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Final Environmental Impact Statement

PROTON-PROTON STORAGE ACCELERATOR FACILITY (ISABELLE)

Brookhaven National Laboratory
Upton, New York

U.S. DEPARTMENT OF ENERGY

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August 1978

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Brookhaven National Laboratory
Upton, New York

Responsible Official

James L. Liverman
Acting Assistant Secretary for Environment

U.S. DEPARTMENT OF ENERGY
Washington DC 20545

August 1978

PREFACE

This is an Environmental Impact Statement for a proposed research facility (ISABELLE) to be built at Brookhaven National Laboratory (BNL). It has been prepared by the Department of Energy (DOE) following guidelines issued for such analyses. In keeping with DOE policy, this statement presents a concise and issues-oriented analysis of the significant environmental effects associated with the proposed action. Critical review of the significant issues involved with this proposed action was greatly facilitated by the use of the BNL Site Environmental Impact Statement (ERDA-1540). This document provides background information about the Laboratory, and is frequently referenced in this report.

ISABELLE is a proposed physics research facility where beams of protons collide providing opportunities to study high energy interactions. The facility would provide two interlaced storage ring proton accelerators, each with an energy up to 400 GeV intersecting in six experimental areas. The rings are contained in a tunnel with a circumference of 3.8 km (2.3 mi). The facility will occupy 250 ha (625 acres) in the NW corner of the existing BNL site.

A draft Environmental Impact Statement for this proposed facility was issued for public review and comment by DOE on February 21, 1978. The principal areas of concern expressed were in the areas of radiological impacts and preservation of cultural values. After consideration of these comments, appropriate actions were taken and the text of the statement has been amended to reflect the comments. The text was annotated to indicate the origin of the comment. Comments were received from the following:

Department of Transportation
Department of Agriculture
Department of Health, Education and Welfare
Environmental Protection Agency
Charles L. Weaver - Consultant
Department of the Interior
Nuclear Regulatory Commission
New York State Department of Environmental Conservation
National Science Foundation

Copies of the comment letters received are included in Appendix A.

Also included in Appendices are a glossary of terms, and listings of metric prefixes and conversions and symbols and abbreviations.

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SECTION 1

SUMMARY

This environmental impact statement was prepared in accordance with the National Environmental Policy Act of 1969 in support of the proposal by the United States Energy Research and Development Administration, merged on October 1, 1977 into the Department of Energy (DOE), for legislative authorization and appropriation of funds for the Proton-Proton Storage Accelerator Facility (ISABELLE). The facility will consist of proton-proton colliding-beam storage rings and associated experimental areas to be operated in conjunction with the Alternating Gradient Synchrotron (AGS) located at Brookhaven National Laboratory (BNL).

High energy physics seeks an understanding of energy and the basic constituents of matter through studies of the fundamental forces of nature governing their structure and behavior. In the last several years, new exciting experimental results together with theoretical efforts which seem to point to an underlying unity among the forces of nature and to new substructures within the known elementary particles make it imperative to extend the exploration of particle physics to higher energies.

Colliding-beam accelerators have been developed in the last fifteen years wherein two beams traveling in opposite directions are made to strike head on yielding much higher energies than can practically be obtained from the more conventional single-ring accelerators using fixed targets. The only proton-proton collidng-beam machine at the present time is at CERN in Switzerland, where proton beams of up to 31 billion electron volts (GeV) energy are collided making available 62 GeV of interaction energy. The ISABELLE Facility will be such a colliding beam machine consisting of two interlaced magnet rings housed in an underground tunnel 3.8Km (2.3mi) in circumference. In these rings protons will circulate in opposite directions at energies up to 400 GeV, making available interaction energies up to 800 GeV. This energy may be compared to the 31 GeV effective interaction energy available at Fermi National Laboratory (FNAL) where fixed targets can be bombarded with protons of 500 GeV maximum.

The new and growing technology of superconductivity will be applied to minimize the total cost of ISABELLE. The interlaced magnet rings will consist of hundreds of superconducting steering magnets which will generate magnetic fields two or three times as intense as those currently generated with conventional copper and iron magnets with appropriate power consumption of only one-quarter that required for conventional magnets.

ISABELLE will be located in an area of 250ha (625 acres) adjacent to the Alternating Gradient Synchrotron (AGS) in the northwest section of the 2106ha (5265 acre) BNL site. The AGS, an important component of the ongoing high energy physics program, will be used to inject protons into ISABELLE. Other existing facilities and systems at BNL will also be utilized in support of ISABELLE.

Experiments will be conducted at ISABELLE at the six intersection points where the counter-rotating proton beams collide. Four of the intersection regions will be permanently enclosed by experimental halls while two will be enclosed with shielding blocks to provide the flexibility to accommodate different experimental requirements.

Brookhaven National Laboratory is located in central Suffolk County in a region of relatively small but growing population. According to land use plans, future population growth will leave open space and relatively low density residential development around the Laboratory. In addition, BNL is located within the central east-west corridor of industrial-commercial zoned land adjacent to main rail and expressway transportation arteries. No significant conflicts with federal, state, local, or Laboratory land use plans, policies, or controls are expected to arise from the proposed location of the ISABELLE facility on the BNL site.

The construction phase of the ISABELLE project, employing an average of 500 workers, is expected to have a duration of approximately five years, from 1979 to 1984. This construction will involve 111 hectares (276 acres) of which about 86 hectares (214 acres) in the center of the ring will remain undisturbed. The effects of construction on the ecology of the area will be minimized by post construction restoration. Other impacts of construction including noise generation, dust evolution, visual effects, hydrological disruption, and traffic will be temporary and for the most part ameliorated by mitigating measures.

The operation of ISABELLE and the associated experimental apparatus is expected to double the Laboratory's present peak electrical demand of approximately 42 MW. In the extreme case of power peak coincidence between ISABELLE and the rest of BNL, the power required would be only 2.6 percent of the Long Island Lighting Company's (LILCO) present total peak demand. The yearly consumption of electricity by the Laboratory including ISABELLE is estimated to be 400 x 10^6 kWh which is approximately 3% of the total amount presently generated by LILCO. Operation of ISABELLE will also require an estimated three percent increase in the present Laboratory usage of fossil fuels and a ten percent increase in the Laboratory's total projected average daily pumping rate of water. Since the bulk of this water consumption will be recharged to the groundwater, there will be no significant lowering of the underlying water table. The effects of operation on noise, wildlife, traffic and offsite visual appearance are expected to be insignificant. The on-site appearance of the ISABELLE facility after restoration will be in congruence with other developed areas of the Laboratory.

ISABELLE will be designed and operated so as to have a minimal radiological impact on the environment. Since it will utilize only a small fraction of the total number of protons accelerated by the AGS, it will be a much smaller inherent source of radiation and will produce much less environmental radioactivity than the AGS which characteristically has contributed less than one percent of the total attributable to BNL operations. An earthern shielding berm and the earth covering the ring tunnel will limit radiation from normal operation or from abnormal conditions to well within permissible levels.

The major unavoidable adverse effect due to operation will be the consumption of electrical energy, and, although both peak demand and sustained load can be met by the Long Island Lighting Company, strong efforts will be made to use solar energy and to recover waste process heat.

The short-term use of part of the BNL site for ISABELLE extending in time through construction and operation well beyond the year 2000 will not cause any deterimental effects to the environment and will, indeed, to a large degree preserve the flexibility to choose future land use options when ISABELLE becomes obsolete. The most significant short-term effects will be the commitment of some resources. The electrical energy needed to operate ISABELLE will be consumed, but approximately 65 percent of the water used will be returned to the groundwater supply. Construction materials are for the most part salvageable and the amounts of critical materials needed for the project are only small fractions of the amounts available.

Balanced against these impacts will be the almost immediate beneficial effects that ISABELLE will have on the high energy physics programs in the United States and abroad, and the long term gain of unspecified but valuable scientific knowledge. In addition, there will be a beneficial effect on the presently recessed economy of the local area where the overall unemployment rate was recently as high as 8 percent with the rate in construction trades even higher.

Several alternatives to constructing a proton-proton colliding-beam accelerator at BNL have been considered. These include abandoning the project, postponing the project, constructing a conventional fixed-target accelerator, using copper or aluminum magnets, changing designs to minimize impacts, and building the facility at a different location.

If ISABELLE were not built, the most energetic nucleon-nucleon collisions available in the laboratory would continue to be those at the ISR in Europe. The stimulus of research at higher energies would be lost and important questions, already evident, whose resolution requires higher energies would remain unanswered. The resources committed to ISABELLE could be used for other purposes, but use of the land for any residential or commercial development would likely have greater adverse environmental impacts.

Postponement of the project would delay any benefits to be gained from increased scientific knowledge and exploitation of new technologies. A delay would not lead to major improvements in design, would not change the environmental impact, and would most likely increase the cost of the resources utilized.

A conventional fixed-target machine to achieve an effective interaction energy of 800 GeV would require a diameter about 400 times that of ISABELLE and would be completely impractical in terms of increased cost, resource utilization, and environmental impact. An optional design using conventional magnets with copper or aluminum conductors was studied and rejected because the size, construction costs, electric power, and cooling water requirements were greater than those for the superconducting design while the predicted beam performance was inferior. A review of electric power demands, water cooling systems, and radiation shielding indicates that other alternative designs would not change environmental impacts significantly.

Fundamental to locating ISABELLE at Brookhaven is the existence of the AGS as a source of protons for filling the rings of the colliding-beam machine. The colliding-beam accelerator could also be constructed at FNAL, using the accelerator there as a source of protons, with environmental impacts similar to those at Brookhaven. The choice of the FNAL site would imply a highly centralized high energy physics program, and a consequent severe weakening of the program at BNL with adverse effects on the diversity and balance of the national program. The FNAL staff and resources, moreover, are heavily committed to an intensive experimental program with the highest energy conventional accelerator and to the energy doubler/saver project.

Both economic and environmental costs would be significantly increased if ISABELLE were built at an entirely new site, since this would require the construction and establishment of essentially another high energy accelerator laboratory including an injection synchrotron and various necessary support facilities.

The ISABELLE construction is estimated to cost approximately $250,000,000 and its operation, with an increased staff of 200, $23,000,000 annually. Its location at BNL is compatible with projected land use and the environmental impacts occasioned by its construction and operation will be less than those from almost any other type of conventional development of the proposed site.

SECTION 2

DESCRIPTION OF PROPOSED ACTION

1 Background

Brookhaven National Laboratory (BNL) is operated by Associated Universities, Inc., as described in the BNL Site Environmental Impact Statement ERDA-1540 (July 1977). The Laboratory was founded in 1947 to provide a center for nuclear science in the northeastern United States. High energy physics research has been a major activity at Brookhaven since 1952, when the Cosmotron became the first accelerator to provide protons with energies well above a billion electron volts.

The goal of high energy physics is the understanding of energy and matter in their most basic forms. One seeks to achieve this understanding through studies of the fundamental forces of nature which govern the structure and behavior of matter and energy. These studies examine the transformations and interactions among the ultimate constituents of matter, search for new fundamental laws of nature, and seek to understand better the established laws of nature.

Four basic forces of nature are known. The strong nuclear force, dominant inside the atomic nucleus, determines the structure of nuclei and the energy released during their fission and fusion. The electromagnetic force, the best understood of the four, acts between charged particles and is the basis for electromagnetic radiation, the laws of chemistry, and the structure of the macroscopic world. The weak nuclear force is dominant in the interactions of neutrinos with other forms of matter, and also governs the radioactive decay of unstable nuclei. The fourth and weakest of the known forces, gravitation, determines the motion of matter on the earth, in the air, and in space, as well as on the astrophysical scale.

Brookhaven was one of the first national laboratories devoted to basic research in high energy physics. There are now a number of such centers in the United States. At each installation there are accelerators currently in use as well as plans for new research devices. Accelerators are the instruments that enable physicists to explore the fundamental behavior of the subnuclear particles. They are like microscopes that make the interactions and patterns of the subnuclear world visible. Cyclotrons, invented in the 1930's, were early accelerators for protons. Here, ionized hydrogen gas formed into a stream of protons is speeded up to high energies. The protons are used as projectiles or probes to bombard the nuclei of fixed targets. Physicists then study the effects of the collisions in an attempt to understand the nature of the atomic nucleus. Because of the very strong forces which bind the nucleus and its constituents together, greater and greater energies are needed to probe constantly deeper.

Some accelerators are circular like the Brookhaven 3-GeV Cosmotron (which is no longer in operation), while others such as the electron-positron machine at the Stanford Linear Accelerator Center (SLAC) are linear. Substantially higher energy protons as probes became available with the discovery of the principle of alternating-gradient focusing, and the construction of the Alternating Gradient Synchrotron (AGS) at Brookhaven which began accelerating protons to 33 GeV in 1961. The highest energy conventional accelerator, or an accelerator which accelerates subatomic particlea (electrons, protons, positrons, alpha particles) to high energies and bombards a fixed target, is now operating at Fermi National Accelerator Laboratory (FNAL) near Chicago. This machine which has a circumference of over four miles is capable of bombarding fixed targets with protons of 500 GeV maximum, but because the targets are fixed, only 31 GeV of this energy is available in the center-of-mass system.

Extension of this fixed-target technique has limits as a means of achieving higher energies. In the last fifteen years colliding-beam devices have been developed where, instead of having one particle beam strike a target at rest, two counter rotating beams are made to strike head on. With this type of device, the maximum amount of energy is released for the minimum cost. The only colliding-beam machine with proton beams existing at the present time is at CERN near Geneva, Switzerland where proton beams of up to 31-GeV energy are collided making available 62 GeV in energy.

The new facility, ISABELLE, proposed for Brookhaven, is an example of this new approach to obtain still higher energies. It will be a colliding-beam machine with proton beams of 400 GeV each whose collision will make available energies up to 800 GeV, considerably higher than can be obtained at present fixed-target machines. At ISABELLE the beams will collide at six locations around the rings where particle detectors will be positioned. By studying the byproducts of the violent interactions, it will be possible to reconstruct the physical processes going on during the high energy collisions.

Scientists from many universities and other laboratories throughout the United States, although primarily from the northeast area, presently use the AGS as a research facility, often collaborating with members of the BNL staff. The mode of operation with ISABELLE will be similar, and it is expected that about 80% of the research will be done with university participation by professors, students, and other staff members.

ISABELLE will provide the United States with a new forefront research facility, available to all researchers, for continued exploration into the basic constituents of matter. It will employ a new technology, namely superconducting magnets. This new development pioneered at Brookhaven will allow the use of hundreds of ring steering magnets with magnetic fields two to three times as intense as those currently generated and with an electric power consumption only about one-quarter of that for an equivalent accelerator constructed with the usual copper and iron magnets.

In the overall plans of the Department of Energy (DOE), three major High Energy Physics laboratories are included: FNAL, SLAC-LBL on the west coast, and Brookhaven. The long-range plans of DOE call for improved capabilities at each center. Congress authorized the construction of colliding-beam device at Stanford Linear Accelerator Center (SLAC) in California in which electrons and positrons will collide releasing 30 GeV of energy. It is expected that this machine will be completed in 1980. At the Fermi National Accelerator Laboratory (FNAL) the proton beam energy is to be increased by a factor of 2 with the realization of an Energy/Doubler ring of magnets. This project is currently underway.

At Brookhaven National Laboratory in New York, emphasis has been on producing a large step increase in energy by constructing the proton-proton colliding-beam machine. The project is technically ready to go and will provide fully-scoped facility for national use.

2.1.1 Description of Site

Brookhaven National Laboratory is in Upton, Brookhaven Town, Suffolk County, New York about 96 km (60 miles) east of New York City at approximately the geographical center of Long Island (see Figure 2.1.1-A). The site was formerly Camp Upton and it was used by the Army during World Wars I and II and as a CCC Camp for part of the intervening period. It was transferred to the Atomic Energy Commission in 1947 for the establishment of BNL. The Army buildings have been improved or removed, and most laboratory departments are now in permanent buildings designed for them.

The principal facilities are located near the center of the 2106 ha (5265-acre) site (see Figure 2.1.1-B) in an area of about 280 ha (700 acres). Two hundred of those hectares (500 acres) had been developed for Army use while the remaining 80 ha (200 acres) were subsequently cleared for construction of the large research machine facilities. Outlying facilities, occupying an additional 180 ha (450 acres), include the apartment area, ecology forest, gamma field, biology farm, landfill and waste management areas, Upland Recharge Project, and sewage disposal plant. The balance of the site (nearly 80%) is largely wooded and unoccupied.

As shown in Figure 2.1.1.-B, it is proposed to locate ISABELLE in an area of approximately 250 ha (625 acres) in the northwest sector of the Laboratory site due north of the Alternating Gradient Synchrotron (AGS). The terrain of the ISABELLE area is gently rolling with a maximum difference in elevations of about 9.2 m (30 ft.). The highest ground is about 27.5 m (90 ft) above sea level. The project site lies on the west rim of the shallow Peconic River watershed; a branch of the river itself rises in the marshy areas in the north and east sections of the site.

About 1.2 million people live in Suffolk County, and several villages and towns are within a radius of 24 km (15 miles). There is a limited amount of aircraft traffic in the vicinity of BNL associated with a small private airport about 3.2 km (2 miles) to the south and a U.S. Naval installation operated by Grumman Aerospace Corp. approximately 3.2 km (2 miles) to the east. Vehicular access to the site is from William Floyd Parkway (CR 46), a divided four-lane parkway running north and south along the western site boundary. The Long Island Expressway (INT 495) borders the southern boundary of the Laboratory.

2.1.2 Existing Facilities

2.1.2.1 Alternating Gradient Synchrotron (AGS)

One of the important components of the U.S. High Energy Physics Program is the circular AGS (Alternating Gradient Synchrotron) at Brookhaven National Laboratory. This machine is capable of accelerating protons to 33 GeV. The proton beam is utilized directly in experiments or to produce a variety of secondary beams to an array of experimental installations. The AGS consists of a number of technical components positioned in a circular tunnel covered by earth shielding. The dominant elements are 240 bending-focusing magnets that bend the beam in a circular orbit. The machine tunnel is 805 meters (0.5 mile) long, interrupted in two locations by experimental areas. The circulating beam is extracted into adjacent experimental halls where the detector apparatus is located.

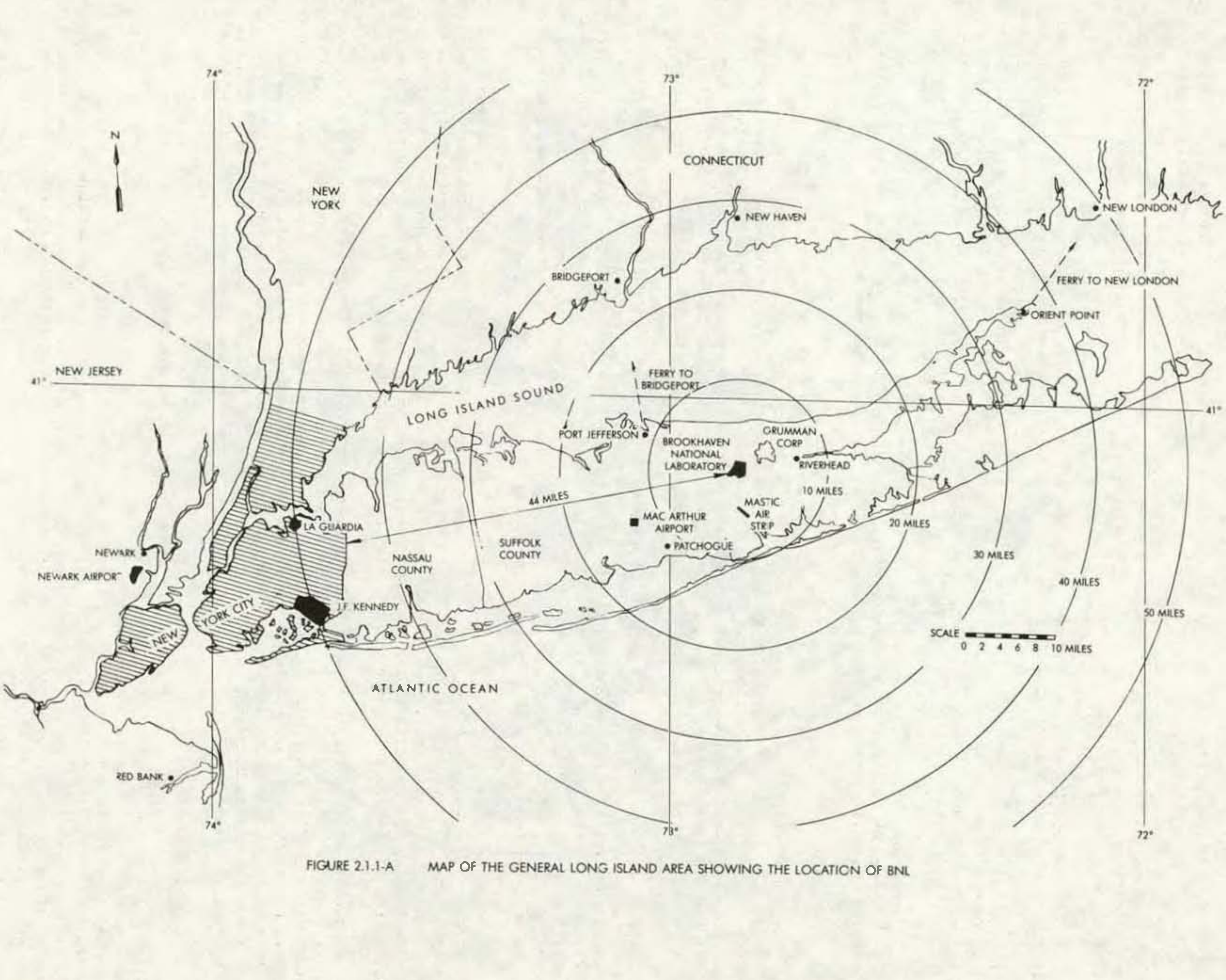


FIGURE 2.1.1-A MAP OF THE GENERAL LONG ISLAND AREA SHOWING THE LOCATION OF BNL

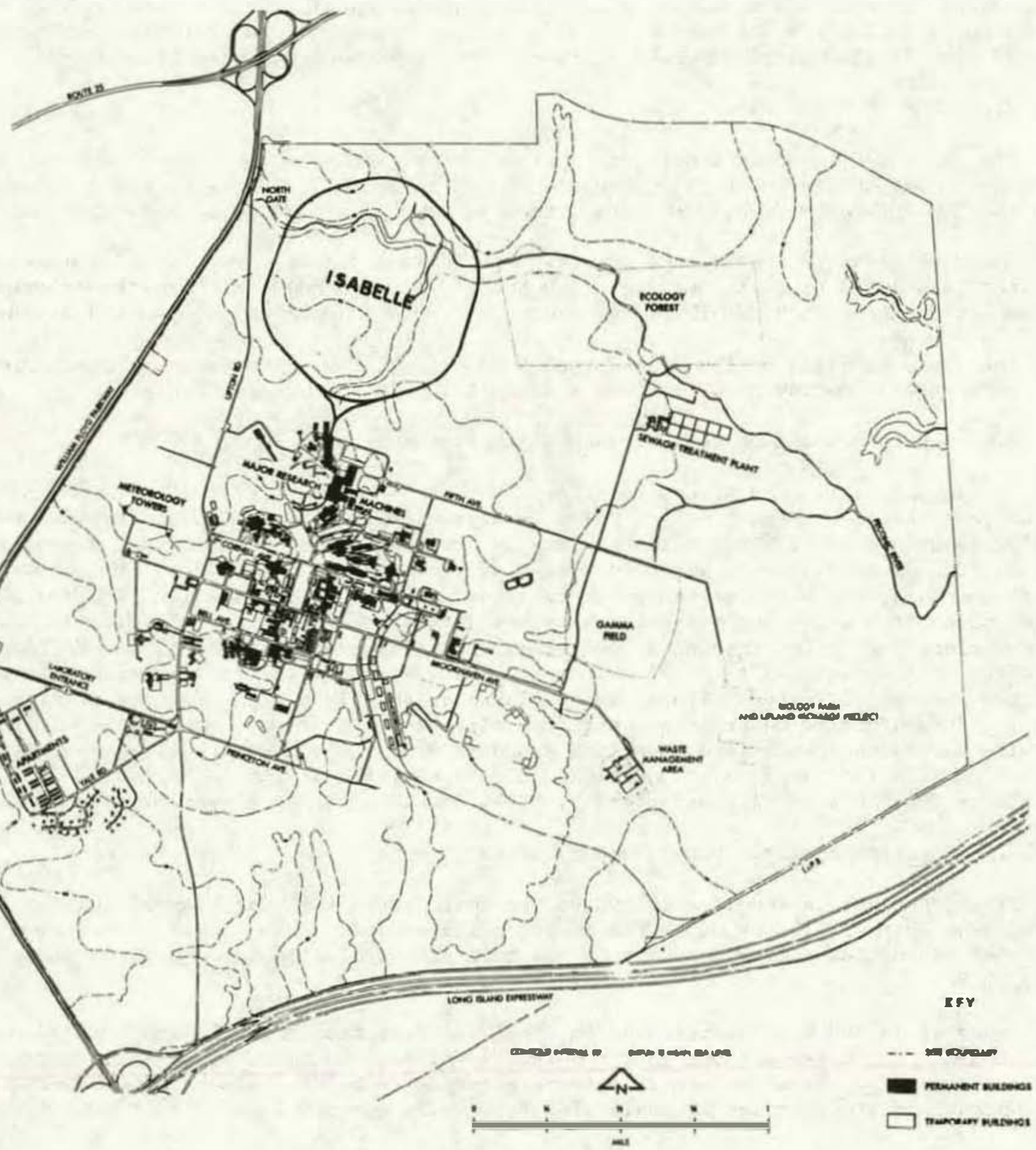


FIGURE 2.1.1-8 MAP OF BNL SITE - SHOWING PROPOSED ISABELLE LOCATION

The beam contains about 10^{13} protons in a typical pulse. Since the beam is normally used to produce other particles, it is carefully removed (extracted) from the accelerator after reaching the desired energy. It is transported inside a concrete and steel-shielded tunnel to a target area. Secondary particles produced from the target are in turn conveyed through shielded passageways to experimental apparatus. The unused primary protons are safely dispersed in a beam dump.

2.1.2.2 Laboratory Support Facilities & Services

This section identifies those Laboratory support facilities & services affected by ISABELLE in enough detail to enable the reader to understand their general nature as background for consideration of environmental impacts in Section 4. More detailed descriptions of these facilities and services may be found in ERDA 1540, Environmental Statement for Brookhaven National Laboratory.

2.1.2.2.1 Central Steam Plant

The Laboratory's Steam Generating System consists of two 27,000 kg/hr (60,000-lb/hr) boilers, one 20,250 kg/hr (45,000-lb/hr) boiler, and one 81,000 kg/hr (180,000-lb/hr) boiler (total design steam capacity, 155,250 kg/hr (345,000-lb/hr). Each boiler is served by an individual stack.

