SSCL-SR-1041 (Rev. 1)

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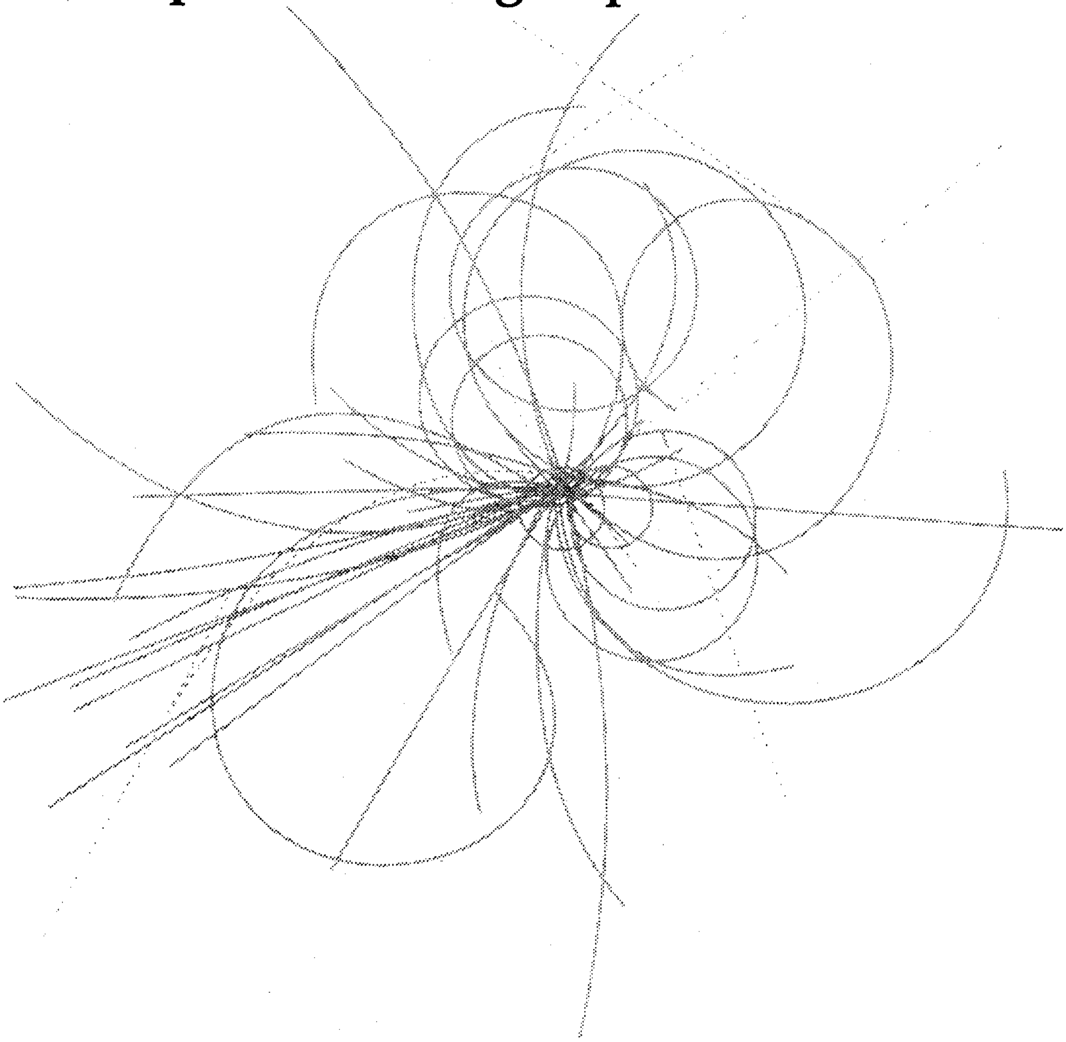
Superconducting Super Collider Laboratory



Footprint Characterization Document

L. Coulson, R. Crawley, H. Edwards, D. Getz,
M. Gilchriese, R. Schwitters, P. Shelley,
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June 1990
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FIGURES

TABLES

1.0 LAND REQUIREMENTS FOR THE SUPERCONDUCTING SUPER COLLIDER

The land requirements for the Superconducting Super Collider (SSC) are specified in the attached Figure 1.1, which shows the definitive configuration developed by the SSC Laboratory with the U.S. Department of Energy (DOE) to accommodate the parameters of the SSC. Figure 1.2 shows the adaptation of these requirements to the specific physical features of the Texas site by the Laboratory, the Texas National Research Laboratory Commission (TNRLC), and the DOE. Variances in this configuration from that offered by the State of Texas in their Site Proposal arise from developments in the design of the accelerator, and from the evolution of the requirements of the experimental program of the facility that have occurred since the issuance of the Invitation for Site Proposals (ISP) by the DOE in April 1987. Further variances arise from the accommodation of the facility to the geographical and geotechnical features of the site as determined by a detailed geotechnical exploration program.

