SSC-N-6

Land Acquisition Requirements for the SSC: Background for the Site Parameters Document[1]

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Introduction

The construction and operation of the Superconducting Super Collider will require acquisition of land for the various underground structures, for above ground facilities, and for buffer zones. The Main Ring consists of a tunnel with a cross-section of approximately ten feet in diameter forming a circle with a circumference of 60 miles (using 6 tesla magnets) or 100 miles (using 3 tesla magnets). The High Energy Booster is similar in cross-section to the Main Ring, but with a circumference of only 4 miles. In addition to these there is a closely-integrated grouping of buildings and facilities comprising the Campus area with the Linac and Low Energy Booster accelerators (cf. Fig. 1). In order to build and operate the Collider sufficient land must be acquired by easement and/or by transfer of title to protect the integrity of the machine and its operation and provide space for necessary equipment and activities.

The Collider Main Ring

The Collider Main Ring, while it encompasses a very large area, only impacts a narrow band along its perimeter. The tunnel itself is only 9-10 feet in diameter. The integrity of the machine and its environment requires that there be no non-Laboratory activities within a minimum of 20 feet of the tunnel. In addition, there must be no non-Laboratory activity within six hundred feet in the radially outward direction in the plane of the machine. For a tunnel close to the surface this protection would probably require transfer of the title to the land. Figure 2 illustrates the calculation of the buffer zone required on the outer radius of the tunnel.

The easements around the tunnel are required to provide a radiation buffer zone against the possibility of accidental loss of the circulating beam from the ring. To put this in perspective, in over a decade of operation of the 400 GeV, 4 mile circumference accelerator at the Fermi National Accelerator Laboratory in Illinois the circulating beam has not been lost catastrophically. In case of malfunctions a multiply-redundant system of detectors and safety devices removes the beam from the machine in a controlled way into a heavily-shielded enclosure, the abort dump. The superconducting magnets envisaged for use in the SSC are more sensitive to radiation than the iron-dominated magnets of the Fermilab conventional ring. For this reason more stringent requirements, similar to those adopted for the newer Fermilab superconducting Tevatron will be adopted for the SSC. However, in order to avoid any reasonable possibility of controversy in such a sensitive area as environment, very conservative guidelines are adopted with respect to radiation protection as it affects the general public.

It is hypothesized that, contrary to experience, the maximum-intensity beam can be lost anywhere in the Ring once a year. Along with this, the criterion for the allowable radiation level under this hypothesis is set at 10 mrem/yr, which is less than 10% of the legal limit of 170 mrem/yr. Under these guidelines a minimum cover of 6 meters of soil with a density of 2.1 gm/cm^3 is required all around the tunnel for hadron shielding.[2,3]

In addition to hadrons, or nuclear-type particles, a second type of radiation, muons, would emanate from such a beam loss. This radiation is more penetrating, because it interacts less strongly with matter. This radiation appears to the outside of the ring, and remains in the plane of the ring. It forms a narrow core tangential to the ring which extends out 2 kilometers for a level of 10 mrem/yr, noted as our criterion above.[4] Given the curvature for a ring of 6 tesla magnets in a 20 TeV accelerator, the radial distance containing this vector is less than 200 meters. (Fig. 3, after van Ginneken.)

The buffer zone required around the ring is, therefore, approximately 20 feet to the inside of the ring and 600 feet to the outside, as illustrated in Figure 4. Control of this zone would take the form of an easement, unless the tunnel were close to the surface in which case the land would likely have to be held in fee simple by the Laboratory. For a near-surface tunnel constructed by cut-and-cover, a temporary construction easement broader than the buffer zone would be required to accommodate the slopes required for the open cuts. The region above the tunnel and buffer would be an unfenced region. Continuous occupancy within the buffer zone would not be permissible, but the presence of wells or similar penetrations in the muon zone would not be a problem.

Besides the protective zone required for the tunnel, 30 acres of land will be required at twelve locations around the Ring for the refrigeration and power supply systems, 1 acre at twelve locations for tunnel ventilation equipment and emergency tunnel exits, and 10 acres at two locations for beam handling equipment. These are illustrated with their relationships to the tunnel buffer zone in Figs. 5 and 6. All of this land, since it contains surface structures and equipment, must be held in fee simple by the Laboratory. (In addition 95 acres will be required at one location for the shielded beam abort system.) Twenty acres of this, containing surface structures, will be held in fee simple. The remaining 75 acres could be in the form of an easement as described below, page 7.

The Experimental Areas

At six locations around the Ring, clustered in twos or threes or uniformly distributed around the Ring as illustrated in Figure 5, will be the Experimental Areas at the beam Interaction Regions. Scaling from designs for the Colliding Detector Facilities at Fermilab and the experimental areas at LEP in Geneva, and taking account of the relative isolation of the Experimental Areas, a surface area of 60 acres is judged to be appropriate for each of the Experimental Areas.

Based on an analysis by van Ginneken[5], the hadron shield around the collision hall must increase to 7.2 meters from the 6 meters used elsewhere around the ring. In addition, a hard core of muons emerges from the interaction region in narrow cones in the forward and backward directions.

This is illustrated in Figure 7. Unlike the muon buffer zone around the ring where the expectation is that, in fact, no muons will be seen in the life of the machine, in this region the muons are a direct result of the operation of the machine, and will be present whenever the accelerator is operating for collisions.[6] For a near-surface collision hall a narrow strip of land, some 10 feet on either side of the tangent at the interaction point, extending for 2.1 miles in both directions from that point, must be held in fee simple by the Laboratory. For a deeper collision hall an easement will suffice as for the buffer zone around the Ring. Most of this land will already be included in the Ring buffer zone.

