlations of earthquakes with tectonic processes and features within the geologic setting, that the magnitude of earthquakes during repository construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]
- no evidence of subsurface mining or extraction for resources that could affect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence of drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]
- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]
- presence of generally flat terrain [960.5-2-8(b)(1)]
- presence of generally well-drained terrain [960.5-2-8(b)(2)]
- general absence of surface characteristics or surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]
- a majority of the preliminary candidate area is beyond 16 km [10 mi] from highly populated areas or areas containing more than 1,000 persons per square mile [960.5-2-1(b)(2) and (c)(2)]
- low population density within its boundaries and within 80 km (50 mi) of the preliminary candidate area [960.5-2-1(b)(1)]
- absence of nuclear installations [960.5-2-4(b) and (c)(2)]

- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2) and (b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)]
- presence of Federal lands less than 130 ha (320 ac) within (i.e., eight) and in proximity to (i.e., 40 within 10 km [6 mi] of) the preliminary candidate area (960.5-2-5(c)(3)]
- presence of State lands less than 130 ha (320 ac) within (i.e., five) and in proximity to (i.e., 30 within 10 km [6 mi] of) the preliminary candidate area [(960.5-2-5(c)(4)]
- projected land ownership conflicts (i.e., presence of White Earth Indian Reservation) that cannot be successfully resolved through voluntary purchase-sell agreements, non-disputed agency-to-agency transfers of title, or Federal condemnation proceedings [(960.4-2-8-2(c) and 960.5-2-2(c)].

The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area NC-9 at this time.

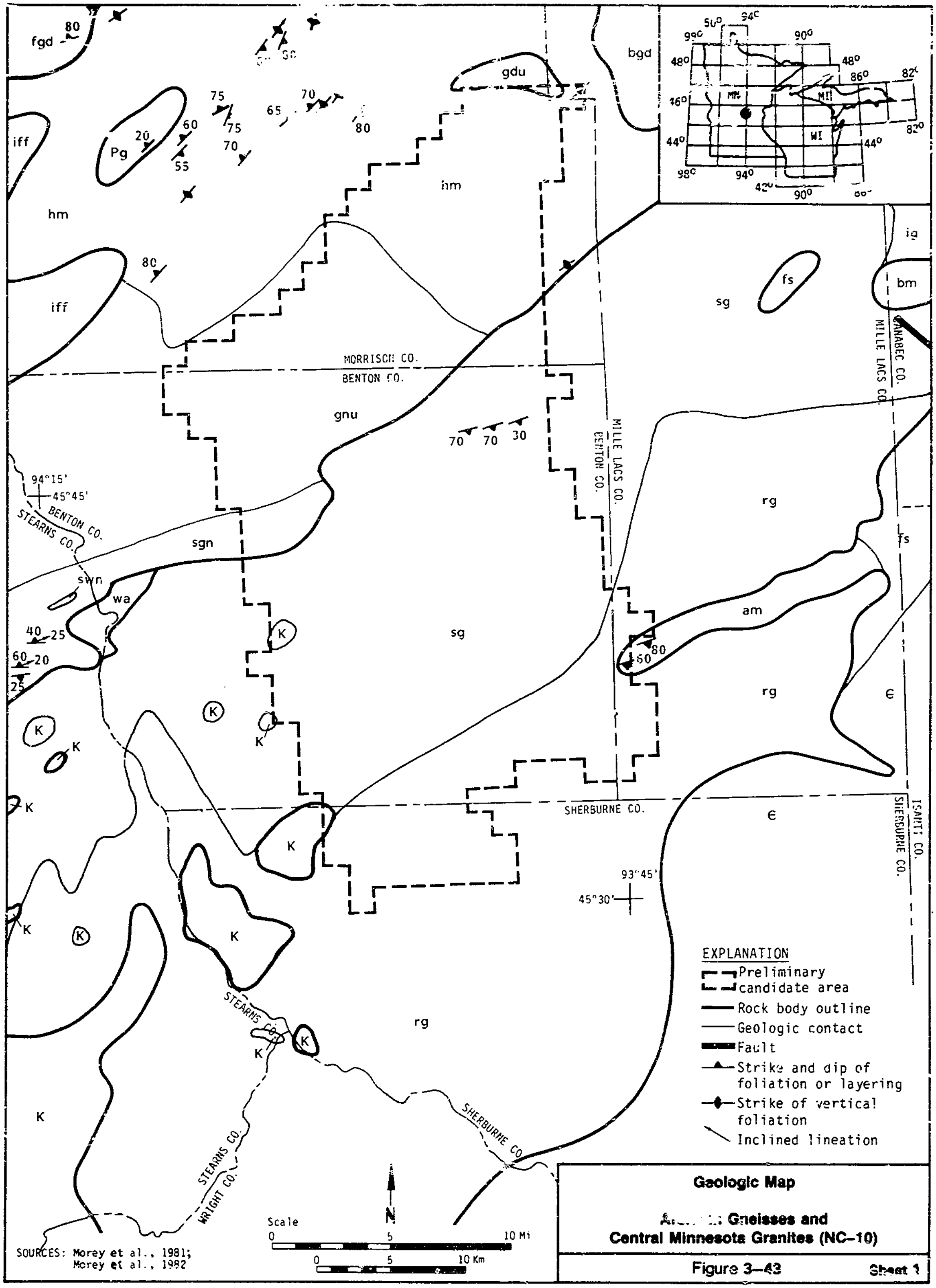
3.2.1.7 Preliminary [illegible] Description - Archean Gneisses and Central Minnesota Gr[illegible]tes (MC-[illegible]