The high pressure steam, used for both heating and cooling, is carried through an underground network of insulated pipes to buildings and facilities throughout the Laboratory complex. The average load is 76,500 kg/hr (170,000-lb/hr) in winter and 40,500 kg/hr (90,000-lb/hr) in summer.

The steam plant is fueled with Number 6 oil containing approximately 1% sulphur. At its present level of operation, steam plant effluents are within the prescribed limits.

2.1.2.2.2 Sanitary and Laboratory Liquid Waste Systems

The sewage collection system consists of about 24 km (15 miles) of underground tile drains, all leading to a sewage treatment plant, which is approximately 2.4 km (1.5 miles) northeast of the main building complex at BNL. The influent flows by gravity through a collection system into a clarifier, where solids are settled out, and then to two of a set of six sand filter beds. After seeping down through the sand, the water is recovered by an underground tile field and, after chlorination, empties into an open ditch which becomes the headwaters of the west branch of the Peconic River. The sludge from the clarifier is put through a biological digestion process that further destroys the organic matter before it is committed to final disposal. The BNL Safety and Environmental Protection Division regularly monitors filtered influent and effluent at the plant, and also the radioactivity in the sludge. Administrative controls prevent the release of significant quantities of radioactive and otherwise hazardous agents (see ERDA 1540 Appendix G). The optimum treatment capacity for this facility is 8700 kl/d (2.3 mgd), and operation would be satisfactory up to 11,000 kl/d (3.0 mgd). The existing flow is 5500 kl/d (1.5 mgd), and 3,000 kl/d (0.8 mgd) is allowed for future increases.

2.1.2.2.3 Existing Electric Power Supply System

Electric power is supplied to BNL by the Long Island Lighting Company (LILCO) directly from its transmission system. Two 69,000-V transmission lines extend from LILCO's Brookhaven substation immediately east of the Laboratory boundary to two main BNL substations, where the voltage level is reduced to 13,800 V.

Power at 13,800 V is distributed to the Laboratory facilities by underground cables installed in ducts, most of which are encased in a concrete envelope. In major buildings, voltage is transformed to utilization levels, either by dry transformers inside or by oil-filled transformers outside. All outdoor substations are enclosed by chain link fences and are provided with crushed stone ground cover.

2.1.2.2.4 Radioactive and Hazardous Waste Management Facilities

The handling, packaging, and/or final disposition of all radioactive and otherwise hazardous waste materials generated at BNL are accomplished by the Waste Management Group of the Safety and Environmental Protection Division in compliance with applicable DOE and Department of Transportation (DOT) standards. This group operates the Reclamation Facility and the Waste Management Area.

The Reclamation operation represents the first line of Waste Management in that it returns decontaminated materials and components to service and thus minimizes waste generation. This facility, located on the eastern fringe of the developed portion of the Laboratory site, has a variety of equipment capable of performing specialized decontamination operations.

The Waste Management Facility is located in an isolated fenced 4.8 ha (12-acre) area in the southeastern portion of the Laboratory site. The principal waste management operations involve collection, sorting, processing, packaging, and transportation off site for disposal when necessary. Small amounts of radioactive waste may also be provided with interim storage at this facility pending ultimate disposal.

2.1.2.2.5 Nonhazardous Solid Waste Disposal System

The Laboratory landfill site occupies about 1.2 ha (3 acres) approximately one-half mile east of the major building area. Solid waste, which is collected five days a week from various sources on site, is deposited on the landfill, distributed, compacted with bulldozing equipment and covered daily with clean fill from an adjacent sandy area. The applicable Environmental Protection Agency (EPA) regulations (40 CFR 241) are met in the operation of this landfill. The landfill has been in operation for about nine years, and the estimated capacity is sufficient for at least another eight.

2.1.2.2.6 Water Supply Systems

The water supply system at BNL consists of a potable water system for domestic use, cooling water, and other process needs; and two other separate systems used exclusively for cooling.

The domestic water system is supplied by six wells with deep well vertical pumps, all drawing from the uppermost geological deposit, the Pleistocene sand formation that occurs at the site. Water from the various wells is delivered to the distribution system after having, for the most part, been processed through the Water Treatment Plant. The Treatment Plant, which was built in 1963 primarily for removing iron and neutralizing the water, is designed to have a hydraulic capacity of 24,600 kl/d (6.5 mgd). Treatment consists of aeration, neutralization, coagulation, settling, and filtration. Presently the plant processes approximately 15,000 kl/d (4 mgd).

The potable water supply is used for all domestic purposes in various buildings at BNL and also serves as the basis for the fire protection system. In addition, various facilities such as the AGS and the High Flux Beam Reactor (HFBR) utilize domestic water for process purposes. Presently the domestic well supply is pumped at approximately 61% of its rated capacity of 29,200 kl/d (7.7 mgd).

Two separate systems use raw water for once through cooling, one at the AGS and the other at the Medical Research Center (MRC). Their supply wells remove water from the Pleistocene formation mentioned above, with the exception of one well which enters the Magothy formation. The three wells which presently feed the AGS have a rated capacity of approximately 12,900 kl/d (3.4 mgd), and are presently utilized to deliver approximately 5,500 kl/d (1.5 mgd) of water. Water treatment for this system is provided at each well by chemicals which are introduced into the pump discharge. Phosphates are added to complex the iron to keep it in solution (See ERDA 1540).

2.1.2.2.7 Environmental Monitoring

BNL maintains a state of the art Environmental Monitoring Program aimed at ascertaining the impact, if any, of the operation of BNL on the environment.

This program is designed (a) to look at the amount of radioactivity and other potential environmental contaminants in the gaseous and liquid effluents from BNL and (b) to estimate any increment in radiation dose to the general public as a result thereof.

This program is essentially divided into three sections, sampling, analysis and data interpretation, and review of the sampling program.

<u>Sampling</u>: The sampling program is designed to look at gaseous and liquid effluents. The location of gaseous effluent monitors corresponds to the predominant wind directions. Special emphasis has been given to monitoring groundwater contamination. Attached Figures (2.1.2.2.7-A and B) indicate the water sampling locations. This is accomplished by a network of surveillance wells located in the established <u>downstream</u> direction of the ground-water flow. In addition, external radiation levels, which include natural background, are also monitored at specific sites.

<u>Analysis</u>: In general, "state of the art" instrumentation is deployed in analyzing the environmental samples.

<u>Radioactive Analysis</u>: The instruments are designed to determine gross beta, gross alpha, gamma activity, and alpha spectrometry. The acquisition of a 145-cc active volume Ge(Li) System with 28.5% efficiency has enhanced our gamma spectrometry. This system is also designed for a variety of environmental samples, such as: air filter, water, soil, vegetation and animal samples. The ambient

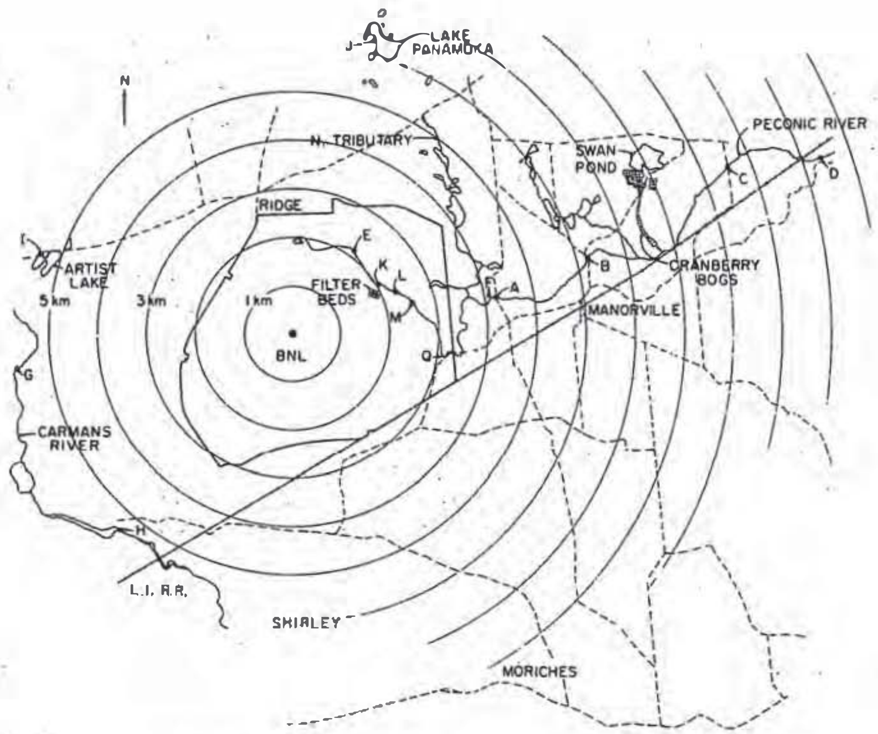


FIGURE 2.1.2.2.A SURFACE WATER SAMPLING LOCATIONS

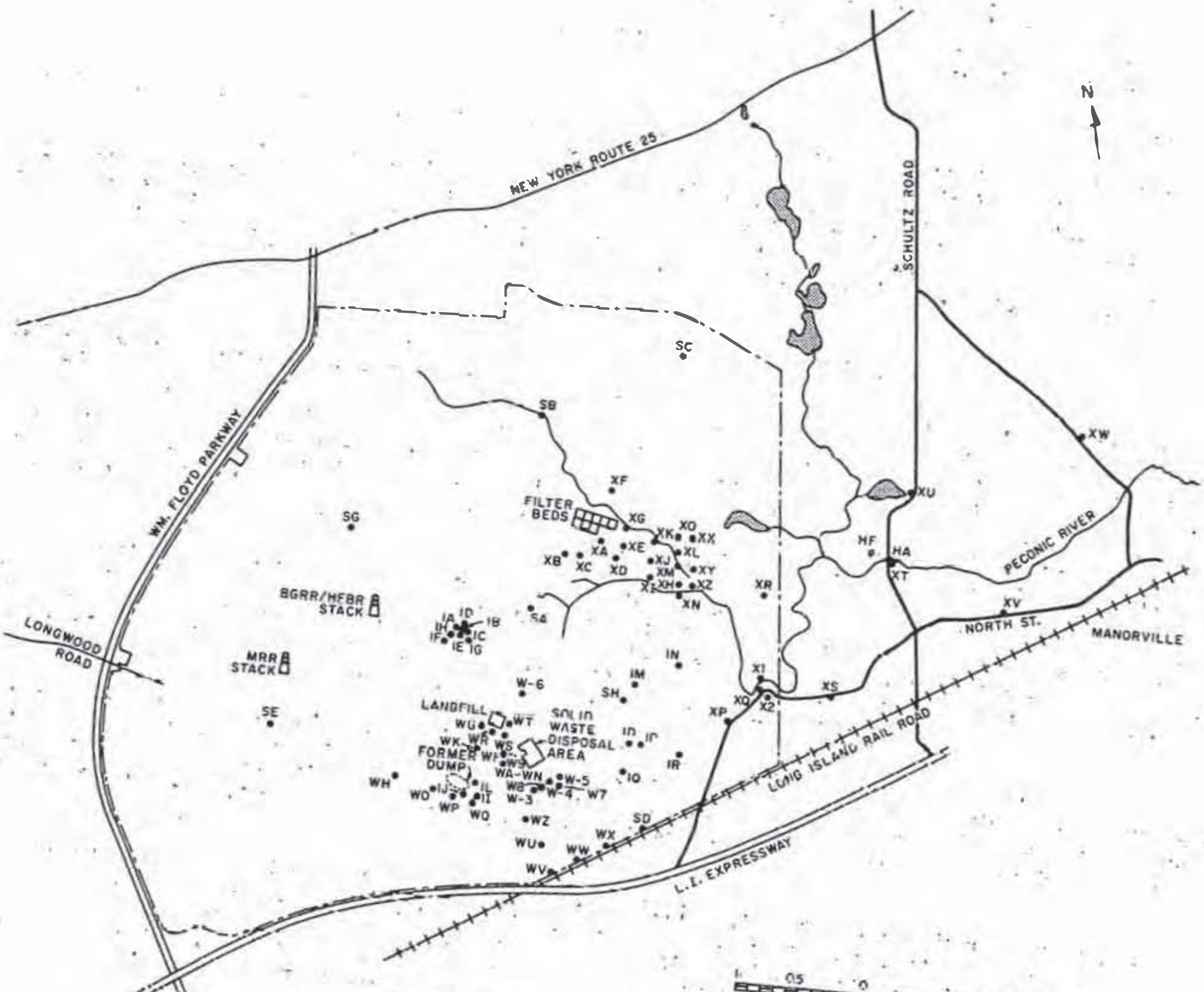


FIGURE 2.1.2.2.7-B LOCATION OF GROUNDWATER SURVEILLANCE WELLS

radiation levels are measured by using thermoluminescent dosimeters (TLD), an unpressurized 6-liter (1.6 gal.) ion-chamber, and a dynamic electrometer. The Laboratory is also equipped to do radiochemical analyses of environmental samples to estimate ^{3}H, ^{90}Sr, ^{131}I, and transuranic content.

Nonradioactive Analysis: The analytical laboratory of Safety and Environmental Protection Division is equipped to routinely measure water quality parameters, such as pH, phosphates, nitrates, chlorides, and other components as deemed necessary. In addition, the acquisition of an atomic absorption spectrometer and a gas chromatograph has extended the capability to include trace element and organic compound analyses. There will, therefore, be no problem in increasing the Laboratory's future analytical capability to include other pollutants.

Data interpretation and review of the sampling program: The data collected by the Environmental Monitoring group are published in the format of an Annual Environmental Monitoring Report. In the process of writing the report, a review of the sampling program is initiated and modifications of the Environmental Monitoring program are incorporated if necessary.

2.2 Description

The proposed colliding-beam facility, ISABELLE, will provide the capability of studying proton-proton interactions to very high energies. The facility will include two interlaced magnet storage rings with experimental areas to house particle detectors at six locations where the rings intersect, tunnels containing equipment to direct 33 GeV protons from an existing external proton beam channel at the AGS and inject them in clockwise and counterclockwise directions respectively in the two ISABELLE rings, a multipurpose service building and six support buildings, and necessary roads and utility systems.

2.2.1 ISABELLE Experimental Programs

At each of the six interaction points of ISABELLE, where proton beams collide, experiments will be set up to observe the nature and behavior of the particles coming from those collisions. The electronic detection equipment used in high energy physics experiments is sufficiently sensitive that a single particle can be detected, with position recorded to a fraction of a millimeter. Two or more position measurements on a particle give its direction. Three or more position measurements with a magnetic field measure the energy, if the mass is known. An appropriate combination of measurements can determine the mass of the particle or other properties that identify it.

In designing experiments to be carried out at ISABELLE, the main objective is to devise observations that determine important properties of particles or provide comparisons with theoretical predictions. Of particular interest are those investigations which will serve to test and explore a new picture of particles and their interactions that has been gaining increasing acceptance. According to this picture, the proton for example, is made up of pointlike constituents called quarks.

This general picture of the proton as an extended composite of pointlike constituents leads us to seek experimental information on the interactions. We will collide protons with each other and in effect study the properties of colliding quarks or in some cases colliding quarks and antiquarks leading to the production of new particles such as W mesons, heavy photons, heavy muons, or, hopefully, charmed particles.

The detection equipment, involving scintillation counters, multiwire proportional chambers, drift chambers, Cerenkov counters, shower counters and associated magnets, calorimeters, and other devices, will be set up in the experimental halls. Some experiments will utilize open areas, and will be enclosed in concrete block shielding. Electronics, computers for data acquisition, and working space for the experimenters will be provided in temporary structures on the hardstand areas on the inside of the ISABELLE ring near the experimental halls.

Installation of experimental equipment will begin when ISABELLE is nearly completed, and some experiments will be ready for testing as soon as colliding beams are available. Soon afterwards, experiments will be at a data-taking stage in all six intersection regions. During normal operation, ISABELLE proton beams will be available from 20 to 24 hours a day, and experiments will be manned on an around-the-clock basis. A detailed operational schedule for ISABELLE has not been setup yet and probably will not be fixed until ISABELLE is actually operating. It is assumed that ISABELLE is in operation 30 weeks per year out of 52, with the remaining time turned off for maintenance, experimental changes, and such purposes. During a week of operation we assume 5 days on and 2 days off. For each of the 5 days of operation we assume 3 fills of each ring at maximum intensity. A typical high energy physics run will last about a day, so this allows two additional fillings of the rings per day, or ten per week, for machine studies. The ratio of protons used for machine studies to protons used for physics research is 2 to 1. In many cases, of course, machine studies can be carried out at low intensity, so there may be more than 10 fillings per week for machine studies in such a case. Of course these numbers are not advanced as limits, but as estimates of what actual operation might be like.

In any given day, the number of people working on these experiments is expected to be about 100, representing 10 to 20 high energy physics laboratories. During the overall lifetime of ISABELLE, most United States institutions concerned with high energy physics research will utilize ISABELLE to some degree, and there will be substantial foreign participation as well. No other accelerator now in existence or under construction anywhere in the world offers the same capabilities for research.

2.2.2 ISABELLE Systems and Facilities

2.2.2.1 Storage Rings

The proposed facility will consist of two interlaced magnet rings providing the bending and focusing fields for counter rotating proton beams. The configuration will essentially be a circle broken by six symmetrically placed long straight segments where the beam lines cross. Its circumference will be 3767 m (12,358 ft). The magnet arcs will be enclosed by an approximately semicircular tunnel about 4.6 m x 3.1 m (15 ft. x 10.2 ft.) in cross section, the floor of which is located at approximately 20 m (65 ft) above mean sea level. This tunnel will be covered by 4 m (13 ft) of earth for radiation shielding. At the locations of the straight segments in the storage rings, experimental halls will be constructed for enclosure of the experimental apparatus around the colliding proton beams. These structures will be surrounded by approximately 4 m (13 ft) of earth shielding. A muon shield (Earth Berm) is provided in the median plane around the ring. The width varies from 92 m (300 ft) to 18 m (58 ft) and the shield extends to about 4.0 m (13 ft), above beam elevation.

The ISABELLE magnet system will be superconducting because of the enhanced performance capability and reduced electric power consumption made possible by this approach. There will be a total of 1116 superconducting magnets in the two storage rings. The magnet design makes use of superconducting coils wound with a flat conductor braided from niobium-titanium wires. The operating temperature of the magnets will be 4.0 K (-269.1°C). Cooling of the magnets will be achieved by forced circulation of high pressure (15 atm) helium gas.

The proposed storage rings are designed to generate a reaction rate per unit reaction cross section (luminosity) of 10^{33} $cm^{-2}sec^{-1}$ at beam energies of 400 GeV. This will be achieved by storing 8 A of proton beam current in each ring and bringing these energetic particle beams into collision in the interaction regions within the experimental detectors. In order to preserve these high intensity beams for a long time for beam collisions, a very high vacuum is required in the beam chamber. Loading of the storage rings will typically occur once per day by injecting the proton beam from the existing 33 GeV proton Alternating Gradient Synchrotron, which is presently being used for particle physics experiments. After multiple injection of the AGS beam in each storage ring, the beams are formed into three beam bunches, which are then accelerated to the desired energy of operation, where the bunches are spread out uniformly around the storage ring.

2.2.2.2 Transfer Sections

The 33-GeV proton beam is presently transported from a fast beam deflection device, located in the AGS ring, to the 2.1 m (7-ft) diameter liquid hydrogen bubble chamber. The beam for ISABELLE will be branched off from this existing external beam channel and transported via an embanked tunnel branching section in two separate tunnels to the ISABELLE injection locations. These beam transport enclosures will be constructed similarly to the main magnet enclosure but will be smaller in cross-sectional area. Interior dimensions are 2.5 m (8 ft) by 2.5 m (8 ft), covered by 3.5 m (11.5 ft) of earth shielding. The total length of the straight section, branching section, and two separate tunnel branches is about 579 m (1899 ft). For the beam transfer lines, room temperature water-cooled bending and focusing magnets will be used since operation of these elements are required for only a short period per day. Consequently, power consumption will be minimized.

2.2.2.3 Experimental Areas

Because of the great variety of experiments planned with the energetic colliding proton beams, specialized experimental halls will be built enclosing the interaction regions. Four of these will be permanently enclosed and two will be enclosed with moveable concrete shielding blocks to provide greater flexibility in the possible experimental arrangements. Experimenters' detection electronics and auxiliary equipment will be located outside the experimental enclosures in movable structures positioned on a paved yard area. A typical view of an experimental hall is shown in Fig. 2.2.2.3-A. Access to the experimental halls will be through concrete shield doors. Three of the permanently covered experimental structures will be serviced by 36 M.T. (40-ton) cranes, and the fourth by a 9 M.T. (10-ton) crane. Shielding will be provided by adopting a building construction method making use of square

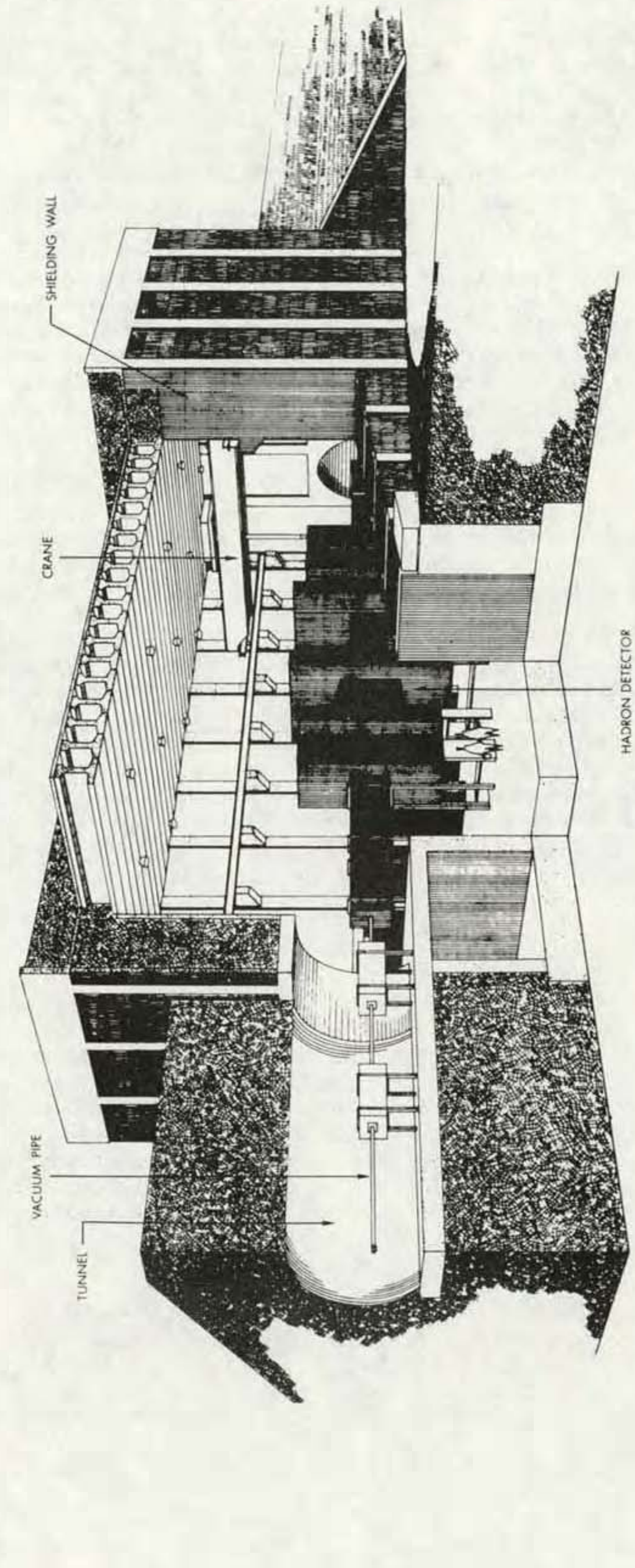


FIGURE 2.2.2.3-A TYPICAL EXPERIMENTAL HALL.

precast concrete silos for the side walls of the structures which are filled with a sand/gravel mixture, available on site. Roof structures will consist of reinforced concrete roof members covered with a 2-m (6.6 ft) layer of sand.

2.2.2.4 Physical Plant

Injection Tunnel:

The existing beam transport tunnel from the AGS requires the existing switch-out tunnel to be modified to accommodate the new ISABELLE injection beam line. The dimensions of this enclosure are approximately 2.5 m (8 ft) wide by 2.5 m (8 ft) high, and the total length is approximately 579 m (1853 ft). A separate support building housing the injection power supply will be constructed at the conjunction point where the enclosure branches into two separate tunnels. This building will be approximately 557 m^2 (5987.8 sq ft) and will house injection power supplies and ancillary equipment.

Main Magnet Tunnel:

The location of the ISABELLE ring recognizes the need for adequate radiation protection at the site boundaries. The circumference of the ring is 3,767 m (12,356 ft) and the beam tunnel is 4.6 m (15.0 ft) wide by 3.1 m (10.7 ft) high. However, an enlarged tunnel, 6.0 m wide by 3.65 m high, (19.7 ft by 12 ft) is provided adjacent to the experimental areas. The tunnel structure will be covered with 4.0 m (13.0 ft) of earth. The muon shield's width varies from approximately 92 m (300 ft) at its thickest point on the site to about 18 m (58 ft) at the southeast sector. The height of the muon shield is about 4.0 m (13 ft) above beam elevation.

Experimental Halls:

The locations and dimensions of the six experimental halls are shown in Table 2.2.2.4-1. In each case, an enlarged tunnel, 6.0 m (19.7 ft) in width by 3.65 m (12 ft) in height, connects both ends of the experimental halls to the ends of the straight sections. The total length of an enlarged tunnel is approximately 160 m (525.6 ft) less the length of the experimental hall within the straight section. In the case of the injection areas, the enlarged tunnel continues beyond the end of the straight section to the point of conjunction of the main ring enclosure and the beam injection tunnel. As previously mentioned the permanently enclosed halls sre constructed of precast concrete silos on reinforced concrete foundations. The exterior cell walls are approximately 3.5 m (11.5 ft) thick and are filled with sand and gravel for shielding purposes. Precast concrete roof beams 1 m (3.3 ft) thick will form the roof structure and will be covered with 2 m (6.6 ft) of sand for shielding. Access to a hall will be through a large shield door from the paved yard adjacent to the hall. Interior space will be heated, ventilated, lighted and fire protected as required. The 3 and 9 o'clock experimental regions will be constructed with portable concrete shield blocks to enclose the beam and provide experimental flexibility.

Table 2.2.2.4 I

Dimensions of Experimental Facilities

Location	Length m (ft)	Width m (ft)	Height m (ft)	Enclosure
One o'clock*	100 (328)	8 (26)	6 (20)	Permanent
Three "	54 (17)	54 (17)	--	Temporary
Five "	15 (49)	48 (157)	11 (36)	Permanent
Seven "	60 (197)	18 (59)	15 (49)	Permanent
Nine "	54 (17)	54 (17)	--	Temporary
Eleven "	60 (197)	18 (59)	15 (49)	Permanent

*12 o'clock = north

Support Buildings:

At each of the six experimental areas a support building will be provided to house services for the respective areas. These buildings will be approximately 107 m^2 (1151 sq ft) in area and contain space for mechanical equipment, rest rooms, and experiments.