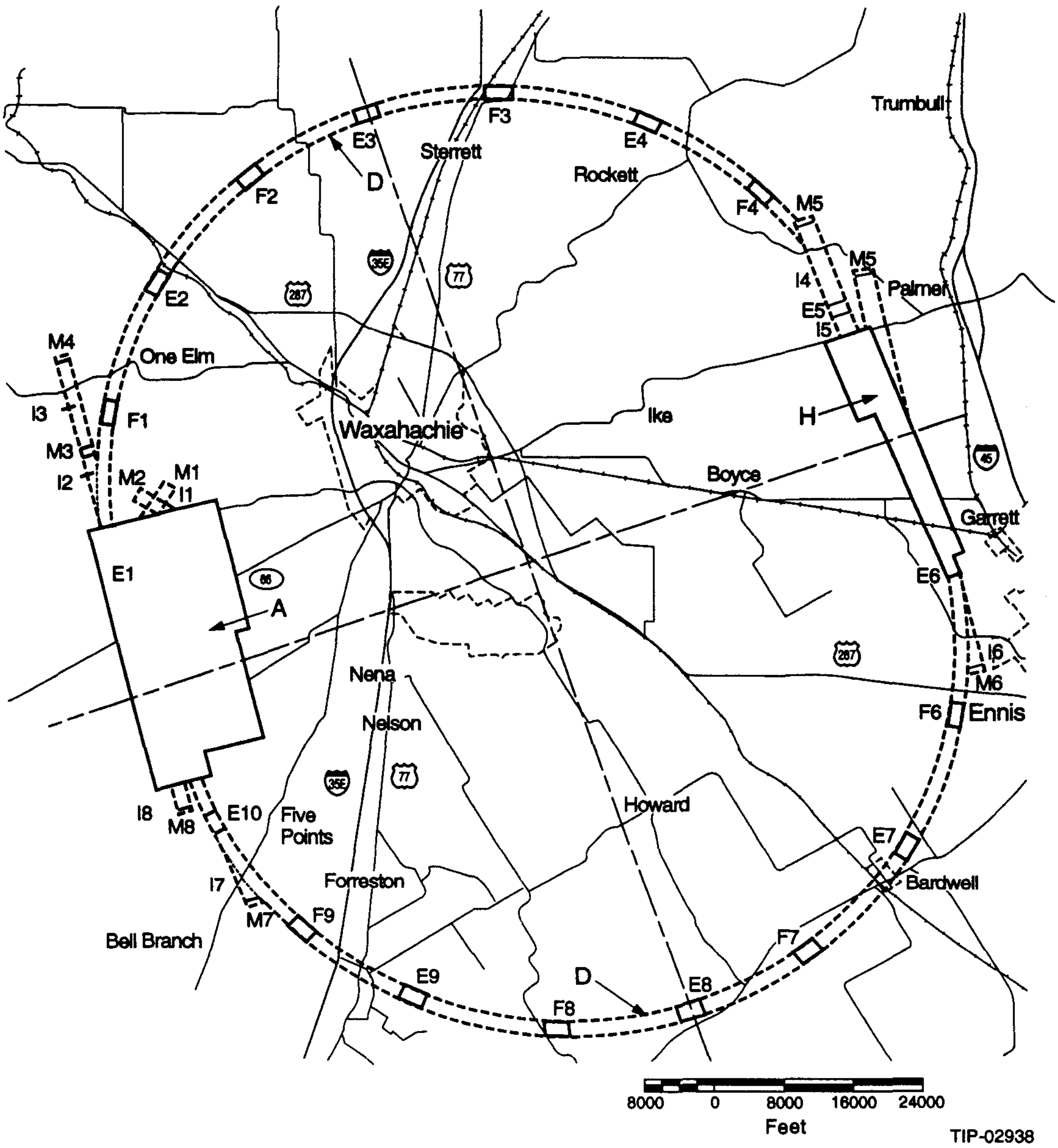

Figure 1.1. SSC Land Area Template.

Area	Dimensions
M1	500 x 1,000
M2	500 x 1,000
M3	1,000 x 1,000
M4	500 x 1,000
M5	500 x 1,782
M6	500 x 1,578
M7	500 x 1,673
M8	500 x 1,000
E5	1,787 x 1,218