The Archean gneisses and central Minnesota granites are located within the Central Minnesota Moraine Complex Upland physiographic division in central Minnesota. The preliminary candidate area is located in Mille Lacs, Morrison, Benton, and Sherburne Counties at approximately 43°43' N latitude and 93°55' W longitude.

3.2.1.7.1 Host Rock Geometry and Overburden Thickness. The preliminary candidate area shown on Figure 3-43 has an area of approximately 1,032 km^2 (397 mi^2) and overlies the Archean gneisses and central Minnesota granites, both of which are largely inferred from geophysical data and scattered outcrops (Morey et al., 1982). The Archean gneisses that contain the preliminary candidate area have a mapped extent of approximately 220 km (134 mi) long by 15 to 40 km (9 to 24 mi) wide. The central Minnesota granites form a composite batholith that is approximately 130 km (79 mi) long and 21 to 48 km (13 to 29 mi) wide. Seismic refraction and reflection data in the vicinity of the preliminary candidate area suggest that the Archean gneisses extend down to the asthenosphere (i.e., several tens of kilometers [miles]) (Gibbs et al., 1984), and the central Minnesota granites have a minimum depth of 2 km (1 mi) (Mooney et al., 1970).

Approximately 1% of the preliminary candidate area has exposed bedrock. Contours of overburden thickness for the preliminary candidate area (Figure 3-44) indicate that the eastern and northern part is generally covered by less than 30 m (100 ft) (Olsen and Mossler, 1982); whereas, the western section is covered by 30 to 61 m (100 to 200 ft) of overburden.

On the basis of the data presented above and the assumed depth and size of a repository in crystalline rock (see Section 1.5), the Archean gneisses and central Minnesota granites are sufficiently thick and



Geologic Map

[illegible] Gneisses and Central Minnesota Granites (NC-10)

Figure 3-43 **Sheet 1**

EXPLANATION OF GEOLOGIC UNITS

CRETACEOUS	K	Sedimentary rocks
CAMBRIAN	Є	Sedimentary rocks
MIDDLE PROTEROZOIC	fs	Fond du Lac Formation
EARLY PROTEROZOIC	ig	Isle granite
	pg	Pierz Granite
	sg	St. Cloud Granite
	rg	Reformatory Granite
	fgd	Freedhem Granodiorite
	gdu	Granodioritic rocks, undivided
	bgd	Bradbury Creek Granodiorite
	iff	Mille Lacs Group
	bm	Vesicular basalt
	am	Biotite Schist and amphibolite
ARCHEAN	hm	Hillman migmatite
	sgn	Sartell gneiss
	swn	St. Wendel metagabbro
	wa	Watab amphibolite
	gnu	Gneissic rocks, undivided

Explanation for Figure 3-43
Archean Gneisses and Central Minnesota Granites (NC-10)

Figure 3-43 Sheet 2