The Injector, Campus, and Test Beams Area

In terms of area, the Injector and the Campus Area form a single entity in the Reference Design. This approach was chosen to facilitate the operation and maintenance of the facility, to improve communications, and to minimize construction costs and schedules by providing a higher density for utilization of expensive facilities. Area utilization is quite different for the two activities, however. In addition, a segment of the Collider Ring traverses the area. See Figure 8.

1. The Injector. The Injector consists of the Linac, the Low Energy Booster (LEB) and the High Energy Booster (HEB). The Linac and LEB are relatively low energy accelerators, 1 GeV and 70 GeV respectively, in a tight configuration and will be located in underground enclosures close to the surface. Because of their size and their shallow burial, and their proximity to the campus, the land for these will be held in fee simple by the Laboratory along with the Campus as decribed below.

The HEB will probably be constructed at the same elevation as the Collider Ring since it is simpler to bend the two 70-GeV beams from the LEB down to the HEB, than to bend the two 1 TeV beams down from HEB to the Collider Ring. Under this hypothesis in the case of a tunneled Collider Ring, the land requirements for the HEB could be provided by an underground easement with only a limited area required on the surface for access and a single service area. However, when the requirements are considered for various injection and ejection service buildings, aborts, access roads, and utilities, this does not seem practical, so in the Site Parameters Document, it is assumed that the entire area, comprising 2000 acres for Injector, Campus, and Test Beams is owned by the Laboratory.

2. Test Beams Area. As shown in Figure 8, the land area for the combined Injector/Campus complex is configured to allow a maximum distance for a 1 TeV Test Beam Area supplied with protons from the HEB. The Test Beam Area utilizes the existing LEB/HEB injection tunnel for transporting and splitting the extracted beam in the manner of the Proton Area at Fermilab. It is presumed that a test beam target station will be dedicated to each of the major detectors, six in all. The splits would follow the model of the Proton area at Fermilab with the target stations below grade level to minimize the muon problem. The available length from the extraction point to the extreme corner of the area is 7500 feet. For reference the length of the Neutrino Area at Fermilab from AØ (extraction) to the 15-foot bubble chamber is 8000 feet, with the target at 3600 feet from AØ.

This arrangement makes the test areas convenient to the shops and facilities of the Central Laboratory area, while utilizing the existing utilities networks. It also simplifies access control and radiation security by making surveillance easier.

3. The Campus. The addition of the Test Beams Facility as shown in Figure 8 required a change from the Reference Design in the configuration of the lower end of the Campus as depicted in Figures 1 and 8. Figure 9 shows a possible rearrangement which separates the Industrial and Warehousing area from the Campus proper. In view of the nature of these activities and the need to handle and store the large number of mildly radioactive materials, like shielding, that accumulate around an accelerator laboratory with time, it is probably advantageous to make this separation in any case, if the Laboratory is to be generally open to the public.

The Beam Aborts

Each of the accelerators that comprise the SSC complex has a beam abort dump or dumps where the beam(s) from that accelerator can be disposed of during tune up and studies or in case of malfunction. These constitute the main radiation burden of the SSC on the site. For the Linac, LEB, and HEB, the abort dumps are all contained within the 2000 acres comprising the Campus/Injector Area. The design of these will follow the well-proven designs for the comparable facilities at Fermilab.

For the Collider Ring two dumps are provided in the Reference Design. The extraction channels leading to the dumps are 1 kilometer in length tangential to the Collider tunnel. The extraction channels make use of conventional water cooled magnets so a source of low conductivity water (LCW) must be provided. Specialized power supplies and controls must be provided, along with monitoring equipment for beam position and for radiation levels around the dumps. Each of the abort channels must have an area of ten acres which is owned by the Laboratory to provide for these facilities. The tunnel itself is already contained in the muon buffer zone provided for the Collider Ring.

Unlike the muon buffer zone provided around the Collider Ring for a hypothesized once per year loss, the abort dump will be in continual use. Based on 500 fills per year, each dump will see approximately 10^{17} protons/year. The radiation burden due to hadrons will be contained by constructing the dump as a massive steel and concrete monolith sealed off from the surrounding geology. The muons must be absorbed in an extended buffer zone downstream of the dump. From Figure 10, after van Ginneken, to reduce the radiation level to the desired 10 mrem/yr for 10^{17} protons will require an exclusion zone of something over 5 kilometers in length downstream of the dump with a radius of approximately 50 feet about the axis of the dump. For a near-surface site the 75 acres encompassed by these criteria must be owned by the Laboratory. For a deeper site a subsurface easement suffices as for the Collider Ring.

References

[1] SSC-15, Superconducting Super Collider Siting Parameters Document, 13 May 1985

[2] A. Van Ginneken, "Shielding Calculations from 2-20 TeV" Report of the 20 TeV Hadron Collider Technical Workshop, March 28-April 2, 1983, Appendix III-5

[3] R.H. Thomas, J.B. McCaslin, "General Shielding for the 20 TeV Hadron Collider Facility: Hadron Considerations", ibid., Appendix IV-6

[4] N. Mistry, "Some General Considerations on Radiation Shielding for the 20 TeV Collider:, ibid., Appendix IV-8

[5] A. Van Ginneken, "Rough Estimates of Dose Rates around Interaction Regions", private communication, 25 March 1985

[6] A De Rujula, R. Rückel, "Neutrino and Muon Physics in the Collider Mode of Future Accelerators", Proceedings of the Lausanne Conference on a Large Hadron Collider in the LEP Tunnel, Vol II, p. 573-596, Geneva, 1985

Table I
Summary of Land Requirements

	Fee Simple (acres)		Fee Simple or Easement (acres)	
Collider Main Ring	6T	3T	6T	3T
Tunnel & Buffer[1]			4522	4023
Refrigerators/Power Supplies (12)	360	360		
Vent./Exit (12)	12	12		
Beam Handling (2)	20	20		
Aborts	20	20	75	75
Subtotals	412	412	4597	4098
Experimental Areas (6)	360	360	20	20
Injector, Campus, & Test Beams	2000	2000		
TOTALS	2772	2772	4617	4118
MAX. TOTALS	7389	6890		

[1] The bend radii from RDS Table 4.7-1, Table 4.4-1, are used rather than the average radii, since the loss is a local problem. Circumferences are from Tables 4.4-1 (scaled) and 7-1.