ISABELLE Service Building:

At the 5 o'clock region of the main ring, a large multipurpose service building will be constructed adjacent to the experimental hall. This structure will contain space for all main magnet support systems including the central cryogenic plant, rf and power supply equipment, ejection dump equipment, and other supporting apparatus for the machine. The central control room, computer area, rf control, and technical supporting services will be provided in a wing contiguous to the aforementioned machine equipment areas. Several offices, a conference room, toilets, a locker room, a stock-room, a tech shop, etc., will complete the facility. A paved yard area will provide access to gas storage and cryogenic areas. A parking area adjacent to building for personnel will be provided. The total area of the building will be approximately 5000 m^2 (53,800 sq ft).

Roads:

The inner-ring road and the access roads, crossing into the ring, will constitute a total of 5 km (3 miles). The new road network to ISABELLE will be basically an extension of the present system serving the AGS.

Utilities:

The underground utilities including water, telephone, and fire alarm and the 13.8-kV primary service will follow the circumference of the ring. The sanitary, steam and condensate lines, and heavy electrical power feeders to the helium compressors will be extensions of the existing site utilities system. The proposed utilities distribution system will parallel the road network wherever possible, thereby minimizing the disturbance of existing vegetation.

2.2.2.5 Construction Schedule

Preliminary site development for ISABELLE will start in 1978.

The actual construction of ISABELLE will begin in 1979 with the machine scheduled to become operational in 1985. Within this schedule, land improvements for the project will be completed in 1982, and construction of the injection and main ring tunnels, experimental halls, service and support buildings, roads, and utilities will be completed one year later.

In parallel with construction of these facilities, technical components for the project will be procured, assembled, installed, and tested as the facilities are available for occupancy.

Major component and systems testing will begin in 1984 and culminate in late 1985 after installation of the various machine systems are completed.

2.3 Anticipated Benefits

This subsection attempts to document the technical and socio-economic benefits that will be derived from the proposed construction and operation of the ISABELLE project.

2.3.1 Technical

The ISABELLE storage ring project will extend the available reaction energy in proton-proton collisions to 800 GeV, thus expanding by more than 10 times our reach into previously unexplored regions. The available reaction energy will far exceed that obtainable at the world's highest energy accelerator, even though the energy of each circulating beam is lower. This is true because when two oppositely directed particles of the same momentum collide, the total energy, i.e., the sum of their energies, is available to the reaction. In contrast, when a beam particle from a conventional accelerator strikes a stationary target particle, most of its energy is necessarily tied up in the continuing forward motion of the reaction products as required by the law of conservation of momentum. Only a small fraction of the energy of the incident particle is available to the reaction. This fact is illustrated in Table 2.3.1-I which shows the available reaction energy for the four highest energy machines now operating, including the world's only proton-proton colliding-beam device, the CERN Intersecting Storage Rings (ISR). This table shows that the ISABELLE facility will provide available reaction energies more than a factor of 10 higher than those available from any other machine.

Table 2.3.1-I

AVAILABLE REACTION ENERGY FROM VARIOUS HIGH ENERGY MACHINES

Machine	Available Reaction Energy
FNAL (500-GeV proton accelerator	31.0 GeV
CERN II (400-GeV proton accelerator)	27.4 GeV
ISR (31-GeV p-p storage ring)	62.0 GeV
AGS (33-GeV proton accelerator)	7.0 GeV
ISABELLE (400-GeV p-p storage rings)	800.0 GeV

It is interesting to note that a proton accelerator capable of producing the same available reaction energy as ISABELLE by striking stationary target protons would have to accelerate the protons to almost half a million GeV, about a thousand times the energy of the FNAL accelerator.

Another major technological benefit from the construction of ISABELLE will be the large-scale use of superconducting magnets. These magnets can be energized to very high magnetic fields in an efficient manner. Not only can they be operated at fields 2.5 times stronger than conventional magnets with copper coils, but they achieve these properties with only one-quarter the electrical energy. Because of the stronger fields, the magnet ring is 2.5 times smaller than it would be with conventional magnets and the costs of construction and operation of ISABELLE are relatively modest.

Since it is expected that superconductivity will play a major role in the future generation and transmission of electrical energy, the experience on ISABELLE with large systems will be very valuable. This is equally true for the cryogenic system, refrigerators and large, dry screw compressors needed to cool the magnets to 4 K.

2.3.2 Socio-Economic

The social-economic benefits derived from the construction and operation of the proposed ISABELLE accelerator are discussed in detail in this Statement in Section 4.2.1.8. Indeed this proposed project, whose present cost is estimated at approximately $250 million for construction, will have stimulating effects on the presently recessed regional economy of Long Island. A significant number of additional jobs will be created for the five-year period of construction as well as permanent Laboratory positions during the subsequent period of machine operation. Additional revenues will also be brought in by visiting scientists and scholars both from the United States and abroad. The project will bolster the regional economy, not only through the work involved in site preparation and general facility construction, but also through the fabrication of machine hardware itself for which technology is available in the immediate area. Moreover, the Laboratory's sociocultural impact in terms of stimulation of local academia and industry will be further enhanced by the operation of this facility.

SECTION 3

CHARACTERIZATION OF EXISTING ENVIRONMENT

In this section, the environmental aspects of the ISABELLE site are described with respect to those features that are related to the construction and operation of this facility. More detailed information concerning the existing environment may be found in ERDA 1540, Environmental Statement, Brookhaven National Laboratory.

3.1 Land Use and Demography

Until recently, "urban sprawl" has been the predominant type of development in the local area; however, creation of a regional planning commission and increasing awareness of the fragile nature of the environment have led to design of a Nassau-Suffolk Bicounty Master Plan to guide future development. This document is further complemented on the local level by a Brookhaven Town Master Plan. In both of these documents the operation of the Laboratory, as well as anticipated future projects on this site such as ISABELLE, is considered in terms of the projected land use and the population distributions for Long Island.

Industrial-commercial zoned land is found mostly along the central east-west spine of the Island, along the main transportation arteries. Major industrial parks exist or are planned along the Long Island Expressway. In this way jobs are most accessible to residents; traffic and noise pollution are minimized. From the central corridor toward the shorelines, residential density decreases. Clustered residential-commercial development is encouraged so that areas will be left for open space and parks. One such clustered development is presently under construction just southwest of the BNL site, and another is planned for construction northwest of the BNL site. Many of the older, developed villages like Patchogue and Riverhead are centers of both light industry and commerce as well as residential areas, and these are expected to be maintained. The eastern end of the Island is valuable agricultural and resort-recreational land and will be encouraged to remain so.

The Laboratory is located in central Suffolk County, just at the fringe of developed areas, in a region of relatively small but growing population. In Suffolk County, natural population growth added 120,000 persons between 1960 and 1970, and in-migration added 360,000. The total population was 1.13 million in 1970, 1.32 million in 1977, and is expected to continue to increase to approximately 1.57 million by 1980. In the immediate vicinity of BNL, the growth rate is about 20 to 30% per year. The population density in Suffolk County is now about 3.5 persons per acre. Near BNL, it is 1 person per acre but is expected to increase to several persons per acre by the early 1980's.

The population distribution around BNL is shown in Figure 3.1-A on a polar grid of 22.5 degrees arc segments, centered on north, with its origin at the BNL Reactor Stack, superimposed on a regional map. The populations within a few miles of BNL represent densities of about one person per acre. Along the north and south shores densities are typically several persons per acre. North, by approximately 32 km (20 miles), is Connecticut, with densities ranging from several persons per acre to greater than ten persons per acre in city areas. West of BNL, the density rises rapidly from one person per acre nearby to five at the Nassau-Suffolk border (W and WSW about 48 km (30 miles) to ten at the Nassau-New York City border (W and WSW about 72 km (45 miles). The total population within a 80 km (50-mile) radius is approximately 4.8 million.

The implications of land use and demography for BNL operations are two-fold. One: BNL is ideally located within the desired corridor-cluster center concept of the land use plan, and is adjacent to rail and expressway transportation links. Two: the present population around BNL is small and future population growth, according to the land use plan, will leave open space and relatively low density residential development in the surrounding area, minimizing future impacts.

3.2 Geology and Seismology

Geology

BNL is located on Long Island which was formed by the terminal moraines of the last two glaciations. The Lab site is in the upper part of the Peconic River Valley which is bordered by two lines of low hills. These hills extend east and west beyond the limits of the valley nearly the full length of Long Island and form its most prominent topographic features.

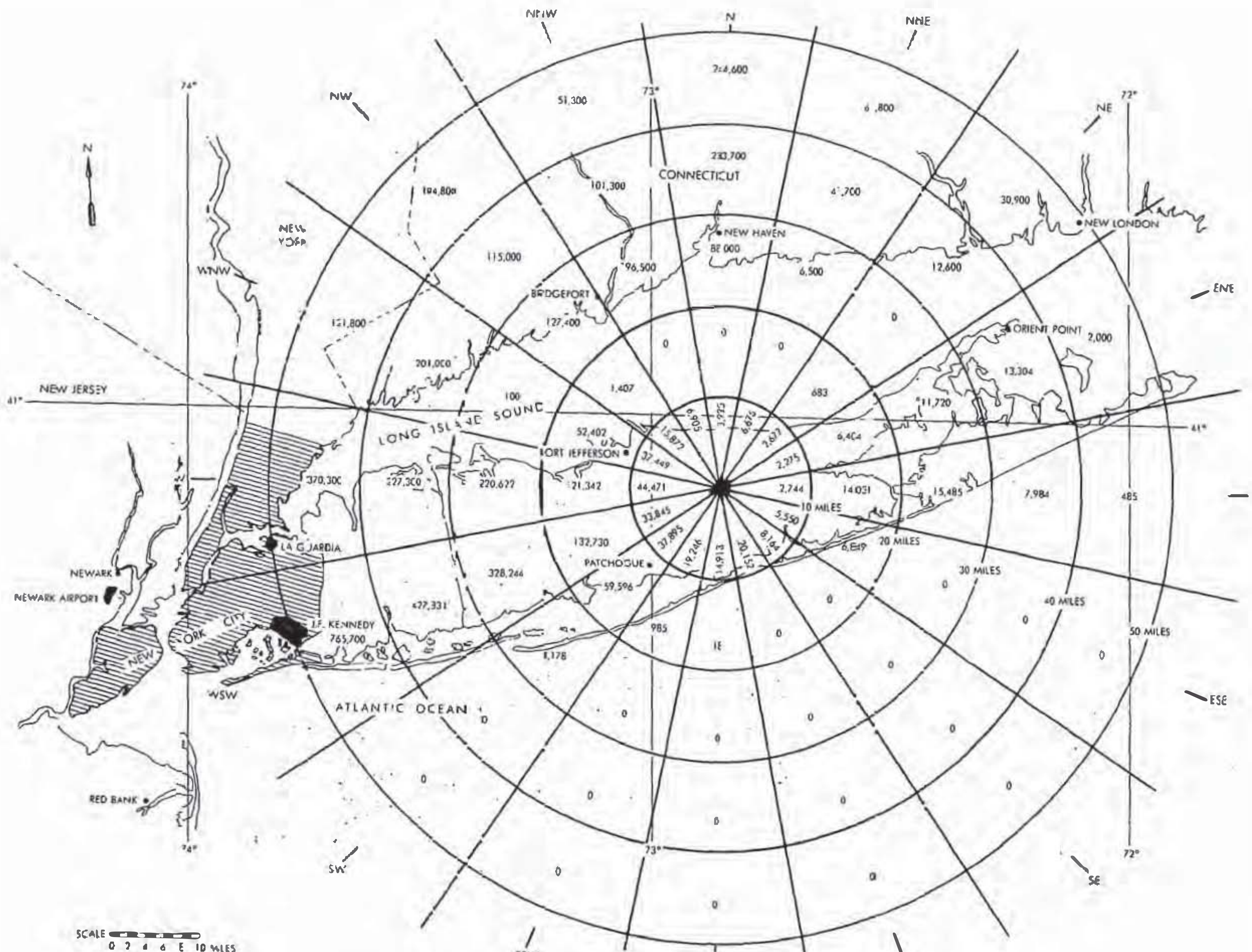


FIGURE 3.1-A RESIDENT POPULATION (1977) WITHIN A 50 MILE RADIUS OF BNL

FIGURE 3.2-A SOIL MAP OF BNL SITE

SOIL LEGEND

The first capital letter is the initial one of the soil name. A second capital letter, A, B, C, D, or E, shows the slope. Most symbols without a slope letter are those of nearly level soils but some are for land types that have a considerable range of slope.

SYMBOL	NAME
At	Atsion sand
Bd	Berryland mucky sand
CpA	Carver and Plymouth sands, 0 to 3 percent slopes
CpC	Carver and Plymouth sands, 3 to 15 percent slopes
CpE	Carver and Plymouth sands, 15 to 35 percent slopes
CuB	Cut and fill land, gently sloping
CuC	Cut and fill land, sloping
CuE	Cut and fill land, steep
De	Deerfield sand
HaA	Haven loam, 0 to 2 percent slopes
HaB	Haven loam, 2 to 6 percent slopes
Ma	Made land
Mu	Muck
PlA	Plymouth loamy sand, 0 to 3 percent slopes
PlB	Plymouth loamy sand, 3 to 8 percent slopes
PlC	Plymouth loamy sand, 8 to 15 percent slopes
Ra	Raynham loam
Rc	Recharge basin
RdA	Riverhead sandy loam, 0 to 3 percent slopes
RbB	Riverhead sandy loam, 3 to 8 percent slopes
RdC	Riverhead sandy loam, 8 to 15 percent slopes
RhB	Riverhead and Haven soils, graded, 0 to 8 percent slopes
SdA	Scio silt loam, sandy substratum, 0 to 2 percent slopes
Su	Sudbury sandy loam
Wd	Walpole sandy loam
We	Wareham loamy sand

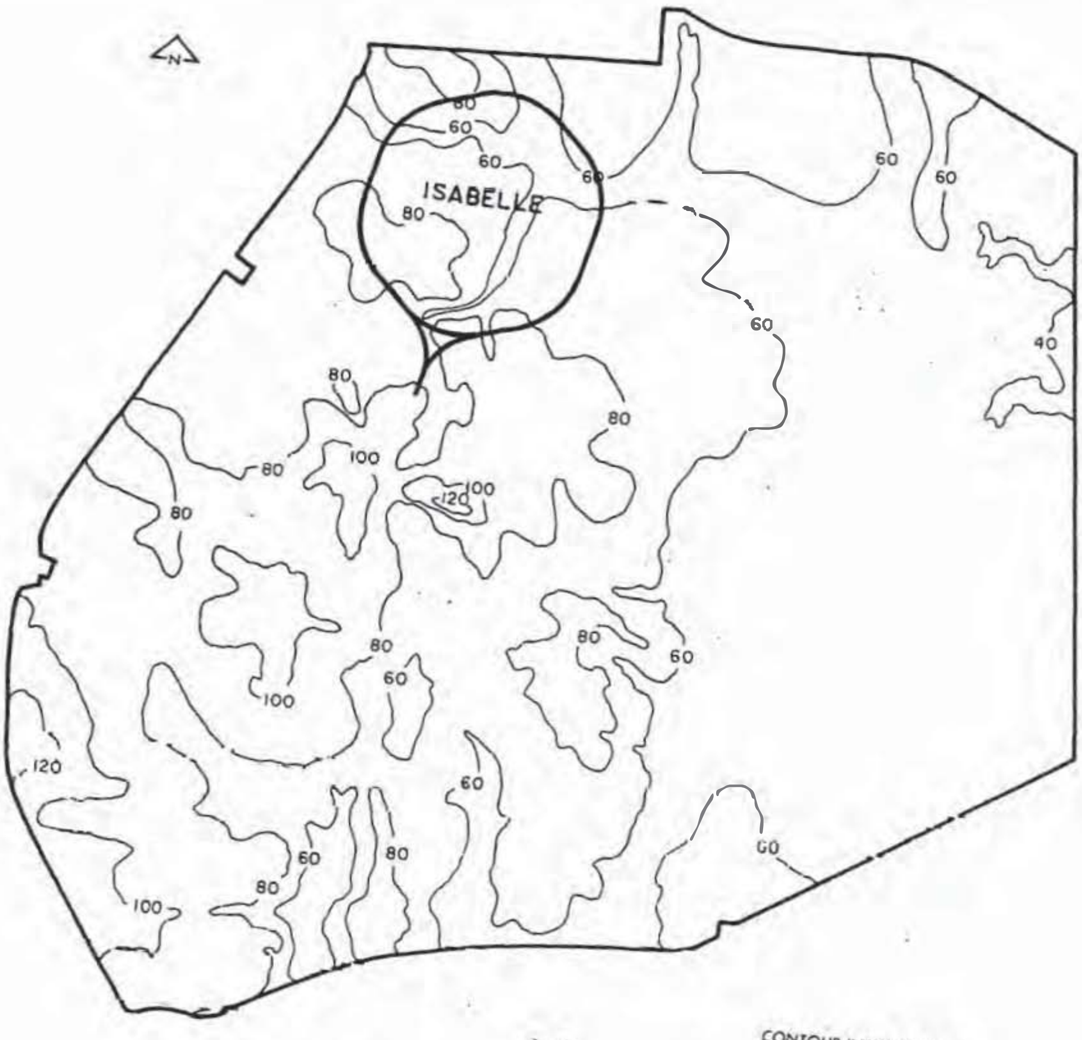


FIGURE 3.2-8 TOPOGRAPHIC MAP OF BNL

Just west of the Laboratory the two moraines are connected by a narrow north-south ridge for which the hamlet of Ridge is named. East of this ridge, and enclosed by it and the two moraines, is the Manorville Basin. The Laboratory grounds are on the Basin's relatively high west margin.

Surface deposits vary in texture from place to place. Soil types on site include Atsion sand, Berryland mucky sand, Carver and Plymouth sands, Deerfield sand, Haven loam, Plymouth loamy sand, Raynham loam, Riverhead sand loam, Scio silt loam, Sandy substrata, Sudbury sand loam, Walpole sandy loam, and Wareham loamy sand. (See Figure 3.2-A.*)

The BNL site has a gently rolling topography (see Figure 3.2-B). The highest ground of the ISABELLE site is about 30.5 m (100 feet) above sea level, and the maximum difference in elevation is about 9.2 m (30 feet).

Seismology

The probability of occurrence in the BNL area of an earthquake sufficiently intense to damage buildings and reactor structures was thoroughly investigated during construction of the graphite reactor. It is the consensus of seismologists that no significant quakes are to be expected in the foreseeable future.

Table 3.2-I shows that no earthquake has yet been recorded in the BNL area with an intensity in excess of modified Mercalli III equivalent to 1 to 8 cm/sec^2 (0.4 in. to 3 in. sec^2 acceleration). However, since Long Island lies in a zone 1, ("minor damage"), seismic probability area, it has been assumed that an earthquake of intensity VII (e.g. damage neligible in buildings of good design and construction) could occur. No active earthquake-producing faults are known in the Long Island area.

TABLE 3.2-I

Earthquakes in the Central Long Island Area*

Year	Date	Epicenter Lat. (N)	Epicenter Long. (W)	Intensity** at Yaphank
1925	Feb. 25	47.6°	70.1°	I-III
1929	Nov. 18	44.5°	55.0°	I-III
1935	Nov. 1	46.8°	79.1°	I-III
1937	July 18	40.7°	73.7°	I-III
1944	Sept. 5	45.0°	74.8°	I-III
1950	March 29	41.0°	73.0°	I-III
1951	Jan. 25	uncertain		not felt

*As reported by U.S. Coast and Geodetic Survey.
**Modified Mercalli intensity scale of 1931.

3.3 Hydrology

Under natural conditions, precipitation is the source of all fresh water on Long Island. The precipitation averages about 122 cm (48 inches) per year, and a major feature of its pattern is the small range of average monthly values, from about 6.35 cm to 12.7 cm (2.5 to 5 inches).

Practically all the precipitation not consumed by evapotranspiration, estimated at 53 cm (21 inches) per year, or discharged into the sea recharges the groundwater reservoir. This estimated recharge averages approximately 58.4 cm (23 inches) per year.

*J. W. Warner, et al., Soil Survey of Suffolk County, New York Soil Conservation Service, U.S.D.A., April 1975.

The groundwater reservoir of Long Island comprises a saturated, unconsolidated mass of gravel, sand, silt, clay, and mixtures of these, which overlies impermeable consolidated bedrock (Figure 3.3-A). Groundwater is found in unconfined water table conditions, and in confined aquifers under artesian conditions.

During the early development of the BNL site, the hydrology of the Upton area was studied extensively.* This area is a north-south strip across Long Island about 20.8 km (13 miles) wide, between longitudes 72 degrees 45 minutes and 73 degrees 00 minutes, and includes all the land and water between Long Island Sound on the north and the Atlantic Ocean on the south. Since then the level and quality of the groundwater have been monitored by means of tests and supply wells.

In the Upton area the main groundwater divide lies about 4.8 to 8 km (3 to 5 miles) south of Long Island Sound and roughly parallel to it. East of the Laboratory tract is a second groundwater divide that defines the southern boundary of the area contributing groundwater to the Peconic. The exact location of the triple-point intersection of these two divides is not known and may be under the Laboratory site. South of these divides, the groundwater moves southward to Great South Bay and to Moriches streams. In general, the groundwater from the area between the two branches of the divide moves out eastward to the Peconic River. The pressure of a higher water table west of the Upton area generally inhibits movement towards the west.

The principal water table aquifer in the Upton area is 30.5 to 61 m (100 to 200 feet) of upper Pleistocene deposits resting on either the Gardiner's clay or the Magothy formation. The thickness of the Magothy formation ranges from 244 to 274.5 m (800 to 900 feet) under the Laboratory, and the position of its upper surface varies from about 30.5 m (100 feet) below sea level at the shore of Long Island Sound to between 61 m and 91.5 m (200 and 300 feet) below sea level at the ocean shoreline south of the Laboratory. Figure 3.3-B shows the contours of the water table on the BNL site.

As noted previously the Laboratory is located almost completely in the Peconic River watershed. Figure 3.3-C shows the drainage map of the BNL site. Of particular interest is the northernmost sector which comprises the Peconic drainage ditch and a small subsurface stream that forms Half Moon Pond located just north of the Laboratory boundary. At the confluence of these two is a small ponded area which is in direct communication with the underlying aquifier. The drainage ditch was for the most part man-made and was enlarged by the U.S. Army for mosquito and flood control prior to the establishment of BNL. The drainage from Half Moon Pond is evidenced by a band of moist soil connecting to the drainage ditch. Although this stream has been covered over in the construction of a firebreak, the sandy nature of the soil has permitted the unrestricted movement of water. Observations made by the U.S. Geological Survey as well as by the BNL staff indicate that the flow in these water systems is intermittent and depends heavily on prevailing precipitation. The first occurrence of perennial surface flow is approximately one mile eastward of the small ponded area mentioned above.

3.4 Meteorology**

The BNL site exposure is a cross between maritime and continental. On a broad scale, the weather is greatly influenced by the Atlantic Ocean, Long Island Sound, and the various associated bays. Their presence moderates both summer and winter temperatures, strongly influences wind and humidity patterns, and greatly reduces the snowfall from that expected at a nearby inland station. On a smaller scale, the site has one feature characteristic of continental exposures, a pronounced tendency for excessive radiative heat loss during the night that results in minimum temperatures markedly lower than those at many nearby locations. From a diffusion standpoint, the site is well ventilated by winds from all directions with a rapid, fairly consistent alternation among various types of atmospheric stability.

3.5 Ecology

The Laboratory is located in a section of the oak-chestnut forest region of the Coastal Plain. Because of the general topography and porous soil, there is little surface runoff or open water. Upland soils tend to be drained excessively, and the depressions generally are marshy. Hence, a mosaic of wet and dry areas on the site is correlated with variations in topography and depth to the water table. In the absence of fire or other disturbance, the vegetation normally follows the moisture gradient closely. In actuality, however, vegetation on site is in various stages of succession, re-

*M. S. Warren, W. Delaguna, N. J. Lusczynski, Hydrology of Brookhaven National Laboratory and vicinity Suffolk County, New York, 1968, U.S. Geological Survey Bulletin 1156-C.