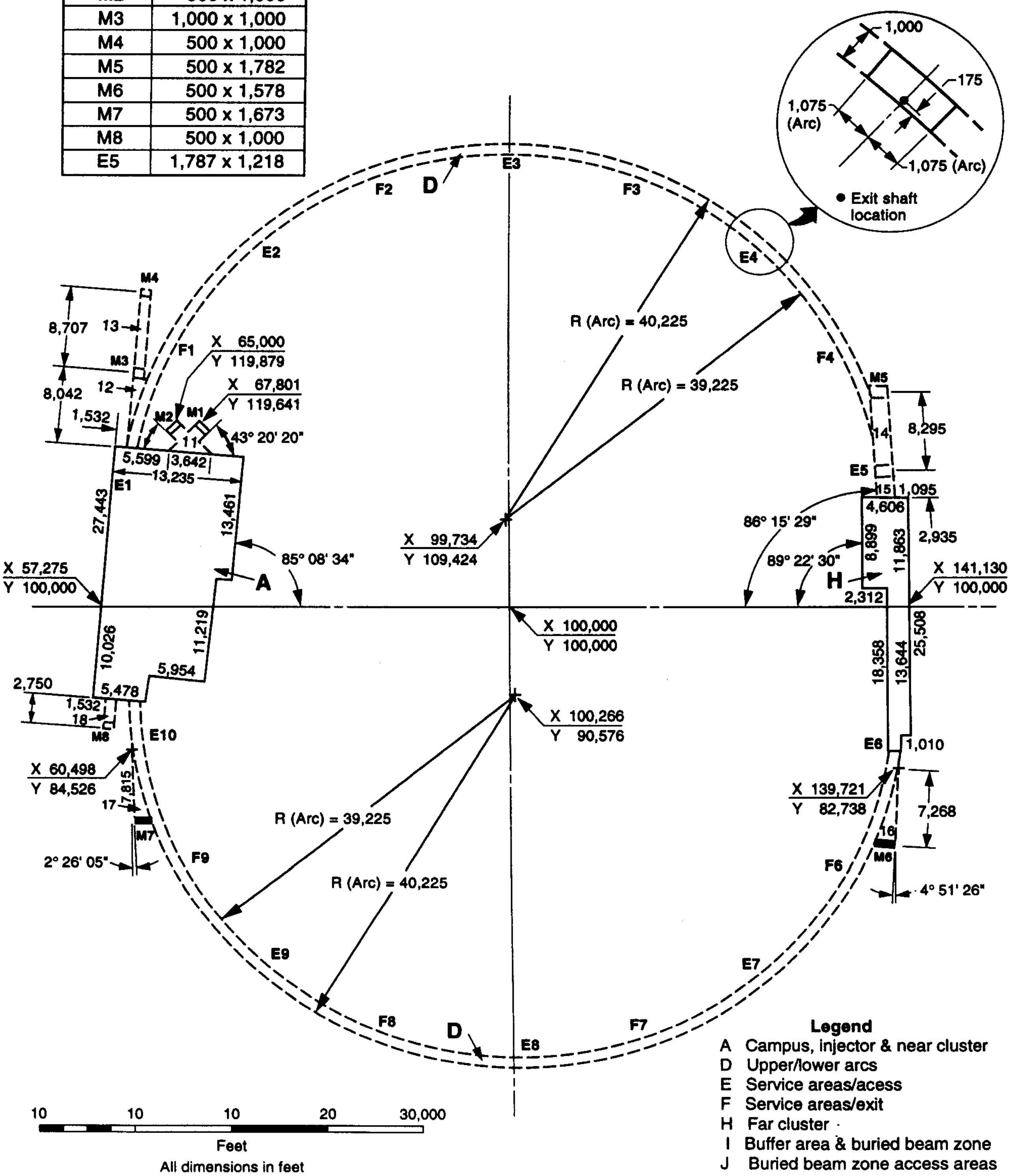

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Figure 1.2. SSC Site Configuration.

The specific developments in the design of the accelerator which modify the land area requirements are an increase from 1 to 2 TeV in the energy of the proton beams injected into the Collider ring, modification of the Collider lattice design to increase the amount of focusing, inclusion in the lattice of a beam switching capability (bypasses) to provide flexibility in the experimental program, and provision for high intensity calibration and test beams from 2 TeV High Energy Booster (HEB) and the 200 GeV Medium Energy Booster (MEB). These modifications lead to a 1.6% increase in the circumference of the Collider ring, and a rearrangement of the land areas in the cluster regions on the East and West sides of the ring. In addition, a slight shift and rotation of the ring were required relative to the ring placement in the Texas Proposal to place the massive detectors in a favorable geotechnical environment.

These changes and their implications for the definition of the SSC "footprint" on the Ellis County site are discussed below. The detailed technical documentation of the footprint is to be found in SSC–SR–1049 "Computer Aided Design of the Digital Footprint" (2 vols), March 1990.

2.0 ACCELERATOR SYSTEMS MODIFICATIONS

Accelerator Description

In this section, the major accelerator features with significance for the footprint are described. The overall layout is shown to scale in Figure 2.1. Many of the relevant features are not apparent in a scale drawing; Figure 2.2 is a not–to–scale schematic of the layout. The major changes to the accelerator chain since the ISP version have received comment in the preceding section. Some further elaboration appears in the succeeding two subsections

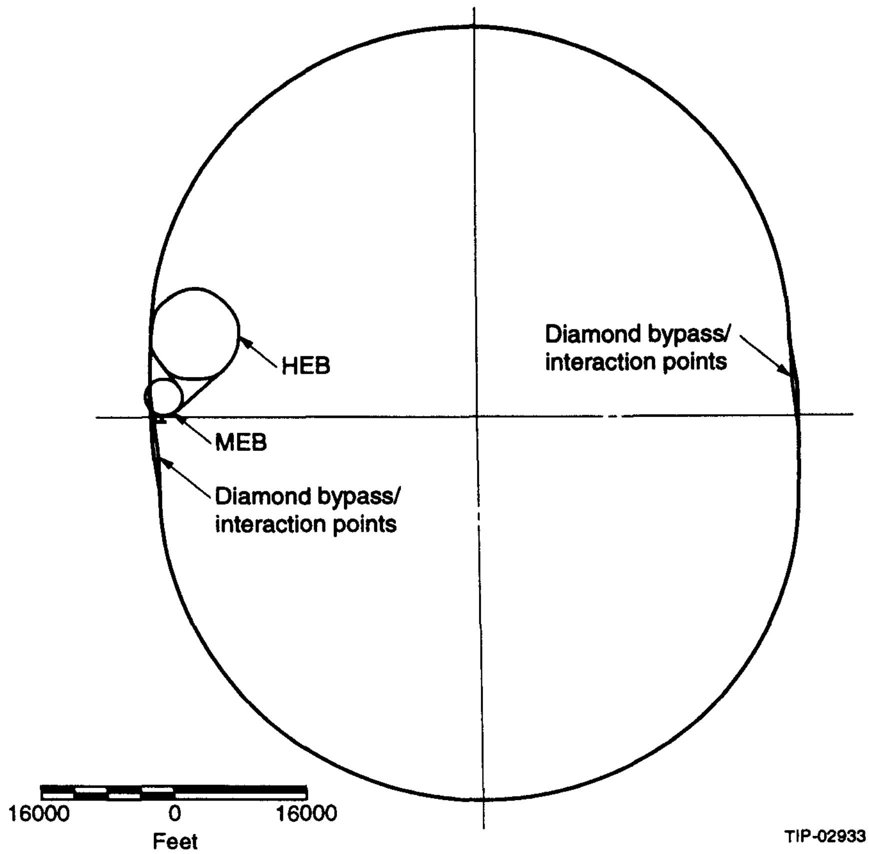

Figure 2.1. SSC Accelerator Layout.