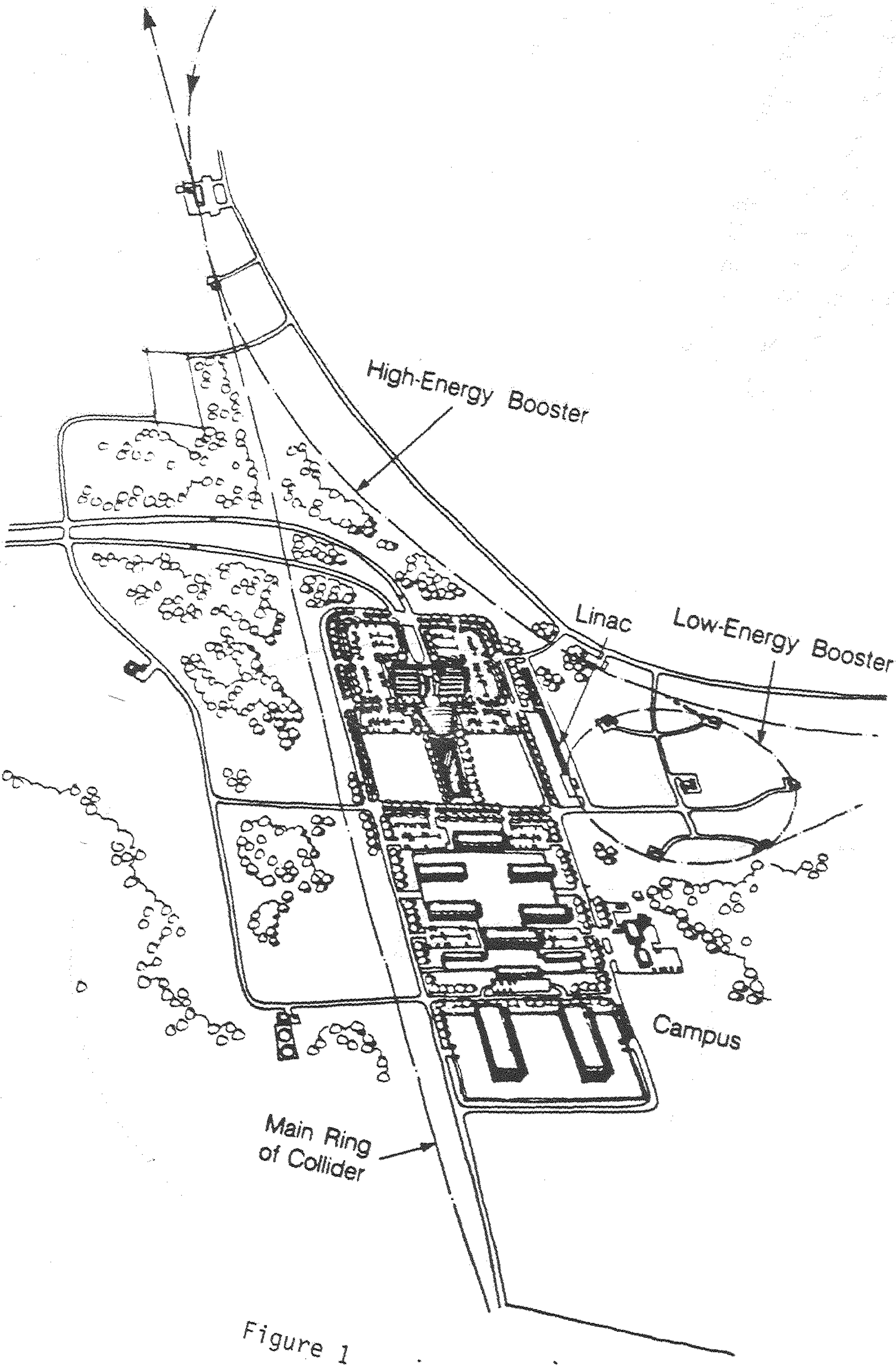
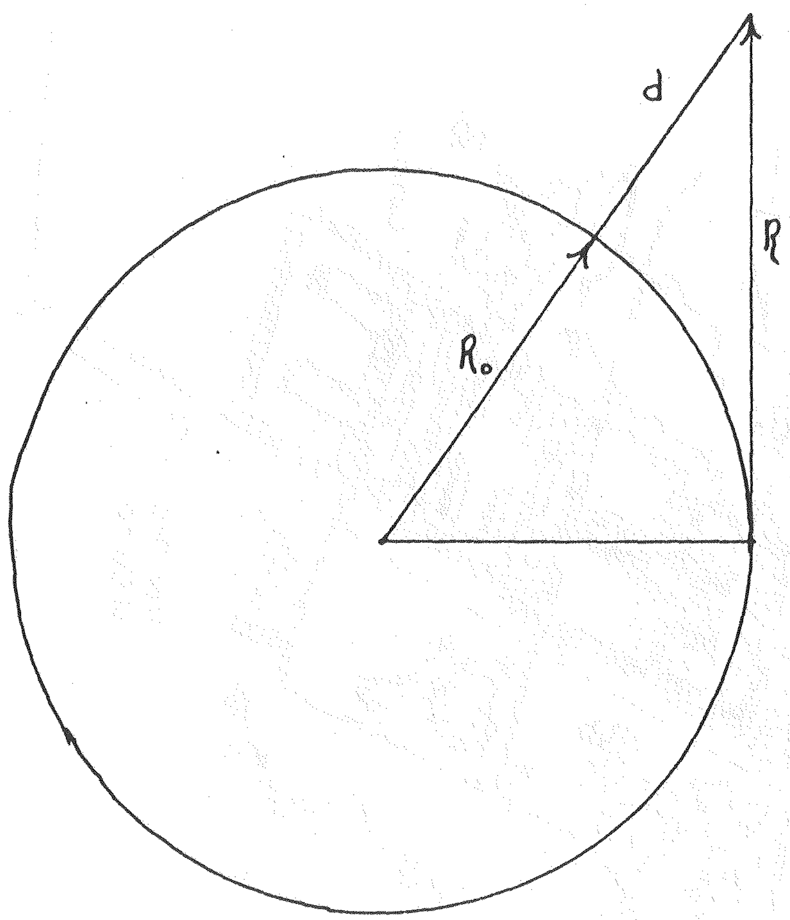