**C. Nagle, General and Diffusion Climatology, Meteorology Group, BNL, July 1974.

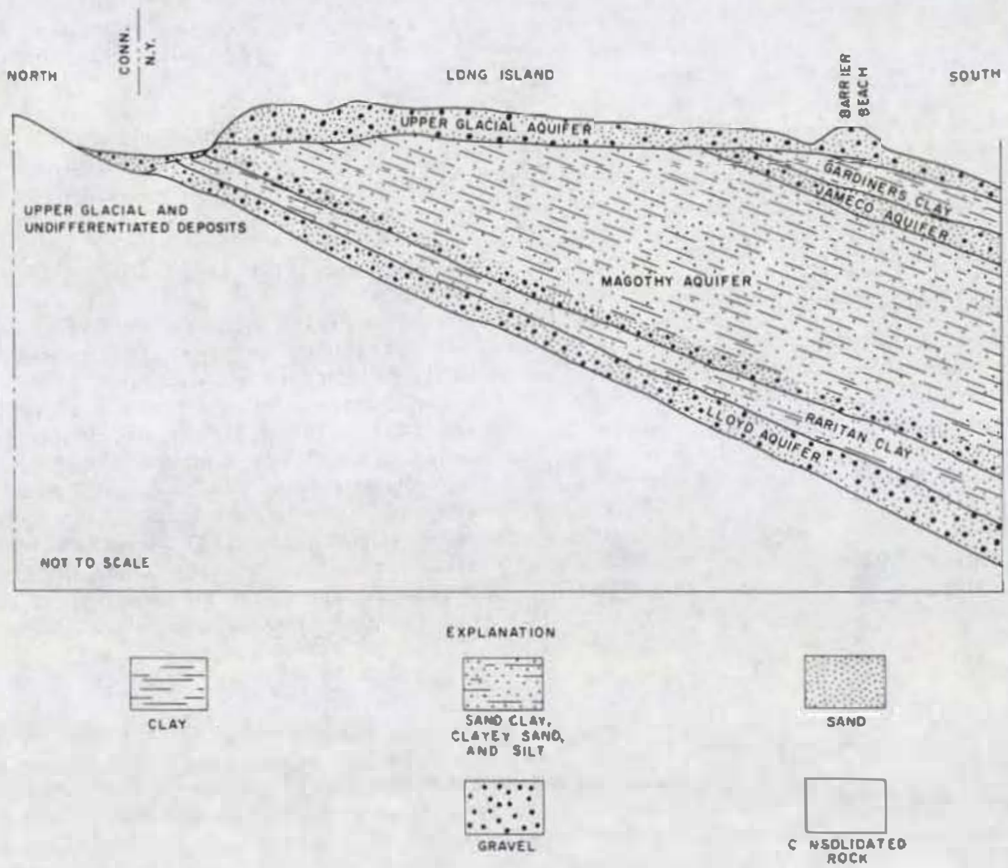


FIGURE 3.3-A STRATIFICATION OF SOILS UNDER BNL

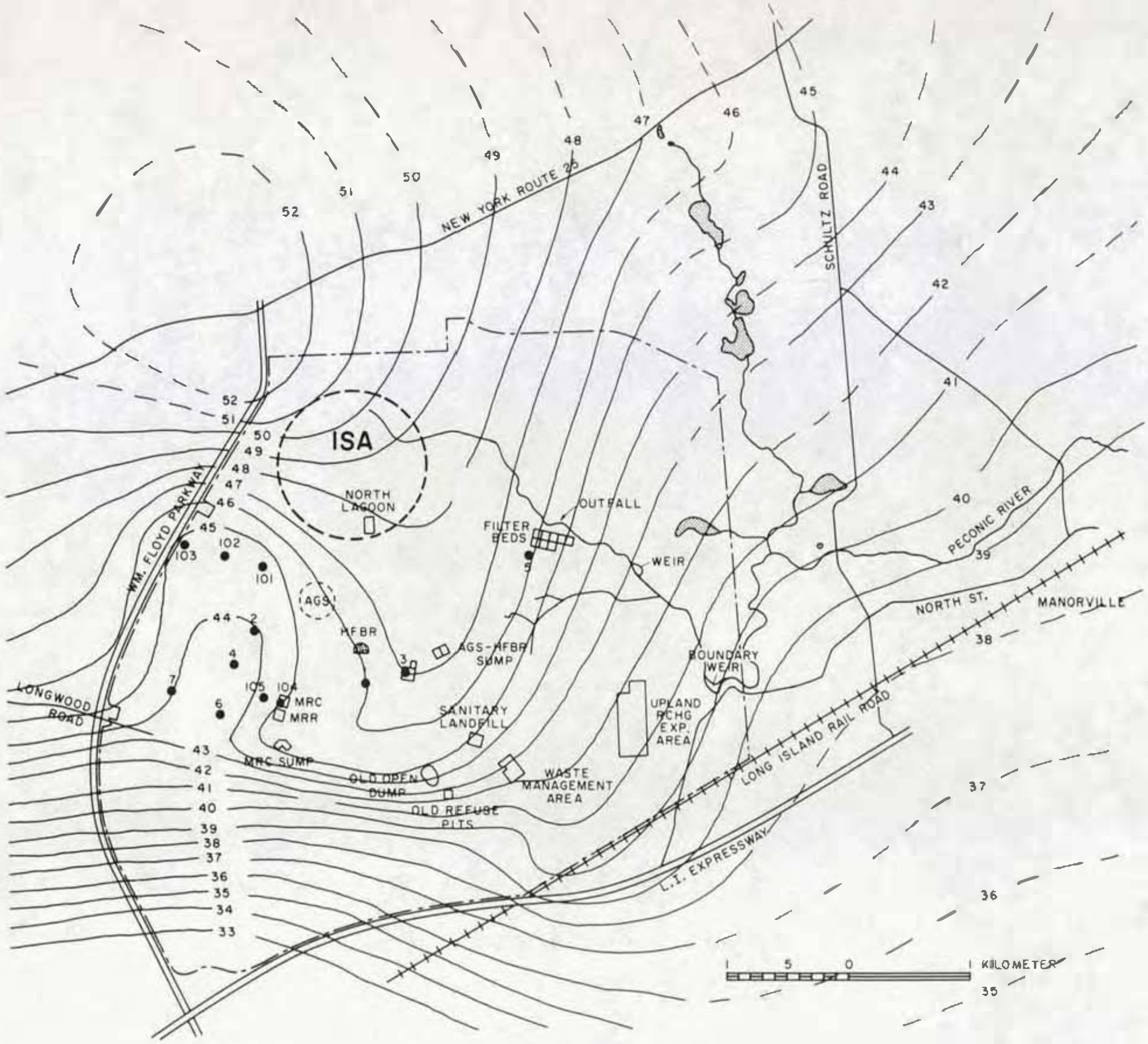


FIGURE 3.3-B BNL SITE WATER LEVEL CONTOURS FOR JUNE 1973

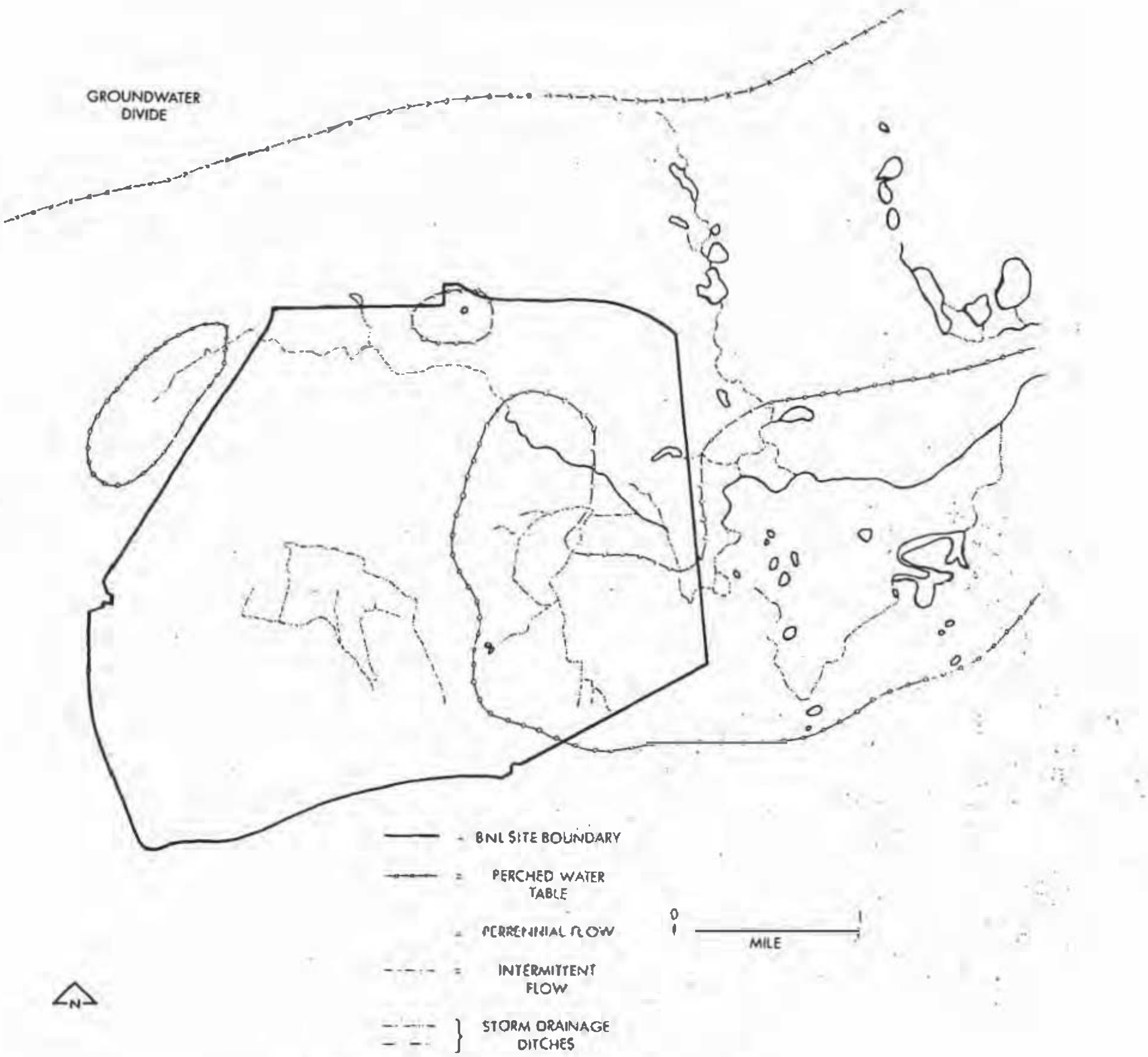


FIGURE 3.3-C DRAINAGE MAP OF BNL AND VICINITY

flecting the history of disturbances of the area, the most important having been land clearing, fire, flooding, and draining (see Figure 3.5-A). The vegetation following land clearing differs from that following fire. After clearing, all species originate from seed; after fire, sprout growth from undisturbed roots occurs. Several areas on site have undergone extensive clearing which has resulted in an extensive growth of pitch pine. These successional processes describe the present condition of that part of the BNL site proposed for the construction of ISABELLE.

The isolation of the BNL site and its variety of wildlife habitats has made it a refuge for a diverse animal population. Essentially, all Long Island mammal species occur on site, which indicates that their habitats have been well preserved. At least 180 species of birds have been recorded on the BNL site. Thirty species of reptiles and amphibians have been observed on site and, except for marine species, these represent approximately all the reptile species presently known to occur on Long Island. Most fish found on site are either small species or small individuals of larger species that work their way up the Peconic River during periods of high water. The variety of invertebrate species seems similar to that in comparable habitats elsewhere on Long Island.

In summary, with respect to both flora and fauna there are no endangered or unique species on the Laboratory site. On the other hand, by virtue of the large amount of undeveloped area on site, the Laboratory has served in the past, and will continue in the future to serve, as both a wildlife refuge and a preserve for vegetation in an area of increasing urbanization. It is suggested that the reader refer to ERDA 1540, Environmental Statement, Brookhaven National Laboratory for a more complete description of site ecology as well as detailed species lists.

3.6 Background Radiological Characteristics

The radiation background in the BNL area includes naturally occurring components from cosmic radiation, airborne natural radioactivity and terrestrial radioactivity. Currently, it also includes small residual components from past world wide atomic weapons testing.

External Radiation Exposure

External X and gamma radiation from cosmic radiation, airborne natural radioactivity (primarily radon, thoron and decay products) are measured by BNL by using thermoluminescent dosimeters (TLD's) at three perimeter locations. In 1976, the average measured value was 70.5 $\pm$ 9.4 millirems per year (mrem/yr).* This includes the ionizing component of cosmic radiation, which is calculated to be 35.3 mrem/yr at sea level, but does not include a neutron component (to which the TLDs are insensitive) of 5.6 mrem/yr.*

The weapons related component (which is included in the BNL measurements) is currently too small to allow for direct evaluation, but is estimated to be in the order of 1 mrem/yr.

Activity in Air

Ambient concentrations of airborne tritium vapor and long-lived airborne radioparticulates are evaluated through the laboratory's routine air sampling program. The naturally occurring radiogases (principally radon and thoron) and their particulate daughters, which in fact make up the largest concentrations of naturally produced airborne radioactivity, are not evaluated directly at BNL.

Reported concentrations of radon, as measured outdoors in the rural New York area in 1975, had a range of 100-200 pCi/m^3, with a mean of 110 pCi/m^3.** The naturally occurring concentration of tritium vapor for 1976 was too small for direct evaluation, but was estimated from off-site precipitation measurements to have been about 1.1 pCi/m^3.

The Radiation Protection Guide*** for radon is 10,000 pCi/m^3 and that for tritium vapor is 200,000 pCi/m^3.

*Naidu, J. R., 1976 Environmental Monitoring Report, BNL Report 22627.

**Oakley, D. T., Natural Radiation Exposure in The United States, USEPA, Report ORP/SID. 72-1.

George, A. C., "Indoor and outdoor measurement of natural radon and radon daughter decay products in New York City air," p. 741 in The Natural Radiation Environment II, Adams, J. A. S., Lowder, W.M. and Gessell, T., EDS., (1975).

***Standards for Radiation Protection, Chapter 0524, ERDA Manual.

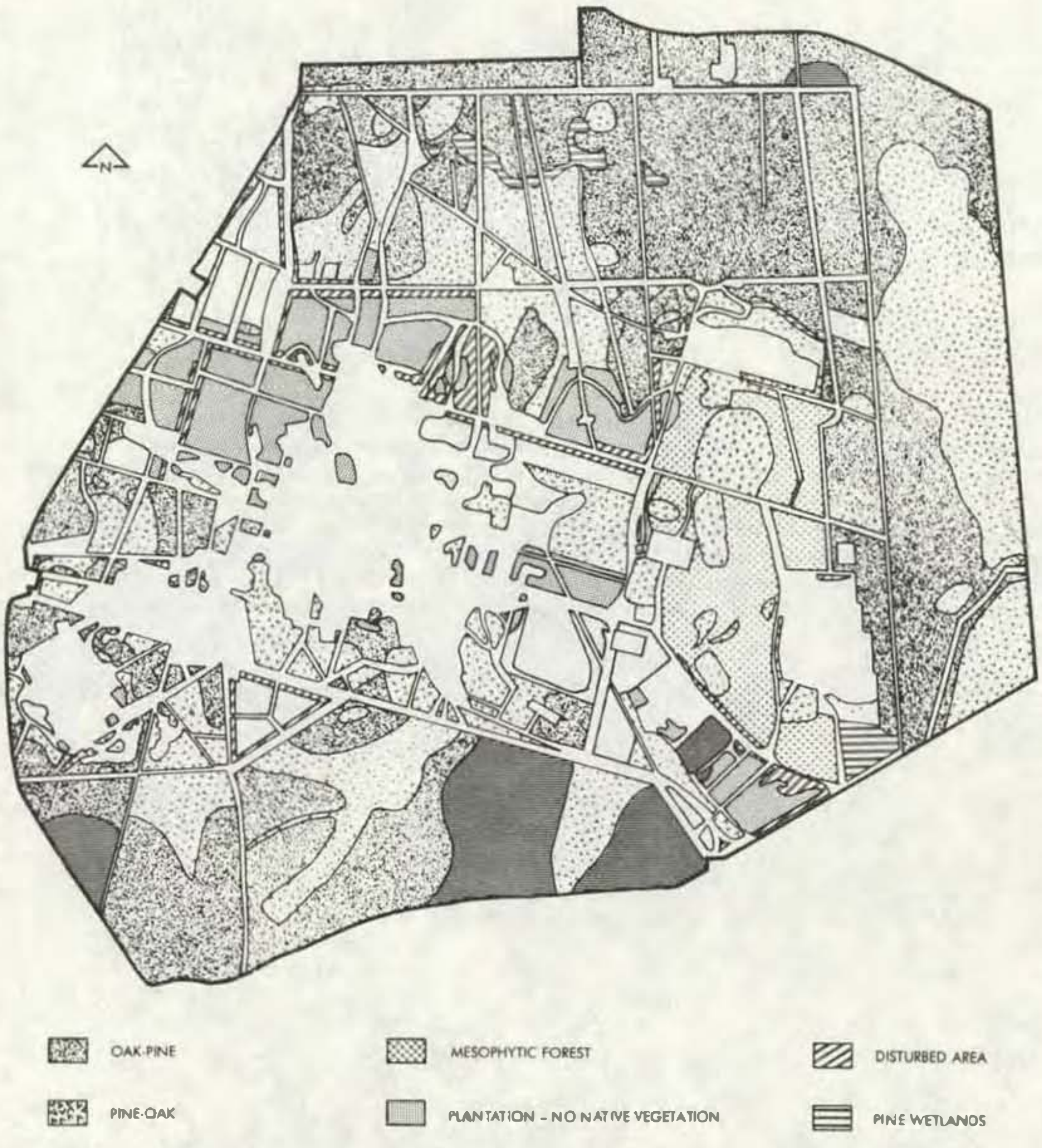


FIGURE 3.5-A VEGETATION MAP OF BNL SITE

The average concentration of gross beta activity (exclusive of tritium) in particulates for 1976 was 0.106 ± 0.011 pCi/m^3. The results of gamma spectral analysis are compared below with ERDA Radiation Protection Guides:

Nuclide	1976 Yearly Average (p/Ci/m^3)	Radiation Protection Guides (for Insoluble Forms)(pCi/m^3)
^{7}Be	0.120 ± 0.020	40,000
^{65}Zn	<0.0002	2,000
^{95}Zr-Nb	0.008 ± 0.002	1,000
^{106}Ru	0.004 ± 0.001	200
^{131}I	0.0007	100
^{137}CS	<0.0003	500
^{144}Ce	0.004 ± 0.001	200

Activity in Water

The concentration of gross beta radioactivity (exclusive of tritium) in composite samples of precipitation at BNL averaged 95 pCi/liter for 1976 and the total deposition was 95 nCi/m^2. In response to a comment made by the U.S. Environmental Protection Agency (see Appendix A) it should be pointed out that these values reflect the presence in October and November of unusually large amounts of short-lived radioactivity from a Chinese atmospheric nuclear weapons test which took place on September 26, 1976. If these months are excluded, the average gross beta concentration was 9 pCi/liter. Tritium concentrations in rainfall collected off-site averaged 186 ± 47 pCi/liter. Rainfall samples were analyzed for 12 specific isotopes, of which five were at levels below detection limits. The concentrations and annual surface depositions for the detectable nuclides were as follows:

Nuclide	Concentration (pCi/l)	Surfsce Deposition (nCi/m^2)
^{7}Be	26 ± 7	26 ± 7
^{22}Na	0.2 ± 0.2	0.2 ± 0.2
^{90}Sr	0.4 ± 0.1	0.4 ± 0.01
^{131}I	4.6 ± 0.5	4.6 ± 0.5
^{140}Ba-La	1.6 ± 0.4	1.6 ± 0.4
^{137}Cs	<0.3 ± 0.2	<0.3 ± 0.2
^{141}Ce	2.4 ± 0.6	2.4 ± 0.6

The nuclides ^{7}Be and ^{22}Na are produced by cosmic rays, and the others are weapons test residuals in the atmosphere.

Analysis of surface water samples from three nearby streams not in the BNL drainage system gave average gross beta concentrations of 3.7 ± 0.9, 2.8 ± 0.7 and 2.0 ± 5 pCi/liter. Tritium was not detectable in these samples, at a detection limit of 0.6 nCi/liter.

The background radioactivity in groundwater was indicated by routine analysis of samples from BNL supply wells upstream from the Laboratory technical areas. Gross beta activity for 1976 averaged 1.8 ± 0.9 pCi/liter, and tritium was not detectable (<0.6 nCi/liter).

3.7 Archaeology

In preparation of ERDA 1540, Environmental Statement, Brookhaven National Laboratory, BNL requested a search for records of archaeological sites and a survey of the areas of potential archaeological interests within the confines of the BNL site. The survey was done by a professional archaeologist associated with the Long Island Chapter of the New York State Archaeological Association. The investigations indicated that there was no record or any other evidence of cultural material relevant to historic and/or prehistoric occupation for the BNL site.

The service of the same archaeologist was again contracted for by BNL to perform a detailed investigation of the area indicated for the construction and operation of ISABELLE. Numerous training trenches remaining from the period of U.S. Army jurisdiction during World War I have been uncovered in the area. The draft archaelogy report is under review. Meetings and discussions have been held with members of the New York State Department of Parks and Recreation, Division of Historic Preservation, regarding the archaeological situation. DOE will take all necessary steps to resolve the relevant issues in this matter in compliance with 36-CFR 800, Procedures for the Protection of Historic and Cultural Properties and 36-CFR 63 Determinations of Eligibility for Inclusion in the National Register of Historic Places.

3.8 Socioeconomic Baseline

BNL is located in the town of Brookhaven which has the largest population (339,183) of the ten Suffolk towns. Most BNL employees live within the Town of Brookhaven and the impact of the Laboratory upon the local area is great. Since the Laboratory is a basic industry, that is, it derives its income from outside the local region, its health is vital to the general industrial base in the area. The Laboratory itself employs about 3000 persons. In addition to the direct impact of BNL expenditures, there is the indirect impact derived from jobs in supporting industry and the commercial sector, and local income is multiplied as these expenditures circulate in the local economy through a whole chain of interactions between individuals, businesses and governments. Laboratory expenditures into the local economy support an estimated additional labor force of about 2400 persons in related industries and the commercial sector. Moreover, almost 70% of all salaries flow into the Brookhaven town economy. Within the town, the BNL median income tends to exceed that of the general populace. As an industry, the Laboratory provides a larger dollar flow into the economy through employees than does the average light industry in the region. There are also large dollar flows into some relatively poor areas. For example, the Patchogue and Riverhead communities have the lowest census median incomes reported in Suffolk County; for these areas, the total salary flow and the total impact is substantial.

In addition BNL serves the local community in a number of social aspects. The Laboratory sponsors minority training programs designed to upgrade technical and business skills of minority persons and move them into permanent positions. A program to assist local minority construction contractors to establish eligibility for federally funded projects has recently achieved success.

Community-oriented activities are numerous. Approximately two cultural events each month are held on-site, including art shows, concerts, lectures and theatre; about ten thousand persons attend these affairs each year. The Laboratory fire department provides demonstrations in new firefighting techniques and equipment for local volunteer departments. Suffolk County police officers are invited to the site for discussions of security and other mutual interests.

The interaction with educational institutions is particularly strong. In addition to formal courses offered by Laboratory staff in outside schools and colleges and joint research projects between BNL staff and scientists at neighboring universities, employees are active as individuals in the design and improvement of science curricula in the local elementary and secondary schools.

Long-term employment trends within the New York Metropolitan Region indicate a continuing job shift from the central city to the surrounding suburbs. The Nassau-Suffolk civilian workforce increased by 52.8% during the ten years between 1960 and 1970. A mark of Long Island's maturing economy is the trend toward services (the term services, as used here, includes service industries, finance, real estate and insurance, and government) and away from manufacturing as the major source of employment.

Unemployment in the Long Island region remains high at 7.1%. However, Suffolk alone had an unemployment rate of 8% in October, 1976. Although the unemployment rates for various trades are not known exactly, the construction field has been particularly hard hit with a decrease of 7.7% in the number of jobs from 1974 to 1975. Unemployment among professional, technical and scientific personnel also remains high.

SECTION 4

POTENTIAL ENVIRONMENTAL IMPACTS

An assessment was made of the probable environmental impacts of the proposed action of construction and operation of ISABELLE at Brookhaven National Laboratory. The methodology used in preparing this assessment involved two steps, identification and evaluation. With respect to the identification of potential impacts the action as described in Section 2 of this statement was related to the environmental base line as characterized in Section 3. All aspects of the proposed action were analyzed with respect to their ability to alter the environment. The criteria used in this process step included; the ERDA-NEPA implementation guide (September 1977), federal and state check lists, previously prepared environmental impact statements on similar actions, text dealing with environmental analysis, and technical publications pertinent to this area particulary those involving actions similar to the construction and operation of ISABELLE.

Once the potential impacts were identified their relative significance was evaluated. This evaluation process involved the expanded use of the criteria referenced above and placed particularly strong emphasis on the use of applicable codes, standards and regulatory guidelines where available. In those cases where the latter were not available, for example, the pre-emption of resources, strong dependence was placed upon the use of professional judgement. Furthermore, experience as gained at BNL with respect to the operation of the AGS and the preparation of ERDA-1540 (Site Environmental Impact Statement) greatly facilitated this evaluation process.

During the entire process the end goal has been a concise and issues oriented assessment.

4.1 Effects from Construction

The construction phase of the ISABELLE project is expected to begin in 1979 and be completed in 1986. An average number of 320 workers per year will be involved during this period. Those construction activities that were considered significant for analysis have been evaluated below.

4.1.1 Land Use

As noted previously, construction of the ISABELLE facility will be completely on the BNL site. Approximately 250 ha (625 acres) of the 2106 ha (5,265 acre) BNL site will be committed to the ISABELLE facility. Furthermore, the central area of the ring comprising 86 ha (214 acres) will essentially remain undisturbed. The area impermeably covered by new construction including buildings, paved roads and areas, and hard stands will comprise approximately 25 ha (62 acres). (This equates to approximately 10% of the total ISABELLE site.) The remaining ISABELLE site will either stay in or be restored to its original condition, such that the natural percolation of precipitation will be only minimally affected. Moreover, since muon shielding will be achieved through the use of sand, the construction of these areas should pose only minimal restrictions to natural percolation.

An estimated one million cubic meters (1.3×10^6 cubic yards) of earth will be excavated, stockpiled, backfilled or mounded for earth shielding during the site development period for ISABELLE (approximately two years). As presently conceived, excavation amounts will equal fill requirements so as to eliminate the need for any off site borrowing or hauling which could have an adverse environmental impact on the areas involved. Should the final design or the actual field construction produce a small requirement for borrowing or for a spoil area, existing firebreaks, which are free of vegetation, could be used without adverse effects to the extent practicable. Top soils will be salvaged, segregated and stored for future use.

4.1.2 Effects on Water Use

The siting of the ISABELLE ring and associated experimental areas has been chosen to minimize the environmental impact on the prevailing surface and groundwaters of the area. As described in Section 3.3, the only surface waters in the northwest sector of the Laboratory site, where ISABELLE is proposed to be located, are the Peconic drainage ditch and a small subsurface stream which drains Half Moon pond, located just north of the site boundary. At the confluence of these two is a small ponded area which is in direct communication with the prevailing aquifer. Records indicate that the drainage ditch was enlarged by the Army for mosquito and flood control prior to the establishment of BNL. The drainage from Half Moon pond has previously been traversed by a firebreak with what appears to be only minimal impact on its flow potential. Field surveys have indicated, as noted on Figure 3.3-c, that the low in these water systems is not perennial but rather is intermittent, depending on prevailing preipitation. These streams are sufficiently small so that culverts may be installed where the ISABELLE ring traverses them in a manner to avoid any perturbations on natural flow and resulting environmental impacts. The ponded area remains totally unaffected since its site is totally within the undisturbed bounds of the proposed ring location. Culvert traverses will be constructed to be capable of accommodating exceptional events such as "one hundred year" storms. Furthermore, the entire ISABELLE facility will lie sufficiently west of the major perennial flowing headwaters of the Peconic River to permit construction and operation without disturbing the hydrological and ecological balance of these streams.

To assure dry construction in those areas where excavations for foundations will be made into the groundwater, a procedure of dewatering may be employed. This is a standard engineering technique whereby a localized area of the groundwater is temporarily lowered by pumping on a series of well points located in the surrounding area. Upon completion of the construction efforts, including waterproofing of the installed structure, the well points are withdrawn and the groundwater is permitted to rise to its normal level. In the case of ISABELLE, this technique may be used in two areas where large experimental halls will be located. Calculations indicate that approximately 1500 l/min (400 gpm) of pumpage will be required at each location and that this practice will continue for a period of approximately three months. All pumpage will be returned to the local aquifer at a point away from the actual construction location and in a direction coincident with the normal groundwater flow across the project site. All silt-containing effluent will be handled through temporary sediment basins prior to discharging to the groundwater. In view of the limited size of the foundations involved, it does not appear that their presence will significantly affect groundwater flow.