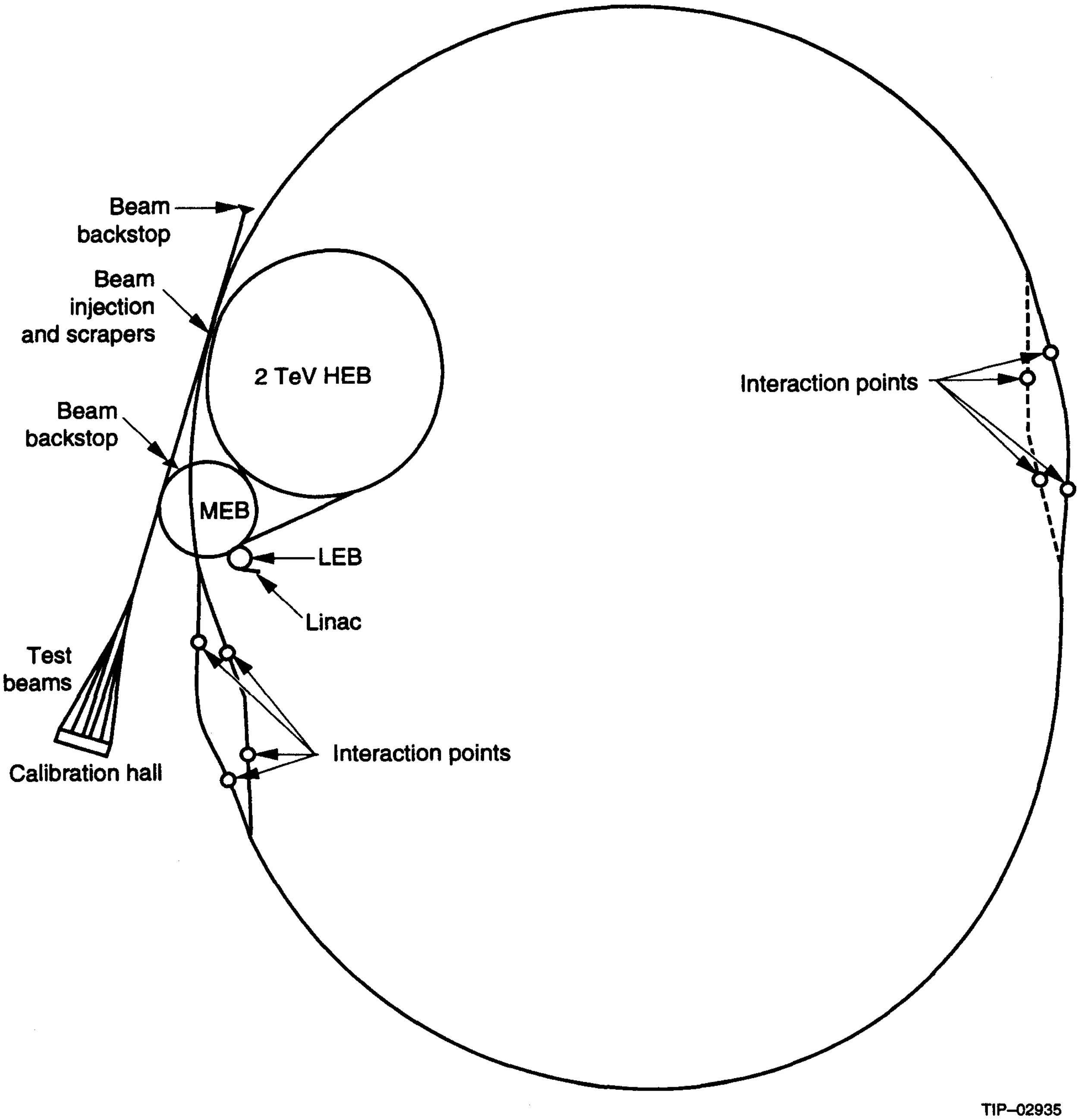

Figure 2.2. SSC Accelerator Schematic.

Collider

The recent changes to the Collider that affect the footprint are:

- Reduction of the quadrupole spacing to 90 m.
- Accommodation of injection energy up to 2 TeV.
- Introduction of interaction region clusters with provisions for adding beam bypass tunnels.
- Minor adjustment of location and strength of bending sections for improved footprint.
- Redistribution and enlargement of service areas.

The first change was made in order to reduce the beam size during the critical injection process. Reduction of the quadrupole spacing from just over 114 m to 90 m implies a larger mean radius of curvature in the arcs, for fixed bend field. In the absence of other changes, the result would be an east–west bulge of several hundred feet with respect to the ISP layout.

Higher injection energy reduces sensitivity to persistent current effects and simplifies the system of correction and adjustment magnets. Final choice of injection energy must await the conclusions of dynamics and cost studies that are in progress, but the conclusion to date is that provision in the footprint should be made for an injection energy of up to 2 TeV.

The use of interaction region clusters with the option of illuminating one or the other of two pairs of crossing points has major operational implications, but relatively modest impact on the footprint. A bypass arrangement in a cluster is depicted in Figure 2.3, where it is seen that the maximum lateral extent is 300 ft. The interaction regions are offset along the periphery of the Collider to facilitate construction of experimental halls.