High-Energy Booster
Linac
Low-Energy Booster
Campus
Main Ring of Collider

Figure 1

4-11-85



$$d = \sqrt{R^2 + R_o^2} - R_o$$

For 20 TeV, $\begin{cases} B = 6 \text{ tesla} \\ R_o = 11.1 \text{ Km (bending rad.)} \\ \rho = 2.1 \text{ gm/cm}^3 \end{cases}$

$\left.\begin{array}{l} R = 2.0 \text{ Km} \\ d \approx 180 \text{ m} \end{array}\right\}$ for 10 mRem

$I_o = 1.3 \times 10^{14}$ ($\mathcal{L} = 10^{33} \text{ cm}^{-2} \text{ sec}^{-1}$)

SSC Collider Ring
Muon Shielding Geometry

Figure 2

3-22-85
A.V.G.

1.3×10^{14} protons lost , B = 6 Tesla , 20 TeV R = 11.1 km.

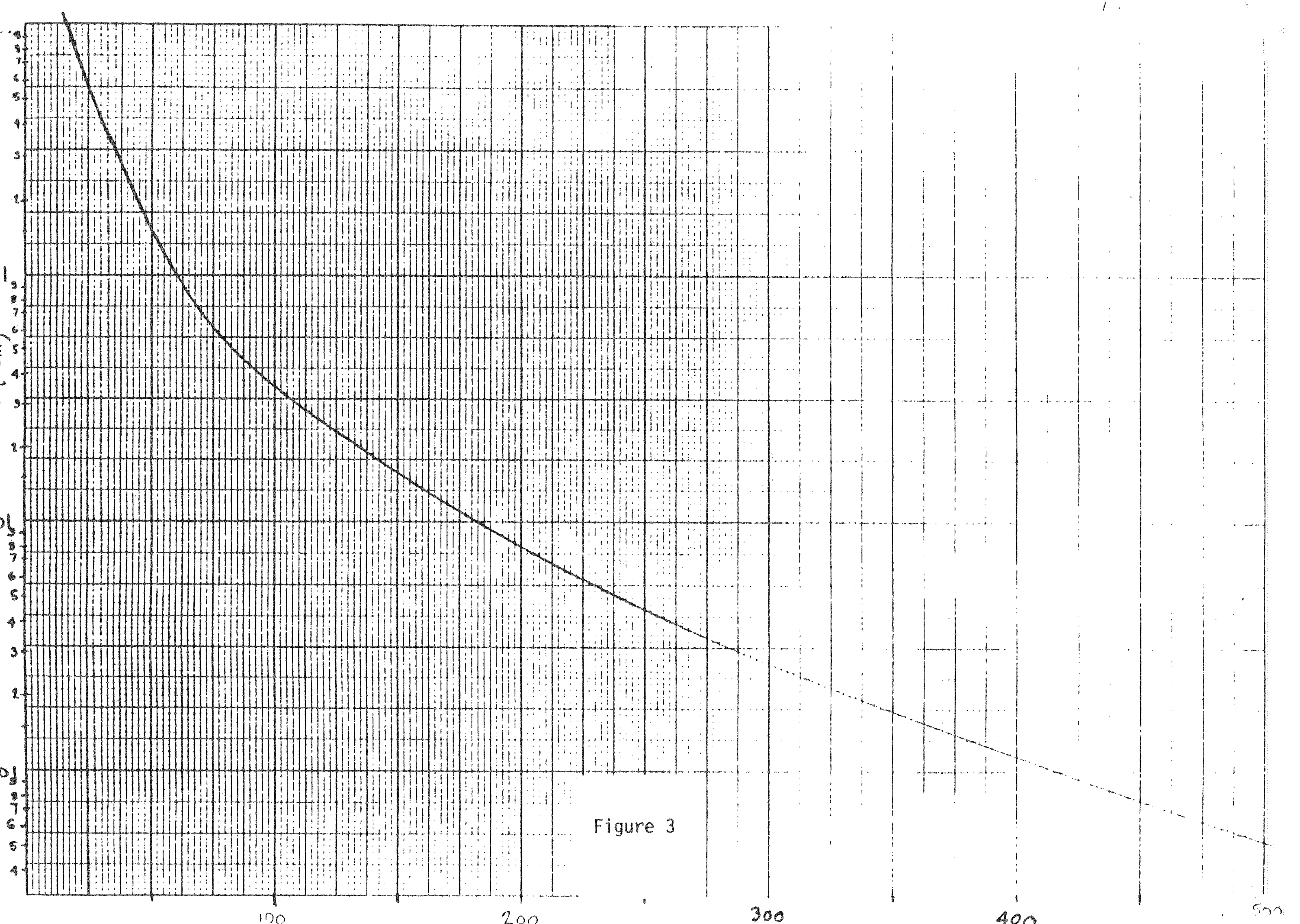
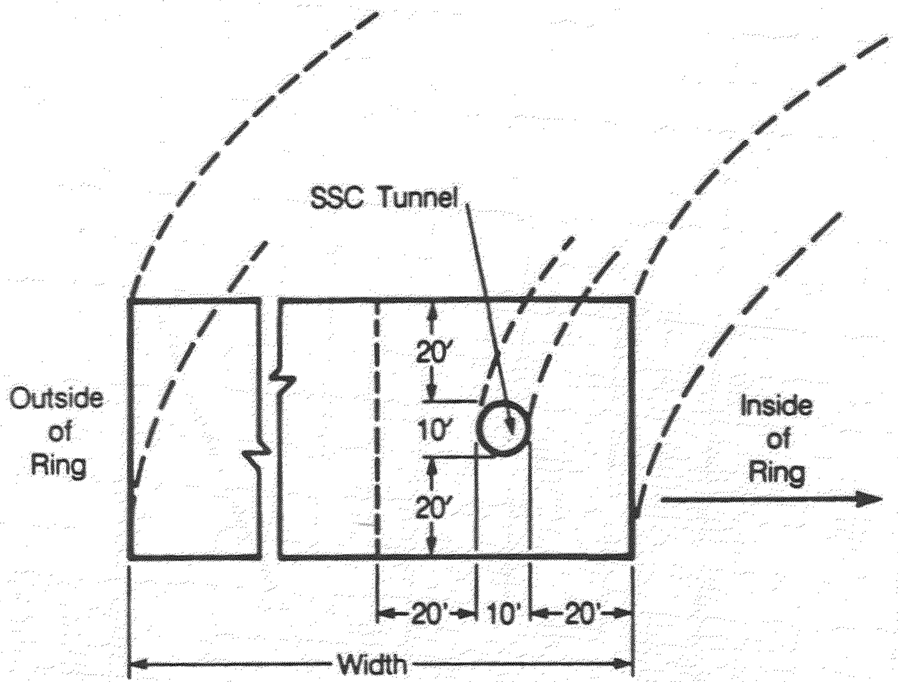