Owing to the sandy nature of the soils in the project site, a rather steep slope (in excess of one to one) would be required in order to produce any adverse sedimentation as a result of erosion and runoff. In those cases where steeper slopes are required, such as stockpiles, shielding berms and/or construction trenches temporary sediment basins will be installed to avoid excessive erosion and siltation as a result of torrential downpours. In addition, appropriate vegetative materials such as quick growing grasses will be used to protect stock piles, shielding berms and denuded areas from erosion. Thus, in no case will silt-containing water be allowed to enter surface streams.

Chemicals used during the construction of ISABELLE will most probably include soaps, paints, cleaning fluids and concrete mixtures. Contractor operations will be administratively controlled to ensure that the disposal of waste quantities of these materials will be carried out in an environmentally safe manner. Sanitary waste will be handled by portable chemical toilets. All other trash generated by construction activities will be disposed of in the on site landfill.

4.1.3 Effects on Air Quality

During the construction stages of ISABELLE, the principal adverse effects on air quality will result from the generation of dust and exhaust fumes. The dust will be created both as a result of vehicular traffic on unpaved surfaces and from earthmoving operations. To the maximum extent practicable, this dust generation will be controlled by established engineering practices, chiefly involving water sprinkling of all disturbed earth surfaces. There will also be spray watering of earth stockpiles in hot and windy weather to avoid the creation of dust. Exhaust fumes from internal combustion equipment used at the construction site would be expected to be rapidly dispersed and, therefore, not have any significant environmental effects. In the case of both the dust and exhaust fumes, any effects that do take place would be expected to be temporary and local in nature.

4.1.4 Noise Effects

The major source of noise during the construction of ISABELLE will be the diesel engines of various earthmoving machines. This noise can be largely controlled by mufflers, the use of which will be specified in construction contracts. Specifications will limit noise produced by any one piece of construction equipment to 83 dB at a distance of 7.6m (25 feet). Since each machine will operate at full load for only short periods of time, this noise level will not be continuous. Owing to the distance and buffering effect of natural vegetation, separating the construction area from both existing on site Laboratory facilities as well as off site areas, it is expected that no significant noise effects will occur in either. Average noise levels at the site boundary are not expected to be significantly in excess of 40 dB which is similar to levels already found in residential areas.

Furthermore, site investigations have not identified any rock formations in the area, and therefore blasting is not envisioned to be required during the construction of ISABELLE.

4.1.5 Effects on Ecology

Impacts from clearing and excavation for ISABELLE should be minimal, as the entire construction site shows evidence of either burnover or clearing within the last several decades. Hence, none of the trees or vegetation is in the category of old virgin timberlands or of such striking esthetic value as to prohibit removal. In fact, as noted in Section 3.5 of this Statement, most of the site is vegetated in scrub oak or pitch pine, both of which species are ubiquitous on Long Island. The loss of vegetational biomass, resulting from the clearing of approximately 25 ha (62 acres,) will not significantly decrease the amount of food available to local fauna. Moreover, post construction restoration is anticipated to include the planting of a selection of vegetational species similar to those presently on the site, including pines, scarlet oak, white oak, and ground cover comprising grass and legume that are compatible with site conditions. This latter category of vegetation becomes established much more quickly and thereby serves as an interim erosion control.

Since the construction as well as the operation of ISABELLE will not present any permanent barriers to migration, it appears that populations of terrestrial fauna resident therein can migrate to adjacent undisturbed areas of the site. After construction, these same populations will be able to remigrate to restored areas at the construction site. Construction noise should pose no serious impacts on resident populations other than to cause them to nest temporarily at some distance from the construction activity.

As mentioned previously in Section 4.1.2, both siltation and discharge of pollutants to local surface waters will be controlled by temporary sediment basins. Therefore, adverse environmental impacts to aquatic flora and fauna would be expected to be both minimal and temporary in nature.

4.1.6 Traffic

The impact on traffic in the vicinity of the Brookhaven National Laboratory, arising from the transportation of workers and materials to the construction site for ISABELLE, will be minimal. The traffic burden, due to the transportation of workers, is not expected to exceed 10 percent of that arising from present Laboratory operations. The transportation of materials and supplies is expected to be temporary and intermittent in nature and is anticipated not to coincide with peak traffic times. Since the Laboratory is served by a network of major road systems including the Long Island Expressway (Interstate 495), the William Floyd Parkway (C.R. 46) and New York State Route 25, and, in light of the fact that during construction the ISABELLE site will be accessed by a separate gate in addition to three others presently used for the existing Laboratory operations, no traffic congestion is expected to arise.

It should be noted that the Laboratory is on the Riverhead branch of the Long Island Railroad and is served by a spur siding on the site. Where possible, efforts will be made to use this mode of transportation for shipments of materials and large components.

4.1.7 Visual Impact

Visual impacts during construction phases are expected to be only those normally associated with projects of this nature. These impacts for the most part will be experienced only on site and will be intermittent and temporary (approximately two years). These impacts will be primarily generated during cut and fill operations as well as being associated with the temporary maintenance of dirt stockpiles. Off site impacts will be limited to certain areas of William Floyd Parkway and possibly to the community of Ridge in the immediate vicinity of the northwest sector of the Laboratory. Large equipment with boom structures such as cranes and other earthmoving equipment, when in place on top of a shielding berm under construction, will be visible intermittently from these areas.

4.1.8 Economic Effects

Over the period of its construction, the ISABELLE project is expected to contribute a direct income increment of $117 million. This represents local labor and material expenditures which, in turn, constitute income gains for Long Island residents and businesses. The project will be a distinct stimulation to the Long Island labor market and the construction trades in particular which have suffered from considerable continued unemployment. More than 10% of the construction trades in the vicinity of Brookhaven are presently unemployed. Due to the consumption demands of the individuals receiving direct income from this project, an additional $56 million will be generated representing an implicit project income multiplier of 1.48.

Over the period of construction, the project will require a direct dedication of on site effort equalling nearly 2800 man-years. As project-related direct and indirect incomes are realized and spent, there is an induced employment effect which further benefits the Long Island economy. It is conservatively estimated that the indirect employment effects will give rise to an additional demand for labor of 3100 man-years. Thus for every man-year of effort devoted to this project, an additional 1.1 man-years are created as a result of the increased consumption demands. The ISABELLE project will impact many disciplines of labor force including physicists, designers, architects, engineers, technicians, carpenters, electricians, plumbers, mechanics, steam fitters, operating engineers, masons, steelworkers, inspectors, laborers and estimators, many of whom are available and in need of employment within a sixty mile radius of Brookhaven.

The total machine is scheduled for construction such that it will be in operation in 1985. The construction of conventional facilities is scheduled for three years, and will require man power peaks of approximately 370 men on site as well as supporting trades totaling approximately 225 men off site. In addition, approximately 150 man-years of engineering related time will be involved from Long Island and New York City. The above figures are for the conventional facility design and construction. The design, manufacturing, and installation of the technical components will require an additional 950 men, 540 of whom would be off site. Those on site will be working on designs, final assemblies and installation at Brookhaven.

In view of the fact that much of this labor force can be drawn from the local community, many of whom are presently unemployed, additional housing in the area adjacent to the Laboratory is not considered necessary.

4.2 Effects from Operation

This subsection evaluates the significant environmental effects associated with normal and abnormal operation of the ISABELLE facility.

4.2.1 Normal Operation

4.2.1.1 Effects of Energy Use

The major form of energy consumed in the operation of ISABELLE will be electricity. The projected maximum power demand for the ISABELLE ring and associated experimental apparatus is estimated to be 40 MW, divided as follows:

Central Cryogenic System,	15 MW
Main Magnet Power	4
Radio Frequency (rf) Power	2.5
Transport and Injection Power	2.5
Experimental Power	15
Conventional Power	1
TOTAL	40.0 MW

The Laboratory's present peak electrical demand is approximately 42 MW. In the most extreme case, that is of peak coincidence between the Laboratory and ISABELLE, this amount would be only 2.6% of the Long Island Lighting Company (LILCO) present total peak demand. Furthermore, it should be remembered that the utility is required by the Federal Power Commission to have an appreciable reserve capacity in excess of its peak demand. In consideration of these numbers, it is clear that LILCO has the overall capability of meeting both present and foreseeable future Laboratory demands for power without depriving other users in the local region, and, therefore, that direct preemptive impacts associated with the use of electricity at BNL (including ISABELLE) do not appear to be significant.

Present projections indicate that ISABELLE and associated experimental facilities will consume approximately 184×10^6 kWh per year. When considered additively to present operations, the total Laboratory consumption of electricity will be approximately 400×10^6 kWh per year. Therefore, the Laboratory's total electrical consumption will be approximately 3.3% of the total power generated by LILCO for all Nassau and Suffolk customers, or 7% of that generated for industrial uses in the same area.

In terms of the Laboratory's consumption of electrical energy, it must be remembered that ISABELLE along with present BNL facilities, which account for approximately 70% of total power will operate on a 24-hour basis and, therefore, take advantage of the availability of off-peak supply. Furthermore, the Laboratory has had in the past and continues to have an active program directed at conservation of energy, particularly electricity (see ERDA 1540 for more detailed discussion).

Power for the ISABELLE facility will be distributed via 13.8 kV underground cables installed in a concrete-encased ductbanks. At the ISABELLE service building and the experimental areas around the ring, voltage will be transformed to utilization levels by oil-filled transformers of the outdoor type. All local substations will be enclosed by chain link fence and surrounded by a layer of crushed stone. Askarel or other transformer oils containing polychlorinated biphenyl (PCB) will not be used. There will be no extensive clearing of woodland areas for underground distribution of electrical power as utility lines will run generally with the access roadway alignment, and excavation will be in areas already disturbed.

The only other major use of energy in the operation of ISABELLE will be that of fossil fuels. These fossil fuels will be in the form of No. 6 oil consumed at the BNL central steam plant to produce steam for heating and air conditioning. Present estimates indicate that ISABELLE will require approximately a 3% increase in the present production rates of steam for the Laboratory, which equates to 757 l (200,000 gallons) of No. 6 oil per year. This increased demand is well within the reserve capacity of the present BNL steam plant and is expected to have only negligible effects on the steam plant's atmospheric emissions, which are presently within regulatory standards.

Strong efforts will be made to reduce the use of electricity and fossil fuels by utilizing solar energy and waste heat recovery.

4.2.1.2 Effects on Water Use

When the operation of ISABELLE commences in 1984, its estimated water consumption rate will be approximately 2500 kl/d (.66 MGD). This total consumption, comprising requirements for process domestic and fire protection needs, will be approximately 9 percent of the Laboratory's total projected average daily pumping rate for that time. This demand will not cause significant lowering of the underlying water table due to the fact that the bulk of the ISABELLE water consumption, as well as that of the Laboratory, in general, will be recharged to the aquifer.

Routine water consumption at the ISABELLE facility is estimated as follows: Domestic use: approximately 46 kl/d (12,000 gal per day); Process use: (cooling tower makeup) approximately three percent of the total 57 kl/min (15,000 GPM) flow rate through the cooling tower system. Therefore, the total process use will be 2,460 kl/d (648,000 gal per day). This is broken down as 820 kl/d (216,000 gal per day) due to evaporative and windage losses and 1,640 kl/d (432,000 gal per day) for blow down to control solids buildup. Inasmuch as there will be no chemical treatment of cooling tower water other than intermittent shock treatment, and since blow down will be returned at approximately ambient temperature, the recharge of this water stream should represent only minimal adulteration of the underlying aquifers. In those cases when intermittent shock treatment is performed on the cooling tower system for the purposes of controlling algae growth, corrosion and precipitated deposits, the effluents therefrom will be carefully monitored before release. It is anticipated that the chemicals used for this purpose will be similar to those presently in use at the Laboratory in other cooling tower systems which have been selected and are used in accordance with EPA regulations so as to cause minimal environmental impact.

The cooling tower system used is projected to be similar to that presently used for the Laboratory's High Flux Beam Reactor (HFBR), and therefore in light of experiences with the latter facility should not produce any offsite problems in terms of fog and/or ice formation.

All recharge from the ISABELLE facility, as well as drainage and runoff, will be directed to either of two permanent recharge basins located on the circumference of the ISABELLE ring. These basins will also receive approximately 5,680 kl/d (1.5 million gal per day) of cooling water from the AGS, the present recharge point for which will be moved during ISABELLE construction.

The domestic water used in the ISABELLE facility, approximately 46 kl/d (12,000 gal per day), will, for the most part, be discharged to the Laboratory sewage system and ultimately to the Sewage Treatment Plant. Since accelerator operations are relatively clean and no deleterious chemicals are expected to be used, the only anticipated contaminant in this discharge will be sanitary waste. In terms of the sewage treatment plant's reserve capacity, as well as projected increases in its future use, this 46 kl/d (12,000 gal per day) is an extremely small increment.

4.2.1.3 Radiological Impact*

ISABELLE will be designed and operated so as to have a minimal radiological impact on the environment, both with regard to background radiation levels and to local increments occasioned by other BNL activities. It will draw upon some 30 years of world wide experience and over 20 at Brookhaven in the design and operation of high energy particle accelerators.

This experience has demonstrated that these facilities have four possible impacts. In decreasing order of significance, these are:

(a) The production of "prompt" radiation fields, principally secondary interactions of the direct or scattered primary particle beam, during accelerator operation.

*This section has been amended to reflect the comments of the Environmental Protection Agency, the Food and Drug Administration and the National Science Foundation.

(b) The production of radionuclides in air within the accelerator tunnel and/or target areas, and their subsequent release to the environment.

(c) The production of radionuclides in soil and contained water adjacent to the accelerator tunnel and/or target areas, and their subsequent migration into the saturated ground water and eventual migration from the facility site.

(d) The induction of radionuclides in accelerator components, which may eventually be "recycled" and, thus, become a source of environmental radiation dose.

It is anticipated that ISABELLE will utilize only a small fraction (about 1.4×10^{18}/yr or 2.3%) of the total number of protons that are accelerated to 33 GeV within the AGS. After losses during stacking, an even smaller portion (about 6×10^{17}/yr) will actually be accelerated to 400 GeV within ISABELLE itself. It is anticipated that about 90% of these will ultimately be intentionally directed toward an external beam dump and that 10% will be stopped by internal beam scrapers and 0.1% at each beam intersection point. Every effort will be made to maintain good control of beam position, and to maintain unintended losses at arbitrary points around the ring to less than 0.1%.

Thus, ISABELLE should be a much smaller inherent source of radiation and should produce much less environmental radioactivity than the AGS. Characteristically, the latter has contributed <1% of the total population dose equivalent attributable to BNL operations in recent years.*

Prompt Radiation

Operating experience at high energy particle accelerators has demonstrated that outside of thick shielding, neutrons are usually the principal component of radiation dose.** At energies in the hundreds of GeV, and under some circumstances, muons can become a dominant component in limited regions.***

The shielding of above ground portions of ISABELLE will be designed so as to keep radiation exposure as low as reasonably achievable. As a design objective, 1,000 mrem/yr or less has been selected for the highest outside radiation level (probably at the top, somewhat downstream of radiation sources within the ring), for a hypothetical individual who spends 40 hours per week at that location (occupational exposure). As an additional constraint, the shielding will also be designed so as to limit the dose at the site boundary from all sources to not more than 5 mrem/yr (population exposure).**** These design guides are respectively 20% and 1% of the upper exposure limits set forth by DOE, and are consistent with DOE design guidance to maintain radiation exposures as low as practicable.*****

Calculations indicate that there are two significant contributions to radiation dose outside the shield, neutrons and high energy muons. For the neutrons, the 1,000 mrem/yr at the plane of the shield is controlling. Thus, if the limit at the outside of the shield is met, calculations indicate that the yearly neutron dose equivalent at the site boundary will be less than 1.25 mrem/yr.

Compared to neutrons, high-energy muons are extremely penetrating. However, they are emitted in a nearly tangential direction, so that enough shielding must be added only at the outside of the ISABELLE ring to reduce their flux to acceptable levels. Where the beam is sufficiently below ground level, such shielding is inherently provided.

Protons that circulate counterclockwise and which strike an object in the vicinity of the north intersection will generate muons directed toward the William Floyd Parkway, at a distance of about 0.6 km (0.4 mi.) in a westerly direction. The outer thickness of the shield will be designed to limit the

*A. P. Hull and J. R. Ash, "1975 Environmental Monitoring Report, BNL 21320.
J. R. Naidu, "1976 Environmental Monitoring Report, BNL-22627.

**H. W. Patterson and R. H. Thomas, Accelerator Health Physics, Chapter 7, Academic Press, N.Y. (1973).

***S. I. Baker, Environmental Monitoring Report.
Environmental Monitoring at Major U.S. Energy Research and Development Sites, Calendar year 1975, ERDA 76-104 (1976).

****A. J. Stevens and A. M. Thorndike, "Estimating ISABELLE Shielding Requirements," ISA 76-11 (1976)

*****ERDA Manual Chapter 0524, "Standards for Radiation Protection," Part VI "Guidance on Maintaining Exposure to as Low as Practicable."

yearly dose equivalent from muons to $\leq$ 5 mrem/yr at this location (where the neutron component is < 0.5 mrem/yr). At other azimuths, for which the distance to the site boundary is greater and/or there is some natural shielding from ground elevation, the outer thickness of the shield will be variable, but sufficient to limit the site boundary dose equivalent to $\leq$ 5 mrem/yr.

The following information has been added in response to a comment received from the Nuclear Regulatory Commission. The details of the muon shield design are still being determined in accordance with the position selected for proton injection, beam dumps and other components that will be locations for proton interactions. The present design* is given in Figure 4.2.1.3-A which shows the recommended muon shield configuration based on 0.1% loss at any point around the ring. Muon shield thickness varies from 92m (300 ft) to 18m (58 ft).

Air Activity

The quantity of air and aerosol radioactivity produced at a high-energy accelerator depends on the intensity of radiation traversing an air path. For ISABELLE, this intensity will be extremely small, since its successful operation requires a minimal loss of high-energy particles from the beam.

To a first approximation, the concentrations and amounts of air activity should be comparable to those encountered at the Intersecting Storage Ring (ISR) at CERN, for which a "typical" gross gaseous air activity concentration of 4×10^{-6} μCi/cm^3 has been indicated.** At the reported ventilation rate, at ISR, this would correspond to the discharge of 6.67×10^{-4} Ci/sec.

From the application of standard dispersion to this release rate, one would anticipate within 1 km distance a downwind air concentration close to the maximum permissible off-site concentration for the principal radiogases found in accelerator air effluent streams (^{15}O, ^{13}N, ^{11}C), which is about 5×10^{-8} μCi/cm^3. This maximum permissible concentration is based on continuous submersion in an infinite cloud. However, these gases have relatively short half-lives, (^{15}O ∿2 min; ^{13}N ∿10 min; ^{11}C ∿20 min). Also, the assumption of an infinite cloud is very conservative for the small routine release volumes (about two air changes per hour for the tunnel and experimental halls). Thus, the radiation dose attributable to short-lived radiogases is expected to constitute a negligible addition to the design guidance radiation level for scattered radiation of 5 mrem/yr.

In addition to the short-lived radiogases, longer lived particulate nuclides such as ^7Be (53 days), ^{24}Na (15 hours), ^{32}P (14.3 days), ^{33}P (25 days) and radiogases ^{41}A (1.83 hours) and ^3H (12.3 years), have also been reported in the CERN accelerator air effluent streams.

The releases from ISR were found to have a concentration of these nuclides of 8×10^{-14} μCi/cm^3. This may be compared to a concentration of 2×10^{-10} μCi/cm^3 for a mixture of them, which was calculated to produce an inhalation dose of 5 mrem/yr. After atmospheric dilution of releases in such a small concentration as those from ISR, it would be impossible to detect them in the environment.

Earth and Water Activity

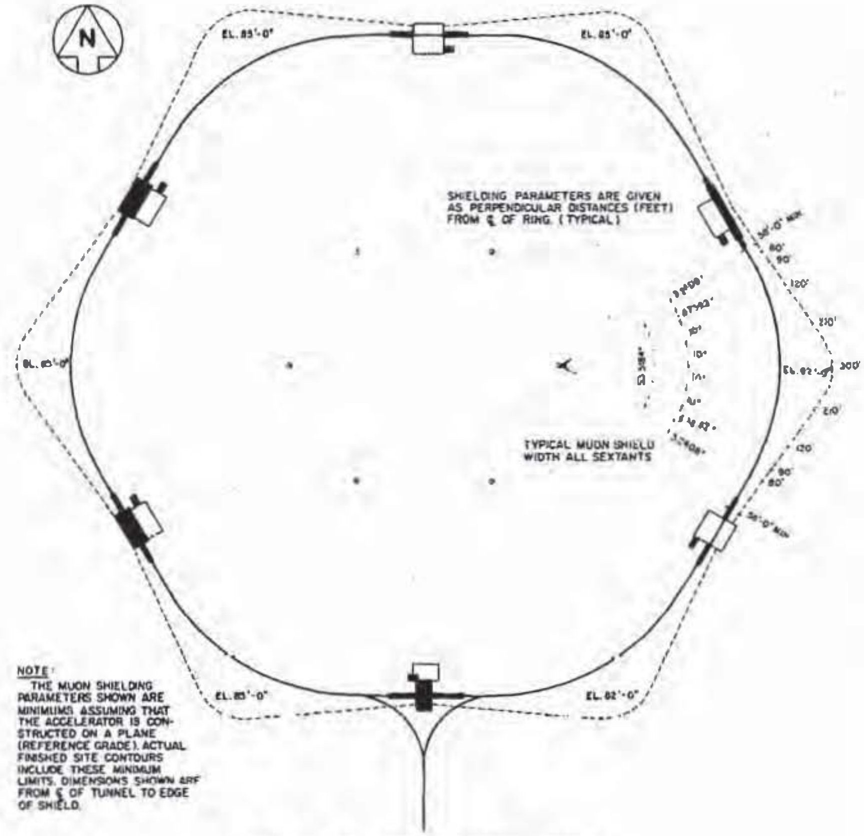
To a first approximation, there should be little, if any, net increase in induced activity in earth and water on and/or under the BNL site due to the operation of ISABELLE. As indicated in the discussion of prompt radiation, ISABELLE will utilize only a small fraction of the protons already accelerated to 33 GeV by the AGS and unintended losses will be minimized. Thus, the total number of high energy particles scattered to unconfined regions of earth and/or water in the immediate vicinity of the ISABELLE tunnel region is not expected to add materially to the overall activity in earth and water created by the operation of the AGS where, as the following consideration shows, the discernible effects are quite local.

It has been estimated that at saturation, the total activity in the shield of the AGS is 3200 Ci.*** Most of this induced activity is in the structure and shield, and therefore, relatively unavailable to move into the environment.

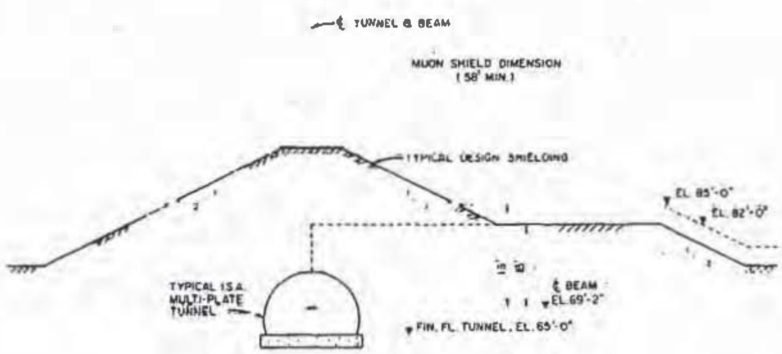
*Technical Note No. 65, "Muon Shielding Requirements for Present Configuration," A. J. Stevens and A. M. Thorndike, May 12, 1978.

**J. Baarli and A. Peetermans, "Air Activity from the CERN Accelerator Installation, DI/HP/176 (1974).

*W. H. Moore, "Source of High-Energy Particles from an Internal Target," GSCD-62, (1966).



PLAN OF ACCELERATOR RING



TYPICAL SECTION THRU I.S.A. TUNNEL & SHIELDING

FIGURE 4.2.1.3-A MUON SHIELD DESIGN

However, some movement is possible along the following potential pathways:

1) The direct production of radionuclides in surrounding groundwater and their migration to the water table.

2) The leaching of radionuclides previously induced in the surrounding earth, by infiltrating rainwater, with their subsequent migration to the water table followed by the subsequent transport in groundwater to a potable water supply well.

Among the possible spallation products from ^{16}O, only ^{7}Be (53d) and ^{3}H (12.3 yrs) have half-lives of more than an hour. By utilizing the empirical expressions of the Stapleton and Thomas* and allowing for an average beam loss of 10%, at saturation, the maximum concentration of ^{7}Be in the groundwater in the immediate vicinity of the AGS shield can be estimated to be about 7.7×10^{-3} μCi/ml and of ^{3}H, about 2.3×10^{-2} μCi/ml. These are about 4 and 8 times their respective maximum permissible off-site concentrations. The estimated total quantities are about 0.2 and 0.6 Ci respectively (or <1% of the total activity). However, accelerator produced ^{7}Be is known to be strongly absorbed and is substantially retained at its production site, so that only ^{3}H is available for migration.

Radioactivity may also be produced directly in the earth matrix itself, as well as in the groundwater contained in its free space. A detailed consideration by Thomas and Rindi** leads to the conclusion that of the many radionuclides which may be so produced, only ^{22}Na (2.2 yrs) and ^{3}H (12.3 yrs) appear to be leachable in sufficient percentage to constitute a potentially significant source of groundwater contamination. In an experiment by Balukova et al***, for a soil water matrix which was 85% in the solid phase and 15% water (when irradiated in a flux of 4.5×10^{7} particles/cm^{2}-sec of E>20 MeV), equal specific activities of tritium were found in each. Thus, they concluded six times more tritium was formed in the solid phase. However, in a similar experiment, Borak et al**** reported induced activities of tritium in soil which were one-fifth or less than those in water. The overall activity of ^{22}Na in their experiment was about one-quarter of that of ^{3}H in soil and therefore, about one-twentieth of its concentration in water.

The more conservative conclusion will be assumed for the purpose of this analysis with the additional assumption of Warren et al***** that drained local sand has a 10% by volume water capacity, that the soil tritium activity would be 9x that of water. Thus the possible impact on groundwater in terms of quantity and mobility would consist at saturation of 6.0 Ci of ^{3}H and 1.5 Ci of ^{22}Na.

However, water and other mobile compounds of the radioactivity created in the earth shield of a high-energy accelerator would have a finite residence time in the zone of activation due to displacement by infiltrating precipitation from the surface above it. As indicated (see Section 3.3), of the total annual average precipitation (122 cm) about 58.4 cm recharges to groundwater. Utilizing the model of Stapleton and Thomas with relevant parameters of the AGS and assuming that in the unsaturated soil adjacent to it the water content is 100 percent, a residence time of 0.7 yrs may be calculated. The calculated amount of induced tritium activity during this residence time adjacent to the AGS shield would be only 4% of saturation, and 24% for ^{22}Na.