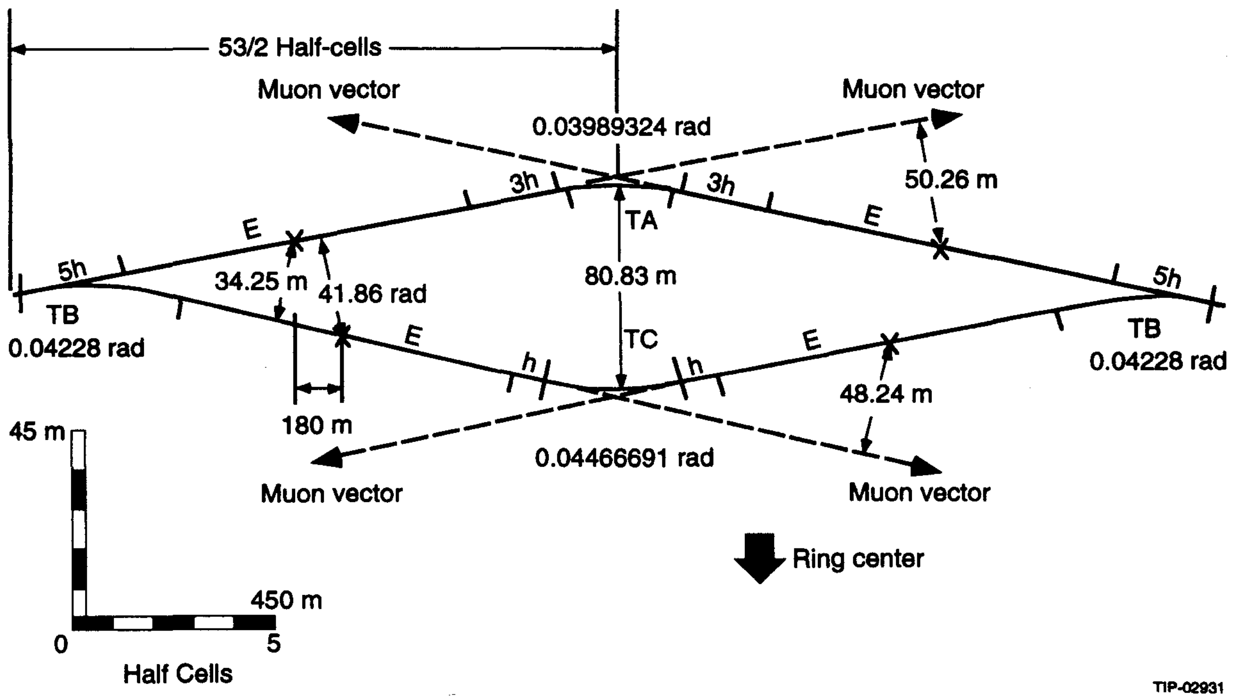

Figure 2.3. Beam Bypass Illustration.

On the west and east sides of the Collider rings there is a single "utility" straight section, with such accelerator functions as injection, acceleration, and beam backstops concentrated on the west. The space between the west utility and west bypass region has been adjusted by the use of bend cells to improve the surface location of the campus area and the subsurface placement of the experimental halls.

The service areas along the arcs were redistributed to suit the revised bend, utility, and interaction region configuration, as well as surface features at the site. The land areas were increased from those specified in the ISP for the reasons outlined in Section 6, below.

With reference to Figures 2.1 and 2.2, the Collider rings may be described as follows. To the north and south are circular arcs of mean radius 12,032 m, each subtending 168 degrees. Each arc of each ring contains 392 half–cells of 90 m length. This half–cell plays the role of a unit of length; all functional segments of the rings can be expressed in integral multiples of half cells.

Proceeding south from the west terminus of the northern arc, the west utility straight section is encountered. The straight section itself follows a dispersion suppressor and is 15 half–cells in length. Injection from the high energy booster to both Collider rings, and extraction from the Collider rings to the external beam backstops is performed here. In addition, the radiofrequency acceleration systems and beam scrapers are to be found here.

Departing from the utility, 12 half–cells with standard bending are sandwiched between two dispersion suppressors to provide a total deflection of 7.4 degrees. This unit is followed by the interaction region cluster.

The outer branch of the cluster consists of 23 half–cells without bends, within which one of the interaction points will be found, followed by a 7 half–cell, 2.3° bend of mean radius 15,792 m, and finally a second set of 23 straight half–cells for the second interaction point.

The inner branch begins with a 7 half–cell, 2.4° bend of mean radius 14,901 m. As a result of the additional bending, the straight path for the interaction region is 16 half–cells in length. The interaction region is followed by a 7 half–cell reverse bend through an angle of 2.6° at mean radius 14,104 m. After the second 16 half–cell interaction region insertion, a final 7 half–cell bend concludes the inner branch.

Because the lattice has 180° rotational symmetry, the description of the east side proceeds from south to north with the same language as the west from north to south, insofar as dimensions are concerned. Of course, the option exists of not including one or both of the branches of an interaction region cluster in the initial construction. The space corresponding to the utility region on the east is free of major accelerator systems, and is available for future development.

The geometrical description of the preceding few paragraphs is summarized in Table 2–1. The total circumference of 87.1 km is to be compared with 85.7 km for the ISP lattice. The bend field remains 6.60 T.

TABLE 2–1.COLLIDER LATTICE *(REV. 4)*, 8 August 1989.