Figure 3



XBL 853-9780

Figure 4

4-11-85

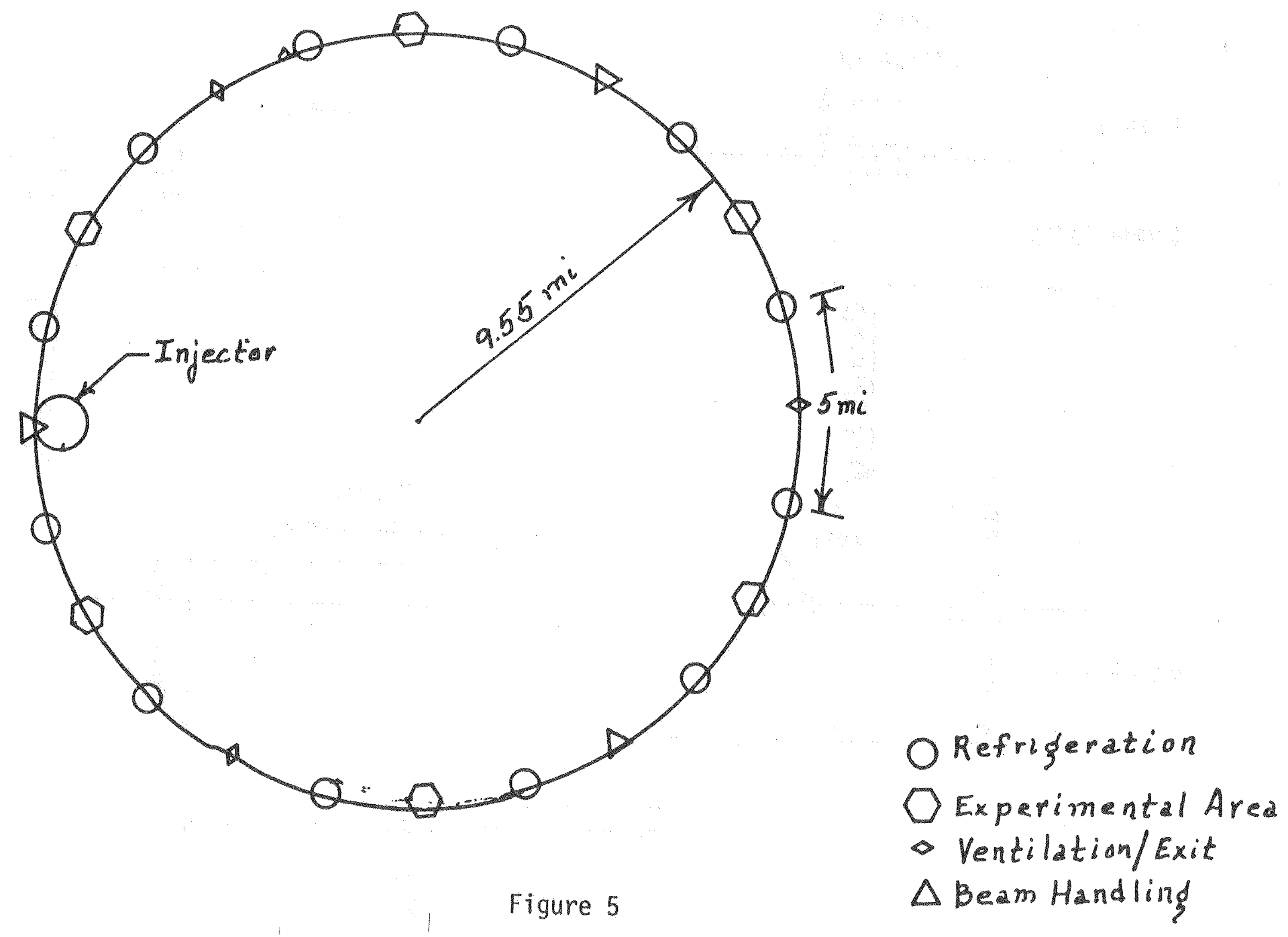
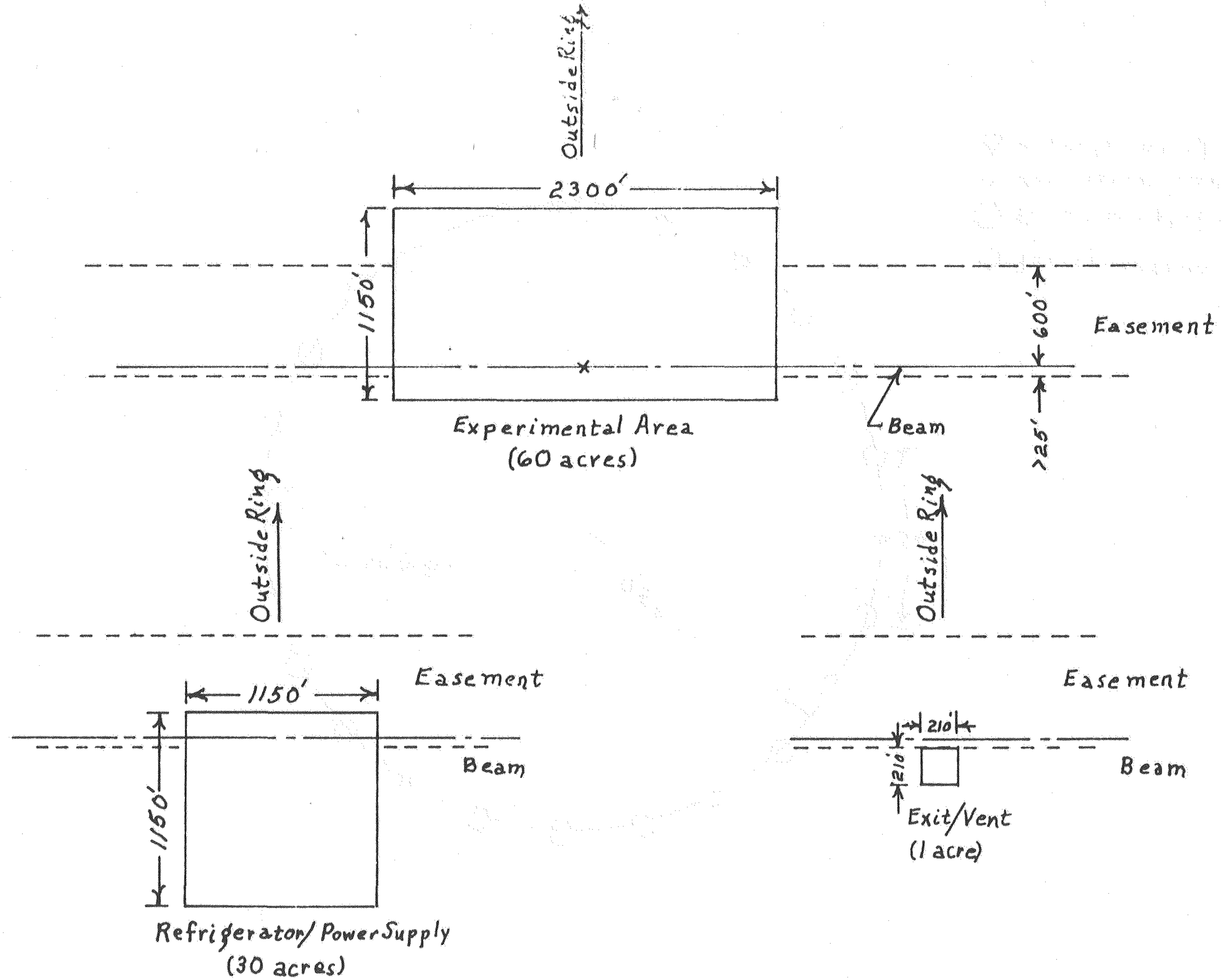


Figure 5