Thus, an upper estimate of the total mobile tritium activity would be 0.24 Ci, and of ^{22}Na, 0.36 Ci. The studies by Borak et al indicate that only the free water component of the induced tritium is mobile, and that up to 20% of the induced ^{22}Na is leachable. However, Thomas and Rindi question the consistency of this conclusion with regard to ^{3}H and Balukova et al consider that all of it is fully washed out. In order to err in the direction of conservatism, the latter will be assumed herein.

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*G. B. Stapleton and R. H. Thomas, "Estimation of the Induced Radioactivity of the Groundwater System in the Neighborhood of a Proposed 300 GeV High-Energy Accelerator Situated on a Chalk Site," Health Physics, 23:5 pp. 689-699 (1972).

**R. H. Thomas and A. Rindi, "Radiological Environment Impact of High-Energy Accelerators" to be published in Critical Issues in Environmental Control, CRC Press, Cleveland, Ohio 44128.

***V. D. Balukova, V. S. Lukamin, B. S. Sychev and S. I. Ushakov, "Radioactivity of the Water in the Ground Shield of Accelerators," Atomnaya Energyia, 41:2 pp. 148-149 (1976).

****T. B. Borak, M. W. Awschalou, W. Fairman, F. Iwami and J. Sedlet, "The Underground Migration of Radionuclides Produced in Soil Near High-Energy Proton Accelerators," Health Physics, 23:5 pp. 679-687 (1972).

*****M. A. Warren, W. DeLaguna and N. J. Lusczynski, Hydrology of Brookhaven National Laboratory and Vicinity, Suffolk County, New York, Geological Survey, Bulletin 1156-C (1968).

For the present purpose, it will be assumed that the only dilution mechanism is the infiltration of rainfall on the area overlying the zone of activation in the earth shield adjacent tn the AGS. The elevation of the AGS beam path is 75 feet MSL, and the saturated zone of groundwater in that portion of the Laboratory site is at about 50 feet MSL (see Figure 3.3-B). Thus, it would require about 13 years for the water in the zone of activation to be displaced by infiltrating precipitation (at a rate of 58.4 cm/yr) downward vertically to the zone of saturation. Following the model of Thomas and Rindi, it may be calculated that at this time, the concentration of ^{3}H would be 1.6×10^{-3} μCi/ml and of the 20% of leachable ^{22}Na, 1.4×10^{-5} μCi/ml. These are 53% and 35% of their respective MPC's.

At the measured average horizontal rate of groundwater movement of approximately 15* cm/day (0.5 ft/day), another 36.6 years would be required for this activity to then be displaced horizontally to the BNL site boundary, some 2 km east-southeast in the direction of groundwater movement (see Figure 3.3-B). Again, utilizing the model of Thomas and Rindi, and assuming that dilution during this transport time is by infiltrating precipitation on an area equivalent to that of the zone of activation, the calculated concentration of ^{3}H at the site boundary would be $4. \times 10^{-6}$ μCi/ml and of ^{22}Na, 2.0×10^{-11} μCi/ml. These would be 0.1% and 5×10^{-5}% respectively of their MPC's.

It should be observed that these are upper limit estimated, since they assume that 100% of the induced ^{3}H is mobile, and since they involve no dilution other than the infiltration of precipitation above the zone of activation. For 10% free water, the assumed zone of activation would contain 1.2×10^{5} liters of water. Were the groundwater to be actively pumped at significant rates, the drawdown would create a larger cone of depression, into which water from a much greater volume would be drawn.

Thus, it is concluded that the operating of AGS does not produce a significant impact on groundwater. Although the energy level of Isabelle will be about 12x that at the AGS, this will be more than offset in that it utilizes only 2.3% of the high-energy protons produced by the AGS, and that the losses of these at internal beam scrapers are expected to be about 10%, at each beam intersection points about 0.1% and unintended losses <0.1%. It is thus concluded that any incremental increase in radioactivity groundwater attributable to ISABELLE will be less than that from the AGS. It is not likely to be detectable beyond a zone immediately adjacent to it and would be expected to be a small fraction of the MPC's for any nuclide at the site boundary.

At most accelerator sites, including BNL, both surface streams and subsurface groundwater are regularly monitored for the presence of ^{3}H, ^{7}Be, ^{22}Na and other accelerator produced radionuclides. At the Fermi National Accelerator Laboratory (FNAL), concentrations of tritium generally in order of 10^{-6} μCi/ml have been found in several sumps adjacent to experimental areas. A few concentrations of about 10^{-5} μCi/ml and one at a maximum of 1×10^{-4} μCi/ml has been reported at FNAL. ^{7}Be is removed from closed cooling water circuits by resins at this facility. Following regeneration of these resins, they have been released with treatment wastes to a perforated tile field at a depth of six feet underground. Recently, some ^{7}Be has surfaced in the area of this field in quantities too small to produce a measurable direct radiation field or significant source of internal radiation dose. Other than the above, there have been no reports to date of any other accelerator radiation concentrations from the migration of ^{3}H, ^{7}Be or any other accelerator produced nuclides in above or subsurface waters at any major accelerator site in the U.S., including BNL.**

Current monitoring of both surface and subsurface waters in the AGS area will be continued and additional points established in connection with the construction and operation of ISABELLE.

Long-Lived Activity in Activated Components

As indicated above, every effort will be made to minimize beam loss at ISABELLE. Almost 90% of the beam will be intentionally dumped to an external beam stop, comprising, in sequence, beryllium powder and an iron absorber in a concrete shield. After removal, this beam stop could be stored on-site for whatever length of time necessary for the decay of residual activity to levels acceptable for reuse. Alternatively, it could easily be disposed off-site as radioactive solid waste.

*This rate was measured in 1948 by the U.S. Geological Survey and confirmed recently by fluorescein dye tests made in connection with BNL's Upland Recharge Experiment. Although higher rates up to approximately 40 cm/day have been observed for short intervals, it was deemed appropriate to use the average value in view of the long time involved for water to move to the site boundary. This information has been added in response to a comment by the U.S. Department of Interior.

**Environmental Monitoring at Major U.S. Energy Research and Development Administration Contractor Sites, Calendar Year 1975, ERDA-76-1021 (1976).

However, it is anticipated that some other components, located near points where particle losses occur, will become radioactive when hit by secondaries of high-energy particle (principally neutrons). Although the specific activity is low, the total could amount to several curies. The pricipal γ-emitters found in such metal parts found are ^{60}Co, ^{22}Na, ^{54}Mn and ^{57}Co.*

The largest component that will become highly radioactive will be the external beam stop. It is approximately 1 m in diameter and 6 m long in the present design, with most of the mass consisting of iron. Radioactivity will be concentrated in the center and activity at the surface will not be high. It is a completely passive component and does not need to be replaced or removed.

Other typical components that will become radioactive are beam scrapers and internal absorbers, some septum magnets and vacuum pipe near beam crossing points. The vacuum pipe will normally be stainless steel approximately a mm thick with diameter from 10 cm to 30 cm, several m in length. Other components will typically be 10 cm to 20 cm in width and height, and 1 m to 3 m in length. The number of such components to be disposed of as radioactive waste should be small (∿ 1 per year).

The existing BNL procedures for the control of radioactive components will be applied at ISABELLE. These procedures involve the survey of the radioactive components prior to release to nonradioactive area use, on or off-site. As appropriate, activated items are stored to allow radioactive decay or they are consolidated with other solid radioactive waste by BNL Radioactive Waste Management Group for off-site shipment and burial. It is not expected that any changes in existing radioactive waste management procedures will be required to handle components from ISABELLE.

Thus, activated materials resulting from ISABELLE operations are not expected to become a source of significant environmental radiations, or contribute to population dose.

This text has been amended in response to a comment of the National Science Foundation.

Initial Operation

Initial start-up of the machine and machine development work certainly can lead to proton losses that are higher than average and corresponding contributions to the radiation levels. Such diagnostic work can be done at reduced beam intensity. In the design of ISABELLE, emphasis is placed on good monitoring of beam behavior and good beam control to achieve a very clean mode of operation. Low radiation levels are a by-product of such operation.

Conversely, radiation levels will be carefully monitored and the need to maintain satisfactory radiation levels will be a constraint on machine operation. If levels at the site boundary or experimental locations should be found to be higher than is acceptable on a continuous basis, it will be necessary to either: a) improve beam control and reduce background or, b) reduce beam intensity or, c) reduce hours of operation.

Summary

In summary, it is anticipated that the resultant radiation dose from the operation of ISABELLE will not increase the total yearly radiation dose to any person working on-site by more than 1,000 mrem/yr, or to any person resident off-site by more than 5 mrem/yr. This evaluation considers that for the most part, the on-site doses attributable to ISABELLE will be quite local. Those off-site from scattered radiation will be at a maximum at different points on the nearest adjacent site boundary, and thus, not additive with those from the AGS, or other BNL facilities. The airborne gas and liquid effluent related doses are expected to remain at very small levels compared to those corresponding to a dose of 5 mrem/yr, and will also not be expected to be additive to doses at the site boundary from other existing sources of BNL air and liquid effluents.

The largest existing source of radiation exposure at the BNL site boundary is from skyshine from the AGS. For both 1975 and 1976, calculations from on-site measurements indicate that the annual dose at the closest location on the site boundary at a position about 1.0 km (0.6 mi) to the northwest of the AGS, was 5.8 mrem/yr. This radiation falls off with distance due to both the $1/r^2$ law and due to absorption in air. At the closest location to ISABELLE north-northwest of the AGS on the boundary of the BNL site, the calculated radiation level attributable to the AGS for 1976 was 1.2 mrem/yr, and at the site boundary due north of the AGS and ISABELLE, 0.5 mrem/yr.

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*. Hofert and J. Baarli, "Some Particular Aspects of Radioactive Waste in Large Accelerator Installations," DI/HP/125, CERN (1975).

Another source of external radiation on the BNL site boundary is scattered radiation from a ^{137}Cs source which is employed to irradiate an otherwise undisturbed forest located in the northeast part of the BNL site, 1,010 m. (3300 ft) from the north boundary (see Figure 2.11.B). In 1976, the radiation level at a measuring location on the boundary, due north of the source, was 4.2 mrem/yr. However, the radiation from this source falls off rapidly with distance. At the site boundary due north of ISABELLE, the calculated radiation level from the forest source for 1976 was about 0.0003 mrem/yr, and to the west of ISABELLE 0.001 mrem/yr.

By comparison to these sources of external radiation, airborne effluents constitute a neglible source of additional radiation at the BNL site boundary. They are due almost entirely to the release of tritium vapor from the 100 m. (328 ft) stack of the High Flux Beam Reactor. Recently, an artifact was found in the 1976 measurements of this nuclide at the site boundary, which led to an erroneous overestimate of the resultant dose.* For 1975, the largest dose from airborne tritium vapor at the site boundary was less than 0.1 mrem/yr.

Both surface and subsurface water from the AGS ISABELLE area of the BNL site would be expected to drain toward the southeast boundary. As indicated previously, there is only a very local impact from the AGS on these waters, and no apparent effect at the site boundary nor is one attributable to ISABELLE anticipated.

4.2.1.4 Noise Effects

The operation of the ISABELLE facility will not significantly increase the presently existing ambient noise levels on the Laboratory site. These levels, measured around the developed area of the site, generally do not exceed 40 dB, which is similar to levels found in residential areas. This noise is typically produced by on site traffic and the operation of heat dissipation equipment (cooling towers). Noises generated by the operation of ISABELLE will be greatest at the service center where large helium compressors and associated equipment will operate. This noise will be controlled locally through the use of sunken pits, earth shielding, mufflers and acoustically-treated barriers. Accelerator and experimental area operations will generate noises similar in intensity to those associated with the present AGS.

4.2.1.5 Effects on Ecology

As noted previously in this Statement, the total land dedicated to the construction and operation of ISABELLE is only a small fraction of the remaining portion of the site which is undeveloped. This undeveloped area represents a refuge area for those species of fauna which cannot exist on the developed areas of site. Those populations forced to temporarily migrate to adjacent areas during the construction phases will be capable of ultimate rehabitation in the restored areas of the ISABELLE site as well as in those areas in the central portion of the ring which will remain undisturbed. Noises associated with ISABELLE operations should have no adverse impacts on the indigenous species as evidenced by observations made over the years in other developed areas of the Laboratory site. As previously mentioned, because of the location of the ISABELLE ring on grade, the facility should not present any significant barrier to the migration of terrestrial species across the northwest sector of the site.

Plantings of select local species will be placed in the disturbed areas in an effort to restore the site, and minimize the perturbation of the existing ecological balance of the area. The planting and revegetation program plan will actually increase the number of pines, scarlet oak and white oak now existing on the site with the exception of the area preempted by the physical plant.

4.2.1.6 Traffic

The operation of ISABELLE will involve the addition of approximately 200 new permanent employees which represents less than a 7 percent increase in the present Laboratory population. Since site access and egress is distributed among three gates and is controlled by Laboratory Security through a variety of signal systems, congestion of surrounding highways should be minimized. Moreover, the site is served by major arteries such as the Long Island Expressway, the William Floyd Parkway and New York State Route 25, which presently operate well within their maximum carrying capacity.

4.2.1.7 Visual Impact

The presence of ISABELLE on the Brookhaven site will not appreciably change its existing appearance. Portions of the shielding berm will be noticeable from some locations on William Floyd Parkway near the northwest boundary of the site where they will protrude slightly above tree top level. This

*J. R. Naidu, 1976 Environmental Monitoring Report - BNL-22627 condition will ultimately be ameliorated as the trees between the highway and the ring, as well as those replanted on the construction site, grow to conceal the top of the berm. The on site appearance of the ISABELLE facility, after restoration, should be aesthetically pleasing and in congruence with the other areas of the presently developed Laboratory site. The ring will be clearly distinguishable from the air which is believed to be desirable.

4.2.1.8 Socio-economic Impacts

The operation of ISABELLE at Brookhaven National Laboratory will create the need for approximately 200 permanent positions on the BNL staff. These positions for the most part will be professional in nature, including physicists, engineers and a supporting staff of technicians. It is estimated that approximately half of the required work force, particularly in the area of technical support, will be recruited from the local area. The remaining positions, particularly where specialized skills are required, will be filled through recruitment in the general northeast area, and to a much lesser extent, particularly in the area of top level professionals, from the whole of the United States as well as from some foreign countries. Since there is at present an abundance of housing available for sale in the local area, reflecting the recessed economic condition of Long Island, the influx of these new people should have only minimal impact. Likewise, the increase in demand for tax-supported services including schools, roads, etc. should be negligibly small. In the cases of those personnel whose employment is either intermittent or transient, such as visiting scientist and students, adequate housing is available in the apartment area on site of the Laboratory.

As can be predicted for the short term (approximately five years), the operation of ISABELLE is expected to increase the Laboratory's annual operating budget by 20 percent or approximately 23 million per year (FY79 Dollars). Approximately 40 percent of this budget will be committed to salaries, the expenditure of which could be subject to a multiplier of up to 1.8, thereby raising the total impact of ISABELLE income to approximately 15 million in the local area. The balance of this operating budget, which comprises materials and services, while important, will be less significant in impact since some procurements, of necessity, will have to be made outside of the region. In addition to the above-mentioned economic benefits are those derived through implementation of Public Law 874 whereby the Federal Government contributes aid to school districts in which children of BNL employees attend school.

The influx of new people associated with ISABELLE will further enhance the Laboratory's presently existing strong impact on the local, social, and cultural well-being of the area. As noted in ERDA 1540, there is a strong interaction between BNL and regional academia as well as industry. The ISABELLE project is specifically dedicated to collaborative efforts between scientists at BNL and those who are staff members of universities in the northeast as well as all of the United States and some foreign countries. In this way, ISABELLE not only contributes to the general knowledge of man but also specifically to his education, particularly in the areas of science.

4.2.2 Abnormal Operation

In any facility, the potential may exist for unusual or abnormal conditions to occur and cause events that could be dangerous or harmful to personnel on or off-site. In this section such events will be reviewed and their effects discussed. The conclusion is that there are no unusual risks to on-site personnel and that the potential risk to members of the general public off-site is insignificant.

<u>Radiation</u>

The radiation levels resulting from routine operations have been reviewed in a previous section (4.2.1.3). A normal operating loss of up to 0.1% of the circulating beam at any arbitrary point in areas other than the planned beam dump and scraper was assumed. Great efforts are made in the design of ISABELLE to limit beam losses to much less than this level; however, the possibility of higher losses or even the entire loss of the beam cannot be ruled out completely.

The radiation levels resulting from the loss of the entire beam can be calculated from a recent report.* We assume that the circulating beam in one ring is 6×10^{14} protons/cm^2/sec and that the loss occurs where the shielding has been designed for a 0.1% beam loss. Table 4.2.2-I lists the exposure per incident to an individual standing on the shielding at the point of maximum dose and to an individual at the nearest site boundary. The loss of the entire beam in a single area could result in damage to the accelerator and the consequent down time could be substantial.

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*Stevens, A. J. and Thorndike, A. (1976) ISA 76-11, "Estimating Isabelle Shielding Requirements."
BNL 50611 (1976) Proceedings of the 1976 Isabelle Workshop
Thorndike, A. (1977) ISA Technical Note No. 30 "Revised Shielding Requirements."

Table 4.2.2-I

Maximum Individual Doses Due to Beam Loss From ISABELLE (Per Incident)

	Maximum On-Sire Dose (At Shielding)		Maximum Off-Site Dose (At Nearest Site Boundary)	
Beam Loss Location	Hadron	Muon	Hadron	Muon
Tunnel	2000 mrem	20 mrem	0.04 mrem	1 mrem
Experimental halls	500* mrem	180 mrem	1 mrem	10 mrem

These exposures are well within permissible levels in both categories. Furthermore, two points should be remembered when reviewing these values: 1) 100% beam loss, assumed at a single point, is considered extremely unlikely. A more realistic "worst case" situation is about 10% of these numbers. 2) The off-site muon expsoure is limited to a narrow beam. For example, at the site boundary, the muon beam would be only a few meters in diameter. Population doses are meaningless to calculate for the muon beam because of its small size.

Fire

Standard fire protection systems will be provided for these facilities in accordance with the requirements of the D.O.E. standards. The new facilities pose no unusual threat and no off-site consequences can be foreseen.

Sabotage

In today's socio-political climate, the possibility for sabotage by dissident individuals or groups cannot be overlooked. However, Brookhaven National Laboratory is not engaged in weapons-related research and development, and continues to maintain an open posture with respect to all its endeavors. For this reason the likelihood of sabotage on this Laboratory site, and particularly at the proposed ISABELLE facility is not considered to be high. In any case, any potential act of sabotage that could be sustained by the ISABELLE facility would appear only to involve the disruption of operations but would not involve any detrimental effects on the offsite environment.

*Preliminary estimate - Final shielding thickness has not been selected.

SECTION 5

UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS

This section discusses the magnitude and importance of those environmental effects identified in other parts of this Statement and judged to be unavoidable and adverse after full consideration of all possible mitigating measures.

5.1 Construction

As noted elsewhere in this Statement, the environmental effects resulting from construction of ISABELLE are, for the most part, expected to be minor and temporary in nature. The preemption of 250 ha (625 acres) for use as the project site as well as the associated land clearing represent an encroachment on the habitat of certain wildlife species as well as the temporary reduction in the biomass productivity of the area. While some wildlife may be destroyed during the construction process, most species will be capable of migrating to adjacent areas of the undeveloped site which will offer similarly suitable habitats. Furthermore, it will be possible for some of these species to remigrate to the ISABELLE area when the construction phase is completed. The loss in biomass productivity will result from the permanent removal of vegetation in those areas where facilities will be constructed as well as the temporary devegetation in surrounding cleared areas. The culverting of certain surface water areas including parts of the Peconic ditch will cause similar reductions in biomass activity because of the reduction in solar insolation.

Section 6 discusses those resources to be used in the construction of the ISA machine and support facilities. These include building materials such as concrete, steel, and asphalt as well as copper, aluminum, stainless steel, titanium, niobium, and polymeric materials to be used for the machine proper. The above-mentioned materials, for the most part, will be salvageable. However, some small percentage of each will be irretrievably consumed. While the use of concrete represents an exception to the above in that its application to this purpose involves irretrievable consumption, it is reasonable to assume that the ISABELLE structures may be recommissioned for other purposes at the end of the useful lifetime of this machine.

While the other effects of construction, including noise generation, dust evolution, aesthetics, hydrological disruption, and traffic are for the most part ameliorated by mitigating measures, they are unavoidable adverse environmental impacts.

5.2 Operations

The major unavoidable adverse environmental effect due to the operation of ISABELLE will be the consumption of electrical energy. The operation of this facility will approximately double the Laboratory's total present demand, increasing it to 400×10^6 kWh per year. While this consumption of electricity represents only 3.3% of the total power presently used in the Long Island Lighting Company grid area, it should be mentioned that the utility is capable of meeting both the peak demand and the sustained load and that strong efforts will be made to use solar energy where possible and to recover waste process heat. In terms of other energy requirements, conventional space heating needs will necessitate the annual consumption of approximately 760 kl (200,000 gal.) of No. 6 fuel oil. This represents a 3% increase over the Laboratory's present use of this resource. As a result of the inherent design of this facility, all effluents, radiological and nonradiological, generated during operation are so small as to have negligible effects.

SECTION 6

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

This section will summarize the extent to which the proposed action would consume, destroy, or transform scarce or nonrenewable resources, thereby curtailing the diversity and range of potential uses of the environment. Inherent in any discussion of this nature is consideration of the ultimate decontamination and decommissioning of this facility. One must project to the time when the facility has reached the end of its useful life and make determinations of the possible extent of reclamation of the resources used. Since the operation of accelerators is adjudged to be relatively clean in nature, the decontamination and decommissioning of these types of facilities present only minimal radiological problems. In the design of the ISABELLE facility considerations have been made for minimizing and controlling potential sources of contamination and/or activation. Specifically, contamination associated with ISABELLE is anticipated to be limited to activation of the machine components with very little effect on local soil and water. These machine components include beam dumps; internal absorbers and scrapers; inflectors; system magnets and some vacuum components.

The following subsections summarize the major resource uses associated with this project.

6.1 Land

The ISABELLE facility will require the intensive development of approximately 25 ha (62 acres) of land in the northwest corner of the Brookhaven Laboratory site. This land commitment will preempt the use of this area for wildlife and forestation. Although there are no specific plans for alternative development of the proposed ring site, the presence of ISABELLE will preserve a large area of open green space well into the future. It is estimated that the useful physics life could extend beyond the year 2000. Except for the small area occupied by the actual structures, the land could be easily and economically restored or put to some other productive use should future circumstances dictate.

6.2 Energy

The operation of ISABELLE will require approximately an increase of 184 x 10^6 kwh per yr. in the present use of electrical energy by Brookhaven National Laboratory, bringing it to a total of approximately 400 x 10^6 kWh per yr. This total electrical consumption is approximately equivalent to 3.3% of the electrical energy annually produced by the Long Island Lighting Company at the present time. The annual consumption of fossil fuels associated with ISABELLE represents approximately a 3% increase over present BNL use or 760 kl (200,000 gallons) of number 6 oil.

6.3 Water

The construction and operation of ISABELLE is expected to involve an increased water demand of approximately 2500 kl/day (.66 MGD) which is 9% of the present Laboratory annual use. This annual increment is equivalent to the water requirements for a community of approximately 11,000 persons. Water is supplied by the Brookhaven-site well system and no noticeable effect on the groundwater table is expected for the life of the project. The bulk of this water will be used for dissipation of waste heat and all but approximately 35% of it, representing evaporative and windage losses, will be returned to the underlying aquifers.

6.4 Funding and Labor

The total estimated construction cost for the ISABELLE project is approximately $275 million, which would be spent over an approximate 5-year period. It is estimated that operation of the facility will add $23 million annually to current BNL expenditures. Construction efforts will require nearly 2800 manyears over the 7-year duration. In addition, approximately 200 engineers, scientists, technicians, and other employees will be added to the permanent staff at the Laboratory for operation of the ISABELLE facility.

6.5 Construction Materials

The estimated quantities of the major materials that will be used in the construction of the ISABELLE facility are as follows:

Concrete	47,000 m^3 (61,000 cubic yards)
Steel	6,760 M.T. (7,450 tons)
Stainless steel	1,180 M.T. (1,300 tons)
Aluminum	73 M.T. (80 tons)
Copper	155 M.T. (170 tons)
Titanium	11 M.T. (12 tons)
Niobium	13 M.T. (14 tons)
Asphalt	5.3 ha (13 acres)
Polymeric materials	4.5 M.T. (5 tons)

As evident above, concrete and steel constitute the bulk of the materials. This concrete requrement is equivalent to approximately 4.8 km (3 miles) of a six lane highway; the quantity of steel involved would make 3500 standard sized automobiles. With the exception of concrete and asphalt, all materials will have approximately 80 to 90% salvage value.

With respect to materials contaminated with long-lived radionuclides, the economics involved in their recycling will have to be considered. Items in the categories of precious metals, strategic resources, materials with small natural reserves, or materials whose production is energy intensive will receive individual consideration, but the amounts used at BNL are very small fractions of the amounts industrially available. Efforts will be continued to place contaminated materials into a dedicated reuse program when possible. Some structural and equipment components including those detailed earlier in this section are essentially irretrievable because of the economic aspects of reclamation and/or radioactive decontamination.

SECTION 7

RELATIONSHIP OF THE PROPOSED ACTION TO LAND USE PLANS, POLICIES, AND CONTROLS

No significant conflicts are expected to arise from the proposed location of the ISABELLE facility on the Brookhaven National Laboratory site. Considerations relevant to this matter are outlined below.

The present use of the Laboratory site, as noted in ERDA 1540, is in conformance with all applicable federal regulations. As detailed in previous sections of this document (Section 4), the proposed construction and operation of the ISA facility would also be performed in adherence to federal regulations.

Since the Laboratory is administered under a deed of cession, many local and state rules and regulations are not legally applicable. However, it is the policy of DOE to cooperate with local and state authorities in many areas in an act of comity. It would appear that the use of the BNL site for the proposed construction and operation of ISABELLE is a logical extension of present land use policies as defined by both the Nassau-Suffolk Bicounty Master Plan and the Brookhaven Town Master Plan. In both these plans, the entire Laboratory site has been designated for institutional use. The relatively small commitment of land and other environmental resources required for the ISABELLE project appears to be quite adequately compensated for in terms of the project's contribution to the socio-cultural and economic well-being of the region as well as the nation in general. Such land use is complementary to that of the surrounding areas for which Corridor, Cluster and Center-type planning development have been indicated.

There are no conflicts arising from the proposed location of the ISABELLE project with respect to other BNL plans for the proposed site. The 250 ha (625 acres) involved represent only 15 percent of the remaining undeveloped land on the Laboratory property. It does not appear that the use of this location would affect any future plans the Laboratory may have since the actual land that will be irreversibly disturbed is limited and for the most part construction is below grade. Moreover, this course of site management provides maximum land-use flexibility for the future.