NAME	NO. 1/2 CELLS	LENGTH (M)	AV. RADIUS (M)	ANGLE (DEG)
D	3	270	13536.1279	1.14285714
U	15	1350		
D	3	270	13536.1279	1.14285714
12H	12	1080	12032.1137	5.14285714
D	3	270	13536.1279	1.14285714
Begin Bypass– Outer Branch				
5h	5	450		
S+3h	18	1620		
TA	7	630	15792.1492	2.2857129
3h+S	18	1620		
5h	5	450		
Begin Bypass– Inner Branch				
TB	7	630	14900.6354	2.42246992
S+h	16	1440		
TC	7	630	14104.4001	–2.55922556
h+S	16	1440		
TB	7	630	14900.6354	2.42246992
End Bypass				
D	3	270	13536.1279	1.14285714
Cluster Total	92	8280	39534.08785	12.0
Arc	392	35280	12032.1137	168.0
Superperiod	484	43560	13865.5786	180.0
Ring	96887120	1	13865.5786	360.0

Injector

The injector chain and the associated test beam lines are shown in Figure 2.4. The dominant feature is the 2 TeV High Energy Booster (HEB). It is fed in turn by a 200 GeV Medium Energy Booster (MEB). The 10 GeV–scale Low Energy Booster (LEB) and the linear accelerator are too small to impact the footprint.

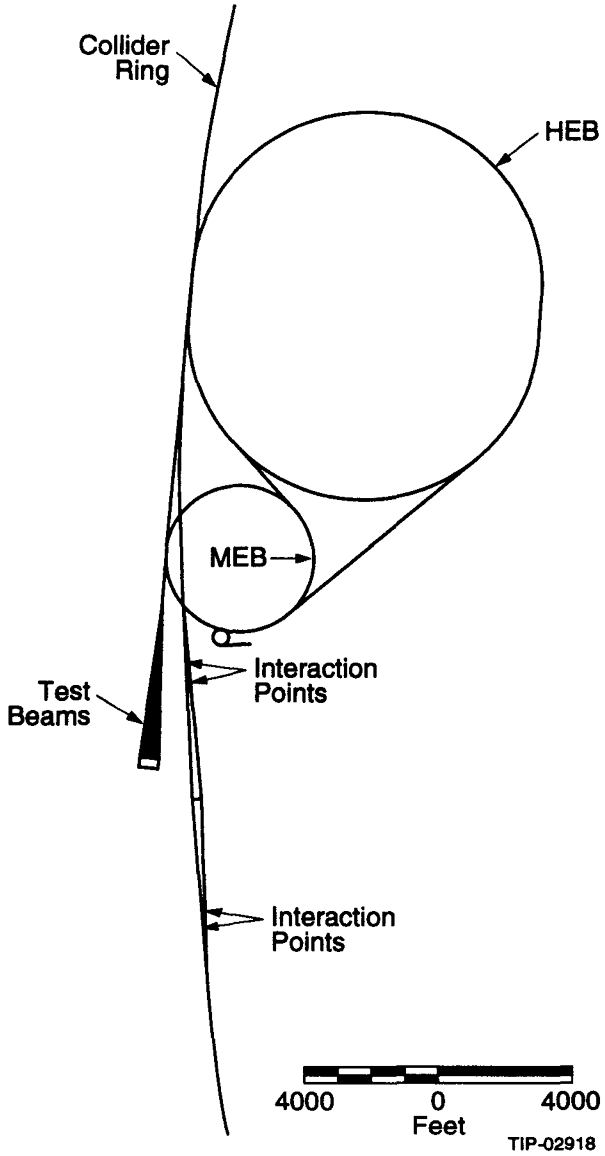

Figure 2.4. West Cluster Region.

The provisional lattice for the HEB is a ring of circumference 10.8 km, at a dipole field of 6.2 T. Six long straight sections are provided for accelerator utilities and future expansion. The HEB is separated from the Collider rings by only about 14 m, and therefore is located at essentially the same level as the Collider enclosure. Just as the west utility region in the Collider serves a variety of functions, so also does the west straight section in the HEB. The HEB will circulate protons in either direction, and both injection lines to the Collider are located in this straight section. The final septa for slow extraction to the test beam areas will be located here as well.

With its circumference of approximately 4 km, the MEB is not a major factor in determining the footprint. However, the desirability of bringing test beams from the MEB to the same area potentially served by the HEB did play a minor role in adjusting the bend center distribution in the Collider. The MEB is located near the surface, and beams extracted from it join the future beam line rising from the HEB below. The test beams are described in Section 3.

Operating Cycles and Radiation Sources

It is assumed that during the lifetime of the project, the peak luminosity may grow by an order of magnitude, or to 10^{34} cm^{-2} sec^{-1}, solely by increasing the number of particles per bunch. The circulating charge in one of the Collider rings is then 4×10^{14} protons. In assessing the Collider as a radiation source, beam backstops, interaction regions, scrapers, and accidental loss must be taken into account.

For the discussion of Section 4, it will be assumed that the full intensity full energy beam will be directed into the beam backstops 500 times per year. At each experimental area, an interaction rate of 1 GHz will be assumed to persist for 6,000 hours per year. Flux from scrapers will be predicated on 20% of the full circulating charge (that is to say, at 20% of the annual beams absorbed). Finally, it will be assumed that the entire beam can be lost once per year at any point on the periphery of the Collider rings.

The majority of HEB cycles can be used for the generation of test and calibration beams. At 30 pulses per hour, each accelerating 10^{14} protons to 2 TeV, for 5,000 hours per year, the beam backstop must accommodate 1.5×10^{19} protons per year.

Similarly, many MEB cycles can be directed toward the test areas. At 20 pulses per minute, each accelerating 5×10^{13} protons to 200 GeV, for 5000 hours per year, the test area beam backstop must accommodate 3×10^{20} protons from the MEB in addition to the flux from the HEB.

Digital Lattice

A precise beam optics solution for the Collider lattice has been developed, and it is this solution that provides the input "digital lattice" for the digital footprint referenced near the end of Section 6. The description in the form given in Table 2–1, in terms of average radii and turning angles, differs from the digital lattice at the one–foot level, an entirely negligible difference for the purposes of this document.