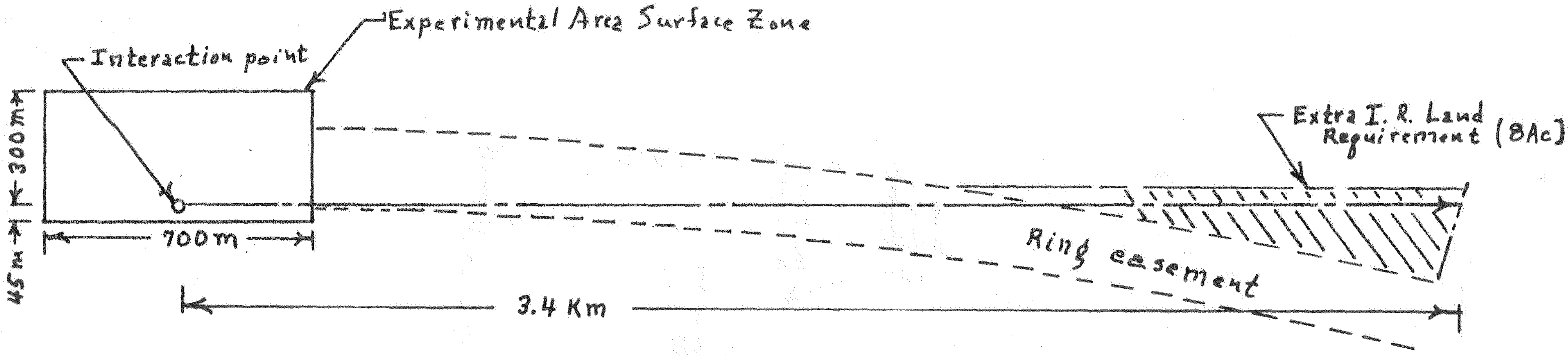
4-12-85
TET



SSC Land and Easements

Figure 6

6 May 1985



Land Requirements, Interaction Region (symmetrical)