SECTION 8

RELATIONSHIP BETWEEN SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

ISABELLE represents a third generation accelerator for Brookhaven. Its proposed location is the northwest corner of the existing site, in a zone previously allocated to the location of large facilities. Construction of the facility will take place during the period 1979 to 1986, and operation which will commence in 1985 could conceivably extend well beyond the year 2000. As noted elsewhere in this Statement, the Short-term use of this site, during this projected period, will not cause any significant detrimental effects to the environment. The primary short-term effect will be the commitment of a certain amount of land, materials, energy, manpower, and capital resources for design, construction, and operation of the proposed facility. Balanced against these will be the almost immediate beneficial effects that the operation of ISABELLE will have upon the stimulation of the High Energy Physics program both here in the United States and abroad. In addition, there will be a profoundly beneficial effect on the presently recessed local economy created by the project's funding and employment opportunity. Furthermore, the presence of ISABELLE on the Brookhaven site will enhance the Laboratory's present role of preserving a valuable reservoir of open space and natural habitat, both of which are extremely important in the rapidly developing Suffolk County area.

Inasmuch as it is a relatively clean facility, ISABELLE, at the end of its useful lifetime, can by virtue of planning and design be easily decontaminated and decommissioned. Once those components including beam dumps, internal absorbors and scrapers, inflectors, system magnets and some vacuum equipment, with induced radioactivity are removed, the remaining facilities are expected to be suitable for reuse. Furthermore, to restore this land completely to its original condition should entail no insurmountable physical obstacles and should be feasible with current technology, although the decision to do so will necessarily depend on economics, principally prevailing land values.

While it is impossible to be specific at this point, the long-term gains expected from the operation of ISABELLE should have a profound effect on man's cultural development in that they will directly increase his ability to understand the world in which he lives.

SECTION 9

ALTERNATIVES

This section will attempt to evaluate reasonable alternatives to the proposed action of construction and operation of the ISABELLE facility at Brookhaven National Laboratory.

Analytically the alternatives are considered in two categories: alternatives to the proposed action and alternatives within the proposed action. The first category includes no-action and alternate facility location. The second category includes alternatives to accelerator and facility design.

9.1 No Action Alternative

9.1.1 Abandonment of Project

If the United States chooses not to build a high energy proton-proton colliding-beam machine, the most energetic nucleon-nucleon collisions available in the world would continue to be those at the ISR in Europe. Proton beams from FNAL striking stationary target nucleons provide collisions with lower energies available in the center-of-mass, but greater numbers per second. Without a new facility, there would be no substantial increase in energies available for use until such time when colliding beam experiments might be undertaken at FNAL or in Europe or Russia. However, at FNAL, particle collision rate would be less favorable and facilities abroad would have only limited availability to American scientists.

The experiments envisioned for ISABELLE, which it is hoped will provide a better understanding of the weak and strong interactions and the basic constituents of matter, would have to be abandoned and the stimulus of this frontier research to universities throughout the United States would be lost. The balance of the high energy physics program would be deprived of a major facility in the eastern part of the country as the AGS eventually becomes obsolescent. The economic benefits of the construction and operation of ISABELLE would be lost to the regional area.

The resources devoted to ISABELLE could be used for other purposes, or saved for future use. These include manpower, energy and construction materials as described in Part 6. Other desirable uses might be found for the land, though it has few features to make it attractive for park or recreational use. Most uses involving residential or commercial development would have adverse environmental impacts greater than those associated with construction and operation of ISABELLE.

9.1.2 Postponement of Project

Any postponement of ISABELLE would delay execution of the experiments on weak and strong interactions and on basic constituents of matter for which ISABELLE is needed. The stimulus to universities would be postponed, and a period of reduced adequacy of research facilities in the eastern part of the U.S. would be introduced. The direct economic impetus of ISABELLE would similarly be deferred. While a postponement of ISABELLE is a logical possibility, some loss of momentum in the project would undoubtedly result from such action. Serious consideration of ISABELLE design possibilities began in 1971; a stretchout such that completion would be delayed for more than 15 years would have some practical difficulties.

Postponement would defer the use of the resources devoted to ISABELLE as described in Part 6. The resources would still be required at the later time, however. In general they would be as valuable then as now, if not more so, and postponement would have no net effect on resource utilization. The benefits from the scientific knowledge gained by use of ISABELLE, on the other hand, would be reduced because they would be available later. Scientific knowledge is a permanent resource that is not consumed by use.

There is, of course, some possibility that postponement of ISABELLE would lead to improvements in the eventual machine through increased time for research, development, and design. ISABELLE will use many types of new technology, such as superconducting magnets, for which improved capabilities are quite possible. No breakthroughs are expected in the immediate future, however, and the design of ISABELLE is chosen to exploit developments of recent years. The use of present advanced technology in a scientific facility like ISABELLE is an excellent way to introduce new technology into more general use and to encourage further developments in the field.

9.2 Alternatives to Facility Location

To provide colliding proton beams it is necessary to have a source of protons, which makes it convenient and economical to build such a colliding beam machine where a suitable source of high energy protons with a very concentrated beam already exists. The two possibilities in the United States are Brookhaven and Fermilab, and technical considerations would permit construction of a machine with high energy and luminosity at either site. Environmental impacts would be similar in the two cases. Choice of the FNAL site would imply a highly centralized high energy physics research program, with the vast majority of personnel, projects, and expenditures at a single site. Decentralization is considered a preferable route to equitable access, the stimulus of competition, and the innovative climate essential in research enterprises. The FNAL staff and other resources are heavily committed for many years to a very busy experimental program with the highest energy conventional accelerator, to the energy increases of the energy doubler/saver, and to other developments. The addition of ISABELLE would be likely to overload services and facilities such as computers and machine shops, generate crowding in office and laboratory space, and interfere with the expeditious progress of these important programs, even if additional staff were provided to carry it out. The program at Brookhaven would be greatly weakened by such a choice, with adverse effects on the diversity and balance of the high energy physics program. The FNAL site does not have any major environmental advantages that would make such a choice preferable, since it is located among the outer suburbs of Chicago.

On the other hand, ISABELLE could be built at an entirely new site, with all aspects of the facility designed and built from the beginning, including an injector synchrotron. The absence of constraints at a new laboratory site has some advantages; frequent moves fit the pioneering tradition. There are conflicting requirements for such a new high energy laboratory: it must be easily accessible, yet located so as to have plenty of space and to cause few adverse effects in the area. To find a site superior to Brookhaven in important ways would be difficult. A very comprehensive review of sites suitable for a major acceletor was made in 1966 before selection of the Weston, Illinois site for Fermilab. From a total of over 100 sites that were proposed six were classified as meeting all objective requirements. In addition to the one at Brookhaven these included sites near Ann Arbor, Michigan; Denver, Colorado; Madison, Wisconsin; and Sacramento, California, as well as the chosen one near Chicago, Illinois.

In most areas land is not as freely available now as in 1966, and development of a new site would preempt land from other uses. Building a new laboratory would be more expensive than utilization of existing land and facilities. The main environmental effect would be to transfer impacts from one location to snother without any net benefits. In general, both costs and environmental effects would be significantly increased by the establishment of a new laboratory.

9.3 Alternatives to Accelerator and Facility Design

9.3.1 Alternatives to Accelerator Design

Other kinds of accelerators would not provide improvements over the ISABELLE design in reduced environmental impacts for the same scientific effectiveness. To provide the same energy available in the system defined by the colliding particles as will be provided by ISABELLE, a conventional machine with one high energy beam and a fixed target would require a diameter about 400 times that of ISABELLE, which would be completely impractical in terms of increased cost, resource utilization, and environmental impact. Similarly, a machine with colliding electron beams would have to be at least 10 times the diameter of ISABELLE to reach the same energy, and the power needed would also be so much greater that it would be impractical. The cost, resource utilization, and environmental impacts of such a machine, would be correspondingly much greater than those of ISABELLE, which has been designed to be as efficient as possible in maximizing the available energy provided by the colliding particles.

The U.S. high energy physics program includes a fixed target accelerator at FNAL and a colliding electron beam machine at SLAC. In this coordinated national program, it is Brookhaven's role to construct a machine with colliding proton beams and the highest energy that can be attained at acceptable cost and with strictly limited environmental impacts.

Although the outstanding technical feature of the ISABELLE design is the use of superconducting magnets, conventional magnets with copper or aluminum windings could be used. Such an optional design is included in A Proposal for Construction of a Proton-Proton Storage Accelerator Facility, ISABELLE, May 1974. It was rejected because the size and construction costs exceeded those of the superconducting design; electric power requirements for operation were about three times as great; and, finally, the predicted beam performance was inferior to that of the more compact superconducting design. Because of the high electric power requirements there would be a corresponding need for cooling water. Choice of a warm magnet design would clearly be undesirable because of the greater environmental and economic costs. In addition, use of superconductivity in research applications is desirable as a way of stimulating more widespread development and use of this energy-conserving technology.

In determining the overall scope of the ISABELLE facility, the most significant parameter is the beam energy of 400 GeV. A reduced energy would lead to a smaller diameter, smaller energy consumption, and reduced environmental impacts. Conversely, an increase in energy would lead to an overall increase in cost and environmental impact. The great promise of the research program envisaged for ISABELLE depends entirely on the large available energy in the proton-proton collisions. Therefore, it is essential for the energy to be substantially greater than that of the ISR, which provides 31-GeV proton beams. The design energy of 400 GeV satisfies this requirement well. Since one of the main objectives of ISABELLE is to demonstrate the existence of W mesons and study their properties, the energy of ISABELLE needs to be adequate for this specific purpose. Theoretical estimates indicate that 400 GeV is completely adequate, but reduction would increase the running time required to produce a given number of W mesons to an undesirable degree. For the research program the highest practical energy is the best, and in the present design, evaluation of trade-off between scientific capabilities and economic and environmental costs has led to the choice of 400 GeV.

The scope of ISABELLE might also be reduced by providing a lower beam intensity or fewer experimental areas. Such changes would cause a considerable loss in research capabilities with only a very limited reduction in the environmental effects.

9.3.2 Alternatives to Facility Design

Some reduction in electrical power demand could be accomplished by requiring that all magnets used in experiments be superconducting. At present it is expected that some will be conventional warm magnets with copper or aluminum conductors, which are simpler and less expensive to build. A policy of using superconductors throughout might reduce experimental power requirements by as much as 50%, from 15 MVA to 7 1/2 MVA. This, however, would result in an overall demand reduction from 40 MVA to 32.5 MVA, only a 19% reduction. Of course such numbers are only rough estimates, since the apparatus for the experiments has not been designed yet in any detail. In the ISABELLE design figure of 15 MVA for experimental power, it is assumed that large magnets which will run for long periods of time will be superconducting since they are the ones for which economic and environmental benefits justify the initial investment to the greatest degree. It does not appear that it would be worthwhile to require more complete use of superconducting magnets, but the question should be decided, case by case, as specific experimental equipment is designed and built.

Water usage is primarily for make-up water requirements for closed-loop cooling towers. The BNL water system can supply the necessary water, and the environmental impacts do not seem to be a cause for concern. Evaporative coolers of similar capacity are used at AGS and HFBR without generating fog, condensation, or deposits that are troublesome. As an alternative, dry-air cooling which would minimize water use might be employed, but greater expense would be expected, and the visual impact of the large towers would be undesirable.

It would be possible to utilize a cooling pond rather than towers, but, assuming 0.2 ha (0.5 acre) per MW, about 8 ha (20 acres) would be required. Such a pond would be expensive to construct, and its impact might be unfavorable because of the elevated water temperature. The water-cooling procedure in the present design which utilizes evaporative coolers is considered preferable to other alternatives at the present time.

The radiological impact of ISABELLE could be further reduced by increasing the earth shield over the machine. There are two general ways of doing this; either the tunnel floor elevation above sea level could be lowered so that a greater fraction of the machine is below natural grade level, or the thickness of shielding berm over the tunnel could be increased. Lower elevation eventually places construction below the water table, which is undesirable, and a thicker berm increases earth moving and disturbance to the site. Various combinations have been studied and the choice of tunnel elevation has been made that minimizes the volume of earth to be moved. A thicker earth shield would add to the cost of construction and make the experimental areas less convenient to use, thus slowing the progress of experimental work. The proposed design is believed to be an optimum choice in this regard. It relies on good control of the circulating proton beams to minimize undesired beam losses which generate background radiation. With good control of the circulating beam a very clean machine results, which is advantageous for experimental use and keeps radiological impacts at a low level. The emphasis, therefore, is on the most sophisticated techniques for monitoring the behavior of the proton beams and controlling them to provide the desired orbits, rather than on the provision of extremely thick sand shielding. Operating procedures and controls will assure that radiological impacts are well within the conservative levels that have been set.

SECTION 10

ENVIRONMENTAL TRADE-OFF ANALYSIS

The environmental, technical and socio-economic aspects of the beneficial and adverse effects associated with the proposed ISABELLE project and reasonably available alternatives have been discussed in the body of this Statement. This section synopsizes that information in order to provide an analysis of the environmental trade-offs associated with the proposed action and its alternatives so that an informed judgment can be made concerning the wisdom of undertaking the proposed action rather than one of the alternatives.

For the purposes of this analysis, the proposed action is considered to be the construction and operation of the ISABELLE project at the Brookhaven National Laboratory site as described in the body of this Statement. Table 10-I presents the environmental, technical and socio-economic aspects of the beneficial and adverse effects associated with the proposed action in summary fashion. Environmentally, this action supports the continuing Brookhaven National Laboratory policy of preserving natural areas in a manner which minimizes environmental stresses and provides maximum flexibility in terms of future land use options. The technical benefits associated with this project cannot be underestimated in terms of their profound impact on man's pursuit of knowledge. The temporary and permanent employment positions as well as the attendant purchases of materials and equipment associated with this project will have a strong stimulating effect on the presently recessed regional economy. The presence of this project at Brookhaven further enriches the laboratory's contribution to the cultural well being of the region, particularly in the area of education.

Balanced against the benefits discussed above one must consider the adverse effects associated with the execution of this proposed action. Primarily these comprise the preemptive use of resources including 180×10^6 kWh per year of electricity, 760 kl/yr (200,000 gallons per year) of fuel oil, 2.3×10^5 kl/yr (60×10^6 gallons per year) of water, 250 ha (625 acres) of land and varying amounts of construction materials. While project construction will cause some intermittent and temporary local disruption, the operating phases of this project will contribute very minor environmental impacts. Due to the availability of prospective employees for both construction, and to a somewhat limited degree, operation, in the local area, the demands for housing and associated tax-supported services are expected to be minimal.

Juxtaposed to this analysis for the proposed action are similar analyses of the environmental trade-offs associated with reasonable alternarive actions. Logically such alternative actions fall into two categories: alternatives to the action and alternatives within the action. Those alternatives to the proposed action include the no-action alternative (abandonment/postponement) and alternate facility location, the beneficial and adverse effects of which are summarized in Table 10-I. Other than the avoidance of the adverse impacts associated with the proposed action the alternative of abandonment offers no benefits. Furthermore, the pursuit of this alternative could result in the deprivation to society of a facility dedicated to the acquisition of fundamental knowledge and at very least could cause a set-back to U.S. leadership in the field of high energy physics. The alternative of project postponement does not avoid the adverse impacts associated with the proposed action, but rather defers them temporarily. While this alternative may provide extra time for possible design improvements, the development of which are only speculative, it will certainly interrupt the high energy physics research schedule in this country as well as abroad. Moreover, it defers the economic stimulus associated with this project from a time when it would be most productive. While the benefits associated with the construction and operation of ISABELLE at an alternate site are difficult to accurately predict, they would not be expected to be any greater than those associated with the proposed action. On the other hand, adverse effects could be considerably more significant depending on the site location. The requirement for support facilitiea (primarily injection devices such as the AGS) could entail appreciably greater environmental impacts as well as increased construction expenditures. Consideration must also be made of the availability of trained personnel for construction and operation of the facility.

The beneficial and adverse effects of those alternatives within the proposed action are summarized in Table 10-II. These alternatives are grouped into two categories. Alternatives to Accelerator Design consider the variety of experimental machines that could be employed to achieve similar research capabilities. Alternatives to Facility Design consider those changes within the Proposed Accelerator Design which could result in diminished environmental impacts. The pursuit of design alternatives offers no beneficial environmental effects. Conversely, the use of these designs involve significantly greater environmental impacts and economic expenditures associated with increased ring sizes and greater resource consumption. In addition to this, in the case of a conventional accelerator (one with a single high energy beam and a fixed target) there will be significantly increased radiological effluents and for the warm magnet machine, the predicted beam performance would be inferior. The alternatives directed at impact minimization involve more complete use of superconducting magnets, alternate

Table 10-I

Environmental Trade-Off Analysis Summary for Alternatives to the Proposed Action

		No Action Alternative		
Beneficial Effects	Proposed Action	Abandonment	Postponement	Alternate Facility Locations
Environmental	Preserves land use options. Minimizes environmental stresses and conserves natural area.	Land remains as it currently exists.	None	Unknown - benefits depend on nature and location of other site.
Technical	Provides better understanding of the basic constituents of matter and their weak and strong interactions. Stimulates high energy physics research in United States and abroad.	None	Provides time for possible design improvement.	Same benefits as proposed action.
Socio-economic	Provides 500 temporary and 200 permanent employment positions. Contributes direct income increment of $110,000,000 to Long Island economy. Enhances Laboratory's contribution to the cultural well-being of the region, particularly in the area of education.	None	None	Unknown - depends on location economy. Future impacts are similar to proposed action.
Adverse Effects				
Environmental	Requires yearly consumption of 180 x 10^6 kWh of electricity, 760 kl (200,000 gal) of fuel oil, 2.3 x 10^5 kl (60 x 10^6 gal) of water and construction materials. Causes temporary local disruption during construction.	None	Ultimately produces impacts similar to those of proposed action.	Produces at least the same impacts as proposed action and possibly considerably more depending on the existance of support facilities such as AGS.

Table 10-I (Cont'd)

Beneficial Effects	Proposed Action	No Action Alternative: Abandonment	No Action Alternative: Postponement	Alternate Facility Locations
Technical	None	Deprives society of a facility dedicated to the pursuit of fundamental knowledge. Potentially causes a setback to U.S. leadership in field of high energy physics.	Interrupts high energy physics research schedule and reduces stimulus to scientific community.	None
Socio-economic	Creates minimal demand for housing and associated tax supported services due to influx of 100 new employees.	None	Defer economic stimulus from a time when it will be most productive.	Unknown - depends on local economy. Could involve significant additional expenses if support facilities are not available.

Table 10-II

Environmental Trade-Off Analysis Summary for Alternatives Within the Proposed Action

Alternative	Beneficial Effects	Adverse Effects
Accelerator Design		
Conventional Accelerator	None, environmentally	Increases ring size (400 times). Increases radiological impacts.
Colliding Electron Accelerator	None, environmentally	Increases ring size (10 times). Electrical consumption greatly increases.
Warm Magnet colliding proton Accelerator	None, environmentally	Electrical consumption increased 3 times. Increases size of ring. Provides inferior beam performance.
Facility Design		
Complete use of superconducting magnets.	Decreases power demand approximately 19%.	Increases capital expense.
Dry-air Cooling	Eliminates yearly consumption of 1.9 x 10^5 kl (50 x 10^6 gal) of water.	Produces visual impact. Increases capital expense.
Cooling ponds	Reduces aesthetic impact.	Increases requirement for land 8.1 ha (20 acres).
Increased shielding -		
Subterranean	Reduces radiological impact.	Possibly encroaches on underlying water table. Increases disturbance to site. Increases construction expense.
Above ground	Reduces radiological impact.	Increases construction expenses. Decreases experimental flexibility. Increases visual impact.

water cooling systems and in creased radiation shielding. Table 10-II compares the beneficial effects of environmental impact diminishment versus the adverse effects of increased monetary expenses and environmental manipulation associated with these alternatives.

APPENDICES

A - Comment Letters

B - Glossary of Terms

C - Metric Prefixes and Conversions

D - Symbols and Abbreviations

A - COMMENT LETTERS

Comments on the Draft Environmental Impact Statement were received from the following:

- Department of Transportation
- Department of Agriculture
- Department of Health, Education and Welfare
- Environmental Protection Agency
- Charles L. Weaver - Consultant
- Department of the Interior
- Nuclear Regulatory Commission
- New York State Department of Environmental Conservation
- National Science Foundation

The text of the statement has been changed to reflect the comments received and annoted to indicate the origin of the comments.

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
REGION ONE
New York Division Office
Leo W. O'Brien Federal Building, Ninth Floor
Albany, New York 12207

March 6, 1978
IN REPLY REFER TO:

HA-NY

Mr. W. H. Pennington, Director
Office of NEPA Coordination
Department of Energy
Washington, D. C. 20545

Dear Mr. Pennington:

We have completed our review of the Draft Environmental Impact Statement for the Proton-Proton Storage Accelerator Facility at Brookhaven National Laboratory, Upton, New York as submitted with your February 17, 1978 letter. We do not have any comments on the Draft Environmental Impact Statement. Thank you for your coordination efforts.

Sincerely yours,

Victor E. Taylor
Division Administrator

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

U. S. Courthouse and Federal Building, Syracuse, New York 13260

March 17, 1978

Mr. W. H. Pennington
Director, Office of NEPA Coordination
U. S. Department of Energy
Washington, D. C. 20545

Dear Mr. Pennington:

We have reviewed the draft Environmental Impact Statement for the "Proton-Proton Storage Accelerator Facility, Brookhaven National Laboratory, Upton, New York," prepared by the U. S. Department of Energy, dated January 1978.

The following comments are submitted:

(1) Page 3-4

The last paragraph on this page, regarding soils, would be more accurate if it stated: "Surface deposits vary in texture from place to place. Soil types on site include Atsion sand, Berryland mucky sand, Carver and Plymouth sands, Deerfield sand, Haven loam, Plymouth loamy sand, Raynham loam, Riverhead sandy loam, Scio silt loam, sandy substratum, Sudbury sandy loam, Walpole sandy loam, and Wareham loamy sand."

(2) Page 3-15

The vegetation map of the site uses a very similar legend symbol for Pine-Oak Forest and Swamp. This makes it difficult to distinguish between these vegetative types. Some clarification of the symboling is needed.

(3) Page 4-2

The last paragraph discusses excavation and stockpiling. In stockpiling topsoils should be salvaged, segregated, and stored for use later as topsoil. Appropriate vegetative materials such as quick growing grasses should be used to protect stockpiles and denuded areas from erosion. We recognize temporary sediment basins are being considered for use.

(4) Page 4-7 - First sentence

We note a number of specific trees are mentioned for planting. The planting plans should include grasses and legumes that are compatible with the site conditions. These materials become established much more quickly than trees and will serve an interim erosion control purpose.

We appreciate the opportunity to review and comment on this statement.

Sincerely,

Paul A. Dodd /for

Robert L. Hilliard
State Conservationist

cc: R. M. Davis, Administrator, SCS, Washington, D. C.
Office of Federal Activities, EPA, Washington, D. C. (5 copies)
USDA Coordinator, Office of Environmental Quality
Cletus J. Gillman, Director, TSC, SCS, Broomall, Pennsylvania

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
CENTER FOR DISEASE CONTROL
ATLANTA, GEORGIA 30333
TELEPHONE: (404) 633-3311

April 6, 1978

Mr. W. H. Pennington
Director
Office of NEPA Coordination
Department of Energy
Washington, D.C. 20545

Dear Mr. Pennington:

We are responding to the Draft Environmental Impact Statement regarding the Proton-Proton Storage Accelerator Facility (Isabelle) at the Brookhaven National Laboratory, Upton, New York, on behalf of the Public Health Service.

Our review of this statement indicates that the impact of the proposed action and the reasonable alternatives have been adequately addressed.

We appreciate the opportunity to have reviewed this statement.

Sincerely yours,

William H. Foege, M.D.
Assistant Surgeon General
Director

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION II
26 FEDERAL PLAZA
NEW YORK, NEW YORK 10007

Class. ER-2

7 APR 1978

Mr. W. H. Pennington
Office of the Assistant Administrator
for Environment and Safety
Mail Station E-201
Department of Energy
Washington, D.C. 20545

Dear Mr. Pennington:

The EPA has reviewed the draft environmental impact statement (EIS) issued in connection with the Proton-Proton Storage Accelerator Facility (Isabelle) to be located at Brookhaven National Laboratory (BNL) in Upton, New York, and offers the following comments for your consideration in preparing a final EIS.

The EPA finds that the draft EIS provides insufficient detail to independently determine the environmental acceptability of the Isabelle facility. Mr. Andrew Hull of BNL states that the intent of Section 4.2.1.3, Earth and Water Activity is to provide a comparison of the radiological impacts of Isabelle and of the existing Alternating Gradient Synchrotron (AGS) which is the injection source for Isabelle. It is argued that AGS with a 50% beam loss could produce concentrations of ^7Be and ^3H of 1.1×10^8 pCi/l and 3.3×10^8 pCi/l, respectively, and that these concentrations (which could be produced at this time with existing AGS operations) are much higher than the concentrations possible from Isabelle.

The AGS concentrations, based on a method by Stapleton and Thomas,[1] are at least a factor of 15,000 greater than the EPA drinking water standards[2] of 6×10^3 pCi/l for ^7Be and 2×10^4 pCi/l for ^3H. The reasoning continues that, based on monitoring during AGS operations, these concentrations have not been reached in any of the monitoring wells established around the BNL facility. The draft EIS asserts that Isabelle, a smaller radiation source than AGS, should have a radiological impact smaller than the known impact of the existing AGS.

The crux of the argument is the contention that Isabelle would indeed have a smaller radiological impact than AGS. This is based on the fact that Isabelle would use only 2.3 percent of the total protons produced by AGS, and even less would actually be accelerated within Isabelle. However, the final EIS issued in connection with BNL indicates that some sampling wells near the disposal area do exceed EPA drinking water standards.

Because the groundwater beneath BNL is classified by New York State as a source of potable water (GA),[3] we believe that the argument for Isabelle could be better supported by a discussion of the reasons (dilution, availability of water to individual wells, water movement from AGS shield to aquifers, etc.) that such concentrations would not reach a drinking water receptor. The draft EIS does state that the rate of groundwater movement on the BNL site is about 15 cm/day, and that ^3H would decay by a factor of eight before reaching the BNL boundary, some 2 km away. The final EIS should determine whether this decay factor, along with dilution and dispersion factors, is sufficient to guarantee that drinking water standards will be met offsite.

It is also requested that the final EIS explain why the method of Stapleton and Thomas was not used to calculate the maximum concentration of ^7Be and ^3H for the operation of Isabelle at 400 GeV.

The review of the draft EIS would have been easier if a cross-section of the Isabelle facility were provided. Such a figure would clear up questions of how deeply the Isabelle facility is embedded into the ground, whether the materials and the thickness of the protective berms are adequate to prevent excessive irradiation of earth and/or groundwater during beam loss, and what the relation of the facility is to the aquifers beneath BNL.