3.0 EXPERIMENTAL SYSTEMS AND TEST BEAMS

In this section we describe the impact of experimental systems and test beam requirements on the determination of the footprint.

Experimental Halls

The general nature of experimental apparatus and related facilities is described in detail elsewhere.[1] For the purposes of this report it is important to note that:

- Up to four underground experimental halls may be constructed initially with the potential for constructing five more halls.
- Two of the initial halls will be located in the outer branch of the west cluster bypass and two halls in the outer branch of the east cluster bypass. Two additional halls could be added in the inner branch of the west cluster bypass and two in the inner branch of the east cluster bypass in a future upgrade; in addition, the possibility exists of locating an additional experimental facility in the utility straight section on the east side.

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[1]M. Marx, *et al.*, "Site–Specific Study of SSC Support Facilities for Four Generic Detector Designs," RTK Report, July 1989; O. Orban, Addendum, August 1989.

- Some of the halls may be constructed by open–pit excavation, resulting in an excavation area of significant size.
- Some of the detectors may weigh up to 50,000 tons, imposing constraints on the foundations of the underground halls required to house such detectors.

It is also important to recognize that the nature of the experimental program will be determined in the future by specific proposals for experiments made to the Laboratory. It is therefore necessary to establish a footprint now that will allow for implementation of the full potential experimental program for the SSC. The footprint selected will accommodate a diverse experimental program, allowing for future upgrades in the Collider and, if required, in the injector complex.

The criteria for determining the footprint from considerations of experimental systems in the Collider are:

- The heaviest experiments should be located to maximize the amount of Austin chalk in the sidewalls and foundations of the experimental halls.
- The depth of the experimental halls should be chosen such that hall sizes are not significantly limited by the excavation volumes required for open cut construction.
- The desirable luminosity at an interaction region might be as high as 10^{34} cm^{-2} sec^{-1}, a factor of 10 over design, which would result in 2×10^{16} interactions per year. The shielding for muons produced in the proton–proton collisions—the muon "vectors" from each IR—should accommodate this higher luminosity.
- Sufficient land should be acquired to allow for open excavation of the experimental halls.
- The environmental and aesthetic effects of the excavations for the large experimental halls should be taken into account in positioning the experimental areas.

Test and Calibration Beams

The success of Collider experiments has historically been dependent on the availability of calibration and test beams for the detector modules, especially the calorimeters. The experience at CERN in the UA1 and UA2 experiments, and at Fermilab in the CDF and D0 experiments, was used as a basis for formulating a table of specifications for calibration beam requirements for SSC experiments. To meet some of these requirements, calibration beams with very high flexibility are required. Experience at the existing facilities indicates, strictly speaking, a need to provide energies between 0.5 GeV and 2 TeV; they must be capable of high beam intensity of up to 10^9 particles per pulse; and they must be capable of delivering relatively pure electron, hadron and muon fluxes. They must also have the capability of tagging particle momenta to a precision of a fraction of a percent. The footprint includes space adequate to accommodate a number of 2 TeV calibration beams, as well as space to attenuate muon radiation associated with such beamlines (Section 4). To meet some of these requirements in the face of budgetary constraints, a design based on the wide band beam at Fermilab[2] was scaled down. The design for the initial calibration beam system assumes that only 200 GeV beams from the MEB will be available. Experience of earlier Collider experiments has shown the importance of detector component test facilities operating in the hundred GeV beam range. Meeting this need is facilitated by having the ability to extract and target the proton beam from the MEB such that secondary beams of low energy may be transported to the same calibration area as would be served by secondary beams arising from a proton beam extracted from the HEB. The possibility of additional extracted beams from the MEB to other target stations was examined, based on studies for similar beamlines from the Main Injector under study at Fermilab. The dimensions derived from these studies were used to provide space for future experimental beams and calibration stations from the MEB in directions other than the line from the HEB.

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[2]R. Stefanski, *et al.*, "Calibration Beams at the SSC," SSC–230.

The calibration beams and the calibration hall provide a facility for measuring and testing the response of detector modules that will be installed in the experiments in the interaction regions. Typically, the detector modules are built at surface construction facilities, brought to the calibration hall for measurements and tests, and then taken to the interaction regions for installation in the experiments. Such modules or other apparatus may weigh many tons, so distances from the calibration hall to the interaction regions should be kept to a minimum. For this reason, the calibration hall is located midway between the interaction regions in the west cluster. However, movement over long distances between the calibration hall and collision halls will be required for experiments in the east cluster.

Ultimately the Calibration Beam Facility could encompass the following elements: beam transport line from the HEB to the MEB extraction point, and from the MEB to a switchyard; the switchyard would divide the beam extracted from the HEB or MEB into separate beams directed at target stations producing secondary beams; these beams, in turn, would serve one or more calibration halls where they would interact in the detector modules. As indicated, the initial construction phase includes only primary beam operation from the MEB with three 200 GeV target stations and secondary beams servicing a calibration hall described below.

The vertical profile of the various test beams and their relationship to the HEB and MEB are shown in Figure 3.1. The proton beam would be brought to the surface, after extraction from the HEB, by a 20–mrad bend. When the beam gets to the surface, it is bent again to be roughly parallel to the ground surface and then split, following the beamline from the MEB. Since the surface has a downward slope, the beams also are sloped downward at this point. The calibration beams are positioned near the surface to minimize the depth and therefore the cost of the beam enclosures, and to keep the calibration hall close to the surface to facilitate operations. The beams are at a depth of approximately 40 ft., sufficient for the overburden to provide radiation shielding. Provision is made in the design to minimize radiation above the surface in case of loss of the upper bending magnets.