Figure 7

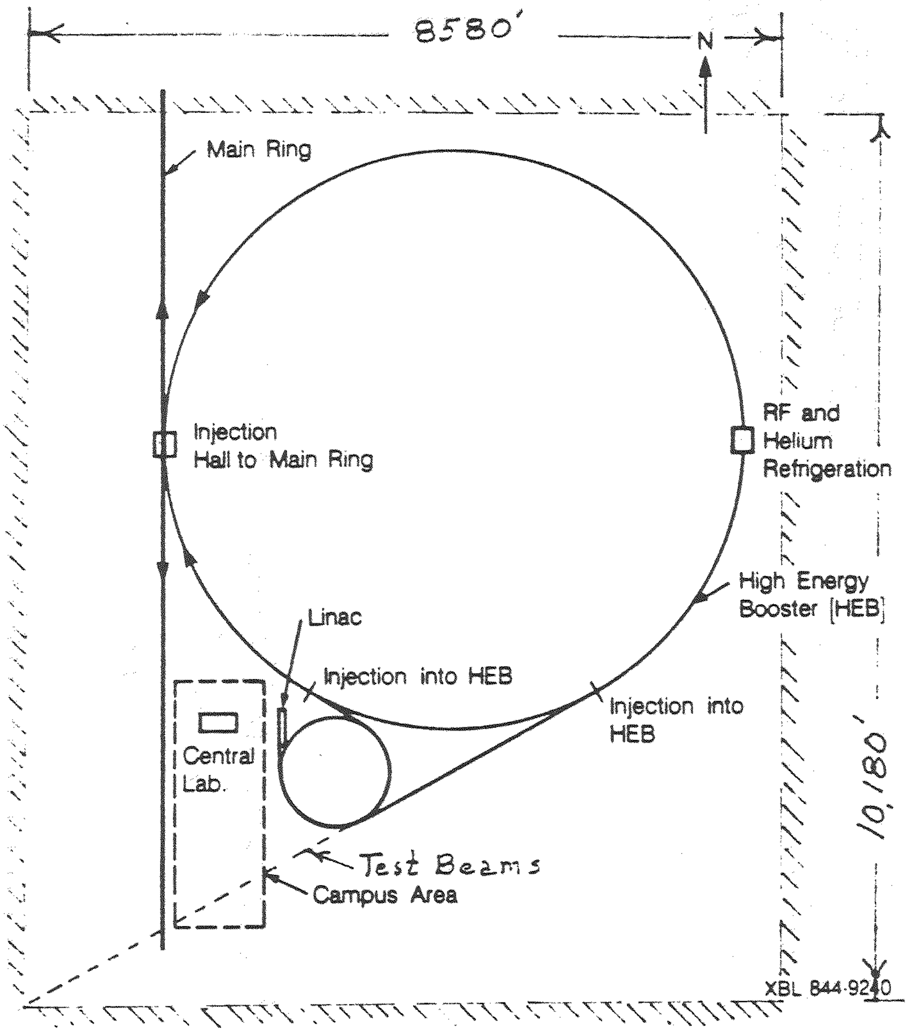

8580'
N
Main Ring
Injection
Hall to Main Ring
RF and
Helium
Refrigeration
High Energy
Booster [HEB]
Linac
Injection into HEB
Injection into
HEB
Central
Lab.
Test Beams
Campus Area
10,180'
XBL 844-9240