On page 3-18 of the draft EIS, the average gross-beta activity in rainwater for 1976 is given as 95 pCi/l. Because normal precipitation activity is usually less than 20 pCi/l, it is requested that the final EIS explain the high average activity.

In light of the above comments and in accordance with EPA procedure, we have classified the draft EIS "ER-2" indicating our environmental reservations (ER) regarding the proposal's radiological impacts, and our need for additional information to complete our review (2). It is requested that EPA be given an opportunity to review the proposed responses to these comments before issuance of a final EIS. For coordination in this matter, please contact Jeanette Eng at (212) 264-4110.

Sincerely yours,

Barbara M. Metzger

Barbara M. Metzger
Chief
Environmental Impacts Branch

cc: A. Hull, BNL
L. Emma, BNL

References

[1]G. B. Stapleton and R. H. Thomas, "Estimation of the Induced Radioactivity of the Ground Water System in the Neighborhood of a Proposed 300 GeV High Energy Accelerator Situated on a Chalk Site," Health Physics 23,689 (1972)

[2]National Interim Primary Drinking Water Regulations, EPA-570/9-76-003, EPA Office of Water Supply

[3]6NYCRR Part 703, Groundwater Classifications and Standards.

April 4, 1978

Mr. W.H. Pennington, Director
Office of NEPA Coordination
Department of Energy
Washington, D.C. 20201

Dear Mr. Pennington:

The Department of Health Education and Welfare has reviewed the Summary Sheet and Department of Energy's (DOE) draft Environmental Impact Statement (EIS) for the Proton-Proton Storage Accelerator Facility (Isabelle) and has the following comments to offer.

Page 2-13 Section 2.1.2.2.7 Environmental Monitoring. The BNL Environmental Monitoring Program is believed to be adequate for detecting planned and unplanned releases of radioactive material to the environment.

Page 4-14, Section 4.2.1.3. The radiological impact discussion indicates that there will be a minimium impact on the environment, but does not include sufficient information to fully support the statement. For instance it states that Isabelle is a smaller source of radiation and should produce less radioactivity than the AGS which contributed less than 1% of the total population dose equivalent attributable to BNL operation in recent years. Sufficient explanation or data were not provided to support the conclusion.

The design objective of 1000 mrem/year for the highest outside radiation level for a hypothetical individual who spends 40 hours per week at that location may not necessarily meet the ALARA criteria if it is arbitrarily taken as 20 per cent of the DOE upper exposure limits without a detailed analysis of the shielding design.

Ground water contamination of tritium is recognized as a potential long range problem. Thus, increased monitoring of both surface and subsurface water should be undertaken prior to construction and operation of Isabelle.

In the summary on pages 4-22 it states that the resultant radiation dose from operation of Isabelle will not increase the total yearly dose to any person working on-site by more than 1000 mrem/year. It is assumed that even with this additional dose the occupational dose would be within presently accepted limits. However, it might be appropriate at this time to re-examine the operations and take steps to reduce the expected occupational exposures.

In summary, it is believed that the Isabelle facility can be operated to meet current radiation protection guidance and provide adequate protection of the public health and safety.

Sincerely,

Charles L Weaver
Consultant
Bureau of Radiological Health
Food & Drug Administration

CLW/dn

cc: Dr. Taylor
Dr. Shleien

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

ER-78/146

APR 14 1978

Mr. W. H. Pennington, Director
Office of NEPA Coordination
Department of Energy
Washington, D. C. 20545

Dear Mr. Pennington:

Thank you for your letter of February 13, 1978, transmitting copies of the Department of Energy's draft environmental statement on the proton-proton storage acceleration facility (Isabelle), Brookhaven National Laboratory, Suffolk County, Upton, New York [DOE/EIS-0003-D].

Our comments are presented according to the format of the statement or by subject.

General

We find that the draft statement adequately describes fish and wildlife resources and mineral resources as well as the project's impacts on these resources.

Cultural Resources

While page 3-19 of the draft statement contains a paragraph concerning archeology, there is no indication of consultation with the State Historic Preservation Officer or evidence of any determination concerning the preservation of historic sites that may be affected by the project. If there were previous environmental documents prepared on the laboratory wherein cultural resource protection was adequately treated, such documents could be reiterated in this draft statement. If no such other documents exist, we believe the final environmental statement should indicate consultation with the National Register of Historic Places and contact with the State Historic Preservation Officer as necessary.

Effects on Groundwater

We note on page 4-20 of the draft statement that the rate of groundwater movement used in evaluating impacts of leachable radionuclides was about 15 cm/day. We suggest that a worst-case analysis should be provided in the final statement using the maximum published rate of groundwater movement about 1.3 ft/day or 39.6 cm/day (Warren, M. A., de Laguna, W., and Lusczynski, N.J., 1968, Hydrology of Brookhaven National Laboratory and vicinity, Suffolk County, New York: U.S. Geological Survey Bulletin 1156-C, p. 56).

We note that on page 1 4 of the draft statement, a return to the groundwater reservoir of about 80 percent of the water used is predicted. However, on pages 6-2 and 6-3, it is indicated that a return of about 65 percent is expected. These figures should be reconciled in the final statement.

For accuracy in appraisal of the environmental impacts from the proposed project, we suggest that the location of Isabelle should be shown on figure 3.3-B, the water-level contour map in the final statement.

Effects on Surface Water

On pages 4-3 and 4-4 of the draft statement, it is stated that culvert traverses of streams will be constructed to be capable of accommodating exceptional events such as five-year storms. We believe that five-year storms should not be considered exceptional events and may not be adequate for conservative culvert design if upstream ponding is to be avoided.

We hope these comments will be useful to you in the preparation of a final statement.

Sincerely,

Larry E. Meierotto
Deputy Assistant SECRETARY

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

APR 21 1978

Mr. W. H. Pennington, Director
Office of NEPA Coordination
Department of Energy
Washington, D. C. 20545

Dear Mr. Pennington:

This is in response to your request for comments on the Draft Environmental Impact Statement for the Proton-Proton Storage Accelerator Facility (Isabelle).

We have reviewed the statement and our comments are attached.

Thank you for providing us with the opportunity to review this Draft Environmental Impact Statement.

Sincerely,

Voss A. Moore

Voss A. Moore, Assistant Director
for Environmental Projects
Division of Site Safety and
Environmental Analysis

Enclosure:
As stated

Comments on DOE Draft Environmental Impact Statement

1. As discussed in Section 4.1.2 to maintain the natural surface drainage, culverts may be installed where the existing streams traverse the ring. However, we note no discussion as to any modification of the shielding characteristics introduced by these structures.

2. On page 4-17, it is stated that the muon shield will be designed to limit exposures at a 600 m location to less than 5 mrem/yr. A more detailed discussion of the shield design should be presented. We note, for example, no estimate is given of the shield thickness.

3. The predicted neutron and muon flux, including their associated energy distributions, should be presented both for the outside shield and site boundary environments. The quality factors assigned in the conversion of absorbed dose to dose equivalent should also be presented.

4. The definition of the Rem on page 10 of the glossary is not correct. See the mrem definition in the same glossary.

New York State Department of Environmental Conservation
50 Wolf Road, Albany, New York 12233

Peter A. A. Berle,
Commissioner

April 13, 1978

Mr. W.H. Pennington, Director
Office of NEPA Coordination
Mail Section E-201
United States Department of Energy
Washington, D.C. 20545

Re: DOE/EIS - 0003-D

Dear Mr. Pennington,

The State of New York has completed its review of the Department of Energy's Draft Environmental Impact Statement for the proposed Proton-Proton Storage Accelerator (Isabelle) at Brookhaven National Laboratory, Upton, N.Y.

The document was found to be an adequate assessment of the impacts of this project. We offer the following comments for your consideration.

1. In Section 4.2.1.2. (Effects on Water Use), the amount of water to be used for blowdown is estimated at 1,640 kl/d, which is two thirds of the total cooling tower makeup requirements. Whereas blowdown volumes normally comprise a much smaller proportion of total makeup water, further explanation of this figure is called for. Alternate cooling tower designs should be considered to minimize the amount of blowdown water needed. Also, the names and amounts of chemicals to be used for shock treatments should be provided.

2. Section 6.5 (Construction Materials) lists the major materials of which the facility will be built and discusses the feasibility of recycling them when the accelerator is decommissioned. This section should also address the estimated amounts of contaminated materials, their curie content and the isotopes involved.

Thank you for the opportunity to review this statement.

Sincerely,

Terence P. Curran, Director
Office of Environmental Analysis

BY:kaf

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

April 21, 1978

Mr. W. H. Pennington
Director
Office of NEPA Coordination
Department of Energy
Washington, D.C. 20545

Dear Mr. Pennington:

I am responding to your letter of February 13, 1978, forwarding a DEIS on the Proton-Proton Storage Accelerator Facility (Isabelle), Brookhaven National Laboratory, Upton, New York, DOE/EIS-0003-D; that letter was addressed to Dr. Edward P. Todd.

The National Science Foundation has only one comment, concerning the discussion of long-lived activity in the activated components on pages 4-21 and 4-22. The physical volume of such components may be as important as the total radiation involved. An estimate of the volume of such wastes should be made and compared with available off-site disposal facilities to determine whether any change in existing BNL procedures may be needed.

The NSF has no further comment and offers no objection to the proposed facility.

Sincerely yours,

Daniel Hunt
Deputy Assistant Director
for Operations

celerators - Accelerators are machines which accelerate either protons or electrons to high energies to permit study of their interactions with matter. Unlike reactors, they use energy rather than produce energy.

AEC - U. S. Atomic Energy Commission, dissolved January 18, 1975, and succeeded by the Energy Research and Development Administration and the Nuclear Regulatory Commission.

AGS - This is the 33 GeV proton synchrotron that currently exiats at Brookhaven. The terms AGS stands for Alternating Gradient Synchrotron.

Alpha Particle - The nucleus of a helium atom, carrying a positive charge.

Antiparticle - The equations of quantum mechanics indicate that for each particle that exists, there can exist another psrticle called the anti-particle. If a particle has a charge, then its antiparticle has the opposite charge. A particle and its antiparticle have the same mass, the same spin, the ssme mean life, and the same magnitude of magnetic moment (with opposite sign, however). When a particle and antiparticle interact, they may annihilate.

Antiquark - An antiparticle of the quark.

Aquifer - A layer of soil or rock which has openings that may contain water and allow the motion of water through the layer.

Available Energy - The energy of colliding particles that may be transformed into secondary particles that are produced in the collision. It may be less than the total incident energy due to conservation of momentum.

A&W - The architectural/engineering firm (Ammann & Whitney) responsible for the design and construction of the buildings and utilities for ISABELLE.

Backfill - That earth replaced in an excavated trench.

Background Radiation - Radiation received naturally from cosmic rays from outer space, received as a result of weapons testing or naturally received from the ground. Also includes radiation gained from medical x-rays. Includes all sources of radiation at a given point other than the source in question.

Barn - A barn is a unit of cross section. $1 \text{ Barn} = 10^{-24} \text{ cm}^2$. $1 \text{ Nanobarn} = 10^{-33} \text{ cm}^2$.

Baryon - Baryons are a class of particles, which includes the proton, neutron hyperons and cascade particle. All free baryons heavier than the proton eventually decay into end-products, one of which is the proton.

Beam Dump - Energy absorption device for halting particle beam.

Beam Energy - Energies of particle beams are measured in units called "electron volts" (eV). Thus, if a proton passes through a potential field of 500 volts, it will acquire an energy of 500 electron volts (500 eV). The AGS is capable of better than 30 billion electron volts (33 BeV in old units. Now called GeV); the ISABELLE machine design calls for a peak of 800 GeV in the center of mass energy.

Beam Intensity - A measure of the number of particles in a beam per unit time. A very large number of particles must be incident on a target in order that enough events occur to be statistically significant. A beam of high intensity must be available if an experiment is to be accomplished in a reasonable length of time. The AGS provides about 10^{13} protons/sec.

Beta Particle - An electron.

BNL - Acronym for Brookhaven National Laboratory. This is a research laboratory located on Long Island in the State of New York. It is operated for DOE by Associated Universities, Inc.

Boson - All elementary particles are placed into two classes: fermions and bosons. Two bosons, as distinguished from two fermions, can occupy the same state at the same time.

Bunches - In this statement, refers to bunches of electrons or positrons in a storage ring beam.

CERN - European Center for Nuclear Research, Geneva, Switzerland. It is a large accelerator center.

c.m. - Center-of-mass; refers to center-of-mass energy available when a beam strikes a target, or when two beams collide.

Collimator - Beam transport system device used to trim or define the beam and to protect magnets and other equipment from physical damage by the beam.

Cosmic Rays - Many nebulae act as particle accelerators and, as a result, the earth is constantly being bombarded by very energetic protons originating in these nebulae. They produce a great abundance of pi-mesons and other particles in the earth's surface in the form of mu-mesons, gamma-rays, electrons, etc. The cosmic ray flux at the earth's surface is approximately one particle per cm^2 per minute.

Cosmotron - The first high energy accelerator at BNL; decommissioned in 1967. The accelerator building and former experimental areas are used by the present ISABELLE staff for development purposes. It will be the assembly area for the ISABELLE superconducting magnets.

Cross Section - In addition to use in conventional sense, i.e., the cross section of a tunnel. The term refers to the measure of the probability for a certain reaction to occur. Cross section, σ, is expressed in units of 10^{-24} square centimeters. This is called a barn.

Cryogenic - Requiring lower temperatures than occur naturally on earth for satisfactory operation. Systems involving liquid nitrogen or liquid helium are examples of cryogenic systems.

Cut-and-Cover - A civil engineering tunnel construction technique. The tunnel is excavated from the surface and then covered with backfill as opposed to boring.

dB - Decibel, a measure of the intensity level of a sound wave. Because of the large range of intensities over which the ear is sensitive, a logarithmic rather than an arithmetic scale is more convenient. Originally a scale of intensity levels in bels was used but proved to be rather large, hence the decibel, 1/10 bel. The unit of measure is named in honor of Alexander Grahm Bell.

DOE - Department of Energy; successor Federal Agency to the Energy Research and Development Administration.

Electron - The lightest particle with non-zero rest mass occurring in nature is called an electron. It has a negative electrical charge of 1 unit. The electron is a fermion which undergoes only weak, electromagnetic, and gravitational interactions.

Electron Volt - The kinetic energy picked up by an electron while passing through a potential difference of one volt is called one electron volt. The electron volt is thus a unit of energy, equal to 1.6×10^{-19} J.

Elementary Particle - A particle which cannot be described as a composite of two or more other particles is called an elementary particle. In the 1930's the ultimate constituents of the atom appeared to be the electron, proton, and neutron. Since then, research has discovered an ever-increasing number of particles, or resonant states, whose role in nature is not yet clear. By the mid-1950's, there were so many particles that the concept of "elementary" had to be questioned. Recent theories suggest that all particles are composed to various combinations of truly elementary constituents called "quarks" (see Quarks).

ERDA - Energy Research and Development Administration; successor federal agency to AEC.

Filling Time - Time required to fill a storage ring with beams of proton bunches. Filling time could vary from five minutes to one hour followed by many hours of experimental time using the stored beams.

FNAL - The DOE laboratory located in Illinois that is the site of a 400 GeV proton synchrotron.

Fission - The breakup of a heavy nucleus into two or more lighter parts.

Fossil Fuel - Coal, oil, and natural gas; opposed to fuel power sources such as geothermal, hydroelectric, solar, and nuclear.

Fusion - The mass of two deuterons for example, is more than the mass of an alpha particle. Hence, if the two deuterons could be made to fuse, energy would be released in a process called fusion. The difficulty lies in overcoming sufficiently the electrostatic repulsion between the two deuterons in order to get them close enough together for the strong interactions to take hold.

Gamma Ray - Radiation similar to x-rays but of shorter wave length, emitted during some nuclear transformations.

GeV - Giga electron volt; represents one billion electron volts. This abbreviation replaces BeV, formerly used.

Gneiss - A laminated or foliated metamordic rock.

Hadrons - Includes more than 100 particles, or resonant states, in the baryon and meson families of particles. They all respond to, or are acted upon by, the strong nuclear force in nature.

Half-life - For unstable atoms or particles the half-life is the time required for 50% of a large number of them to transform to product atoms or particles.

Helium - The gas when circulated by a refrigerator is used to cool the superconducting magnets.

HEPAP - High Energy Physics Advisory Panel. The HEPAP is a group of eminent physicists throughout the United States who are empaneled to advise DOE on broad aspects and direction of high energy physics research in the United States. A special Subpanel on New Facilities, chaired by Professor J. Sandweiss of Yale, met in June 1977, and deliberated on specific recommendations and general comments in regard to the requirements of particle physics for new facilities.

HEP - Acronyn for high energy physics in the field of research and studies of the elementary particles and the forces between them.

HFBR or High Flux Beam Reactor - A fission reactor at Brookhaven National Laboratory used to provide beams with large numbers of low energy neutrons for use in a number of experimental programs.

Interaction Regions - Symmetrically located straight sections on the circumference of the ISABELLE ring where beam collisions will he permitted and experimental data taken.

Interactions - There are four primary types of interactions in nature. They are:

1. Strong interactions. Responsible for the force which holds the atomic nucleus together. These forces are characterized by their short range ($\sim 10^{-13}$cm) and their great strength. They are the primary force in most reactions involving nucleons, pi-mesons, K-mesons, and hyperons. Leptons are not affected by the strong interactions.

2. Electromagnetic interactions. These are the interactions of charged particles with electromagnetic fields. All reactions involving photons or gamma-rays are of this class.

3. Weak interactions. The class of interactions responsible for beta-decay, pi-meson decay, mu-meson decay, k-meson decay, and the decays of the lambda, sigma and psi particles. These interactions are many orders of magnitude weaker than either the strong or the electromagnetic interactions.

4. Gravitational interactions. The weakest, by far. Responsible for an apple falling to the ground.

Isotope - Nuclei which have the same number of protons but different numbers of neutrons are called isotopes.

ISABELLE - The proposed proton-proton storage ring to be built at Brookhaven National Laboratory. It will have a peak center of mass energy of 800 GeV.

ISR - Intersecting Storage Rings, CERN. This is the only existing proton-proton storage ring in operation. It has a peak center of mass energy of 60 GeV.

Jψ Particle - A fundamental particle discovered simultaneously at BNL and SLAC.

Lepton - This is a generic name for a class of light particles which have no strong interactions. Included among the leptons are e^+, e^-, μ^+, μ^-, ν, $\bar{\nu}$.

LCW - Low conductivity water; used for cooling accelerator and experimental apparatus; consists of domestic water which has been distilled to remove or reduce mineral content such that the water resists electricity flow.

LILCO - The Long Island utility that supplies electrical power to BNL.

Linac - Acronym for linear accelerator.

Luminosity - The measure of the rate at which the beam particles collide in a storage ring. ISABELLE design calls for 3×10^{33} per square centimeter per second.

Moraine - An accumulation of earth, stones, etc., deposited by a glacier.

m - meter. Abbreviation for meters, a unit of length in the metric system equivalent to 3.28 feet or 1.09 yards. In conjunction with the eventual conversion by the United States to the metric system, and to be compatible with the worldwide scientific community, design criteria for ISABELLE were developed using metric measures.

Mesons - Particles with mass greater than the electron mass and less than the mass of a nucleon (proton or neutron) are called mesons.

MeV - MeV is a unit of energy equal to one million electron volts.

μCi/ml - Microcurie per milliliter; a unit of measure of radiation.
1 curie = the quantity of any radioactive atom of a specific nuclear constitution in which the number of disintegrations per second is 3.7×10^{10} (1 μCi = 3.7×10^{4}/sec.)

mrem - milli-rem (0.001 rem, see definition for Rem)

Mu-meson - The mu-meson (sometimes called "muon"), is a particle with mass = 207 electron masses and a charge of either plus or minus one electron charge. The mu-meson is a decay product of the pi-meson, and the mu-meson itself decays into an electron and two neutrinos with a mean life of 2.2×10^{-6} seconds (i.e., two microseconds.). The mu-meson interacts only weakly with other particles, and in all properties except its mass and its decay resembles an electron.

MW - Megawatt; one million watts of elecrricity or 1340 horsepower. A measure of electrical power.

Neutrino - A neutral particle that is required to keep the energy, momentum, and other properties of the particles emitted in radioactive decay equal to those of the original atom or particle. It is considered to have (rest) mass equal to zero.

Neutron - The neutron is an electrically neutral particle with mass equal to 1838 electron masses. Neutrons are stable when bound in nuclei, but a free neutron decays into a proton, and electron, and a neutrino with a half-life of twelve minutes.

Nucleon - "Nucleon" is the common name given to either a proton or a neutron, the constituents of nuclei.

OSHA - An act of Congress: Occupational Safety and Health Act.

Peneplain - A land surface worn down by erosion nearly to a plain.

Photon - When the electromagnetic field is represented in quantum-mechanical terms, by particles, they are called photons. Light, x-rays, and α-rays are examples of photons. Photons have charge and mass equal to zero, like neutrinos, but other properties are different.

Positron - A particle identical to an electron, but with positive charge. The positron is the anti-particle of the electron.

Proton - A proton, the nucleus of the lightest and most abundant hydrogen isotope, is a positively charged stable particle of mass - 1836 electron masses.

Quantum Mechanics - In order to calculate the properties and behavior of a system of microscopic particles, such as an atom, the theory of quantum mechanics was developed by Schrodinger and Heisenberg. The theory differs from classical mechanics in that it refers only to the probability of a certain state or the average "expectation" value of a certain measurement, and in that it predicts that energy and angular momentum are always multiples of discrete "quanta."

Quark - Many of the properties of strongly interacting particles, the hadrons, seem understandable, if one thinks of these particles as though they were made up of either 3 quarks (for the baryon family) or a a quark-antiquark pair (for the meson family). Whether or not quarks exist is an open question. None as yet have been discovered. If the quark theory can be proved, it would greatly simplify the classification of elementary particles.

adioactive - Giving off radiant energy in the form of particles or rays by the disintegration of atomic nuclei. Such radiant energy is called radiation and, if exposed to sufficient quantities, is harmful to plant and animal life.

Rem - A special unit used for expressing ionizing radiation dose which includes both physical and biological factors. This unit allows the direct comparison of biological dose from all forms of ionizing radiation such as x-rays, gamma, beta, protons, and neutrons.

Resonance - Can be used interchangeable with "particle" or "excited state." The identification of the constitutents of matter on the subatomic level is indistinguishable from the determination of forms of energy. The distinction between matter and energy vanishes.

rf - Radiofrequency. In order to impart energy to electrons in accelerators or storage rings, it is necessary to feed them with high frequency microwave power. Low frequency electric power from the local utility company at a steady flow is transformed into short rapid bursts of extremely high power and high frequency.

Roentgen - A unit of measure of ionizing electro magnetic radiation (x or gamma). One roentgen corresponds to the release by ionizionation of 83.8 ergs of energy per gram of air.

SLAC - Acronym for Stanford Linear Accelerator Center; a 20 GeV electron linear accelerator and laboratory sponsored by ERDA and located at Stanford University.

Strangeness - After the discovery of the various hypersons and k-mesons, it was found that the details of the production and decay of these particles could not be understood within the context of existing theories. For this reason, they were called "strange particles." The work was formalized by Gell-Mann, when he suggested assigning a "strangeness" quantum number of +1, 0, -1, or -2 to all particles. It is then possible to account for all observations by assuming that the total strangeness of a system is conserved in a strong interaction, such as the production of strange particles, but not conserved in weak interactions such as their decay.

Storage Ring - An experimental device used by physicists to store subatomic particle beams for the purpose of studying the results of particle collisions. The beams are contained in evacuated tubes which form a ring and steered by magnets. The ring is filled by use of an injecting accelerator and beams can be stored for several hours. Colliding-beam storage rings provide an ideal solution to obtaining high center-of-mass energies with moderate beam energies because with two beams of equal energy colliding head-on, the result is that the sum of the energies carried by both of the beams is available for interaction.

Superconductivity - That property exhibited by certain metals and alloys which when cooled to sufficiently low temperatures ($\approx 4°K$) exhibit zero resistance to the flow of electric current.

W meson - When the weak interaction is represented, in quantum-mechanical terms, by particles, they are called W mesons. They are expected to have a very large mass, and have not yet been observed experimentally.

C - METRIC PREFIXES & CONVERSIONS

pico	$(=10^{-12})$	p
nano	$(=10^{-9})$	n
micro	$(=10^{-6})$	µ
milli	$(=10^{-3})$	m
centi	$(=10^{-2})$	c
deci	$(=10^{-1})$	d
kilo	(10^{3})	k
mega	$(=10^{6})$	M
giga	$(=10^{9})$	G
tera	$(=10^{12})$	T

LENGTH

1 centimeter (cm) = 0.39 inches (in.)
1 meter (m) = 3.28 feet (ft.)
1 kilometer (km) = 0.62 miles (mi.)

AREA

1 square meter (m^2) = 10.76 square feet ($ft.^2$)
1 hectare (ha) = 2.47 acres

VOLUME

1 liter (l.) = 0.26 gallons (gal.)
1 kiloliter (kl.) = 264. gallons (gal.)
1 cubic meter (m^3) = 1.31 cubic yards

WEIGHT

1 kilogram (kg) = 2.2 pounds (lbs.)
1 metric ton (M.T.) = 1.10 tons

D - SYMBOLS AND ABBREVIATIONS

A	ampere
Ah	ampere-hour
atm	atmosphere pressure
BeV, GeV	billion electron volts
°C	degrees Centrigrade
Ci	curie
cm	centimeter
cm^2	square centimeter
cm^{-2}	per square centimeter
cm^3, cc	cubic centimeter
cu	cubic
d	day
dB	decibel
dBA	decibel (A scale)
diam	diameter
dkl	dekaliter
D O	dissolved oxygen
E	east
eV	electron volt
ft	foot
ft^2	square foot
ft^3	cubic foot
g	gram
gal	gal
GeV, BeV	billion electron volts
mm	millimeter
MT	metric ton
MV	million-volts
MVA	million volt-amperes
MW	megawatts
N	north
nCi	nanocurie
no	number
pCi	picocurie
ppm	parts per million
R	roentgen
S	south
sec	second
gpm	gallons per minute
ha	hectares
hr	hour
in	inch
K	degrees Kelvin
kg	kilogram
kl	kiloliter
km	kilometer
kV	kilovolt
kVA	kilovolt-ampere
kW	kilowatt
kWh	kilowatt-hour
l	liter
lat	latitude
lb	pound
m	meter
m^2	square meter
m^3	cubic meter
mCi	millicure
MeV	million electron volts
mg	milligram
mgd	million gallons per day
min	minute
ml	milliliter
sec^{-1}	per second
sec^2	second squared
sq	square
µCi	microcurie
V	volt
vs	versus
W	watt
W	west
WSW	west-southwest
yr	year

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