Figure 8

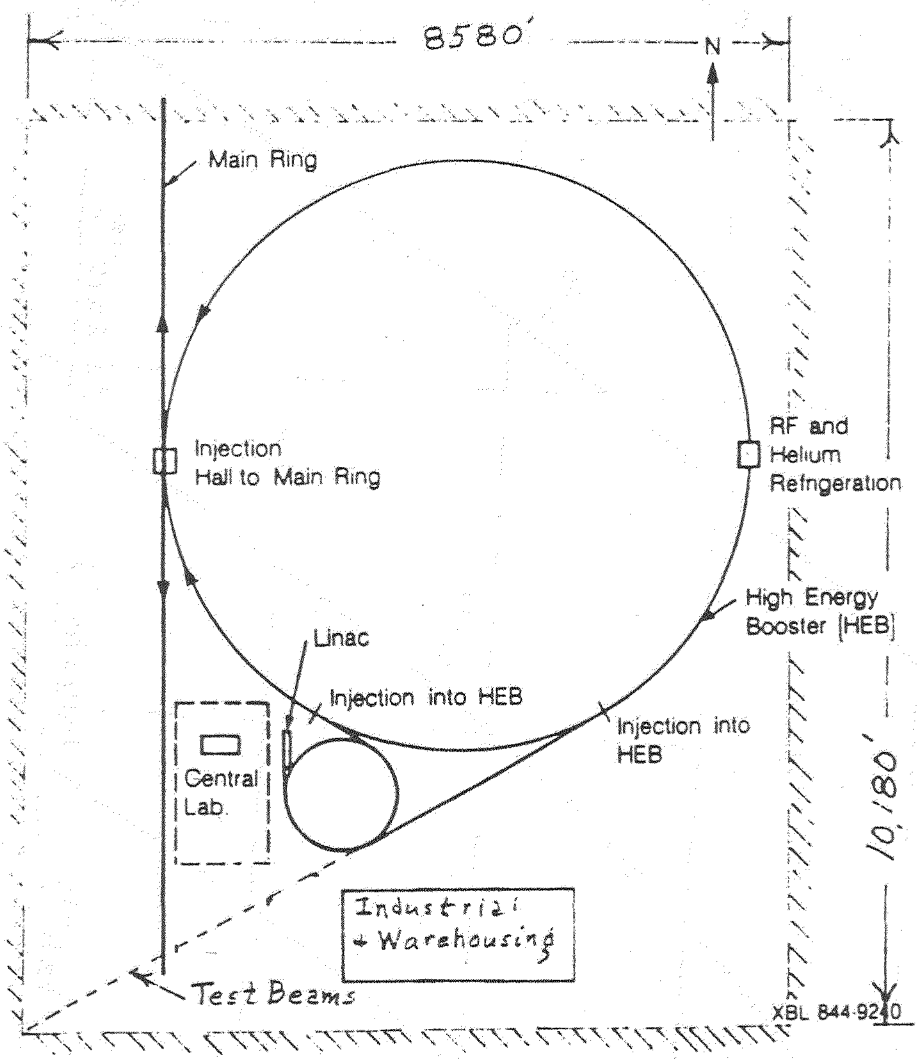
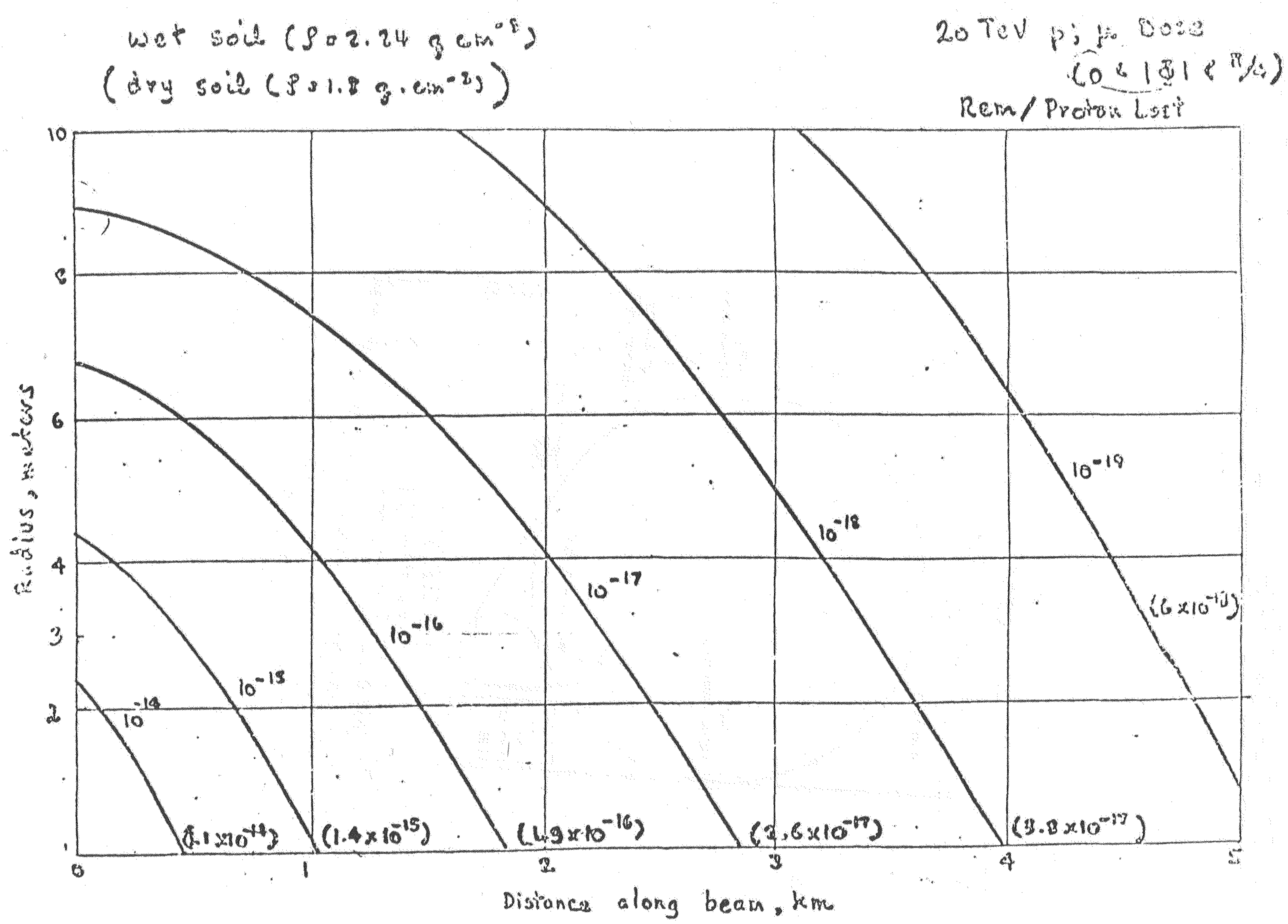

8580'
N
Main Ring
Injection
Hall to Main Ring
RF and
Helium
Refrigeration
High Energy
Booster [HEB]
Linac
Injection into HEB
Injection into
HEB
Central
Lab.
Industrial
+ Warehousing
Test Beams
10,180'
XBL 844-9240

Figure 9



wet soil (ρ = 2.24 g cm^{-3})
(dry soil (ρ = 1.8 g cm^{-3}))
20 TeV p; μ Dose
($0 < |\Phi| < \pi/2$)
Rem/Proton Lost
10
8
6
4
3
2
1
Radius, meters
0
1
2
3
4
5
Distance along beam, km
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-19}
(1.1 x 10^{-14})
(1.4 x 10^{-15})
(1.9 x 10^{-16})
(2.6 x 10^{-17})
(3.8 x 10^{-17})
(6 x 10^{-19})

Figure 10