The plan view of the full–scope facility is shown in Figure 3.2. The splitting function would begin at the point where the HEB beam reaches the surface, and require 5500 ft. to separate the beams sufficiently for targeting for the secondary beams. This length depends on the choice of magnets used and the strength of the electrostatic septa. Superconducting magnets would be used for 2 TeV operation, but not for the initial 200 GeV test beam operation, and the splitting stations depicted are based on existing designs at other fixed target facilities. The size and length of the Switchyard in the design example are, therefore, neither the smallest possible, nor the longest that would be required, if very weak magnet strings were used. The design strikes a balance between land use and power requirement.

The secondary beamlines are 1500 ft. long and extend from the end of the switchyard to the calibration halls. A layout was anticipated that would provide future users with beams that have a wide dynamic range for all of the diverse measurements that Collider detector modules require. The length of the beams is determined by the shielding needed along the beamline to reduce muon backgrounds in the detectors located in the Calibration Halls.

The calibration hall facility for 200 GeV operation consists of the following elements: the three calibration beamlines with twenty–ton crane coverage over two of the lines and fifty–ton coverage over one line, two complexes of counting rooms, office space and shops located between the beamlines, and a truck access area for bringing detector modules into the Hall. The counting rooms contain electronics and computers needed for control of the beam, for data acquisition, and for operation of the detector modules. The separation between bays was chosen so that activity could take place in any bay, even if a beam were running in an adjacent bay. The length of the bays is based on operating experience at other comparable facilities. Each bay typically contains several stations where different types of modules are set up for positioning into the beam. The truck access area provides for truck entry, and for crane coverage to transfer modules to the detector floor level, where they may be handled by the building cranes.

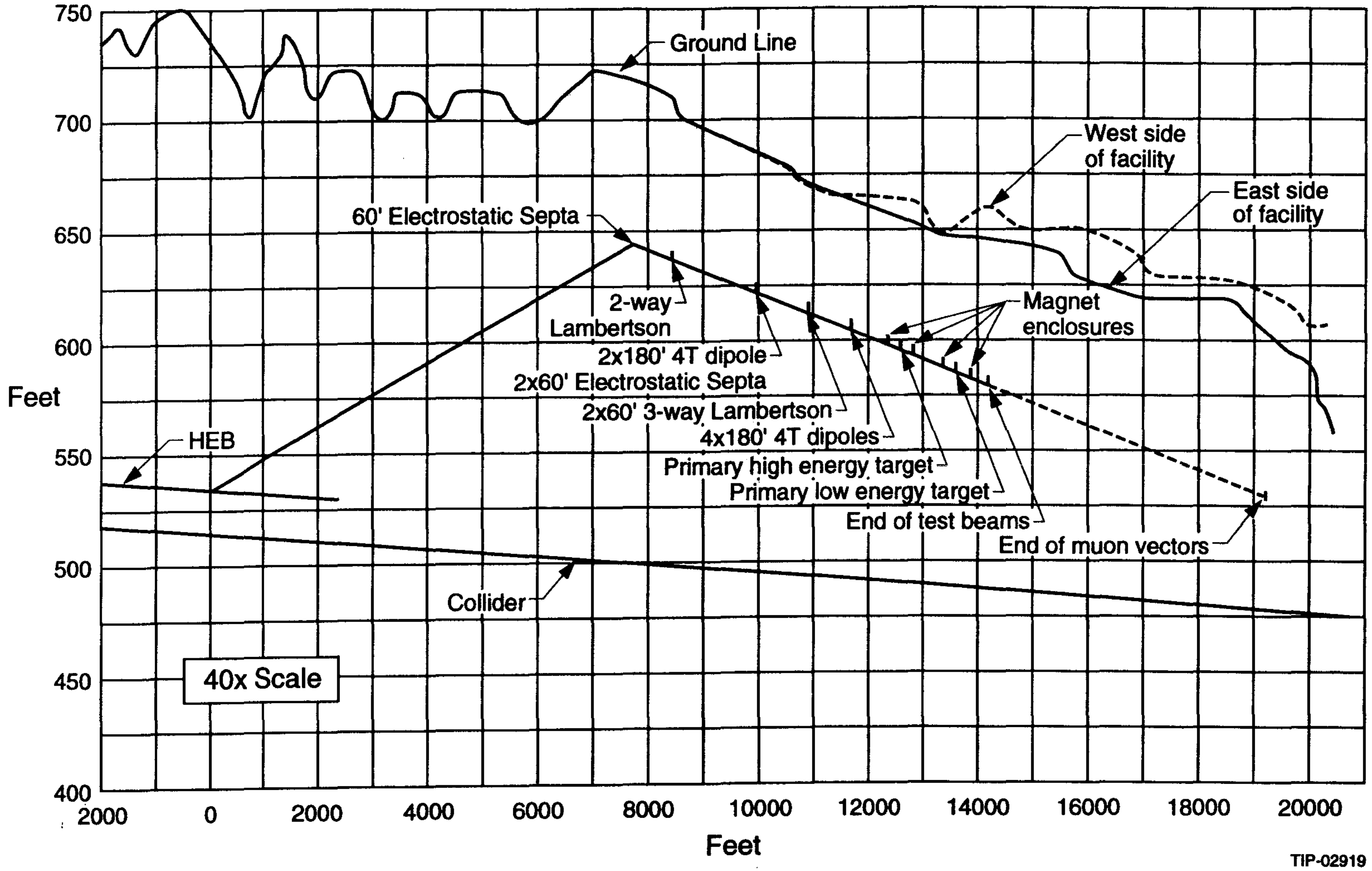


Figure 3.1. Calibration Beams—Profile.

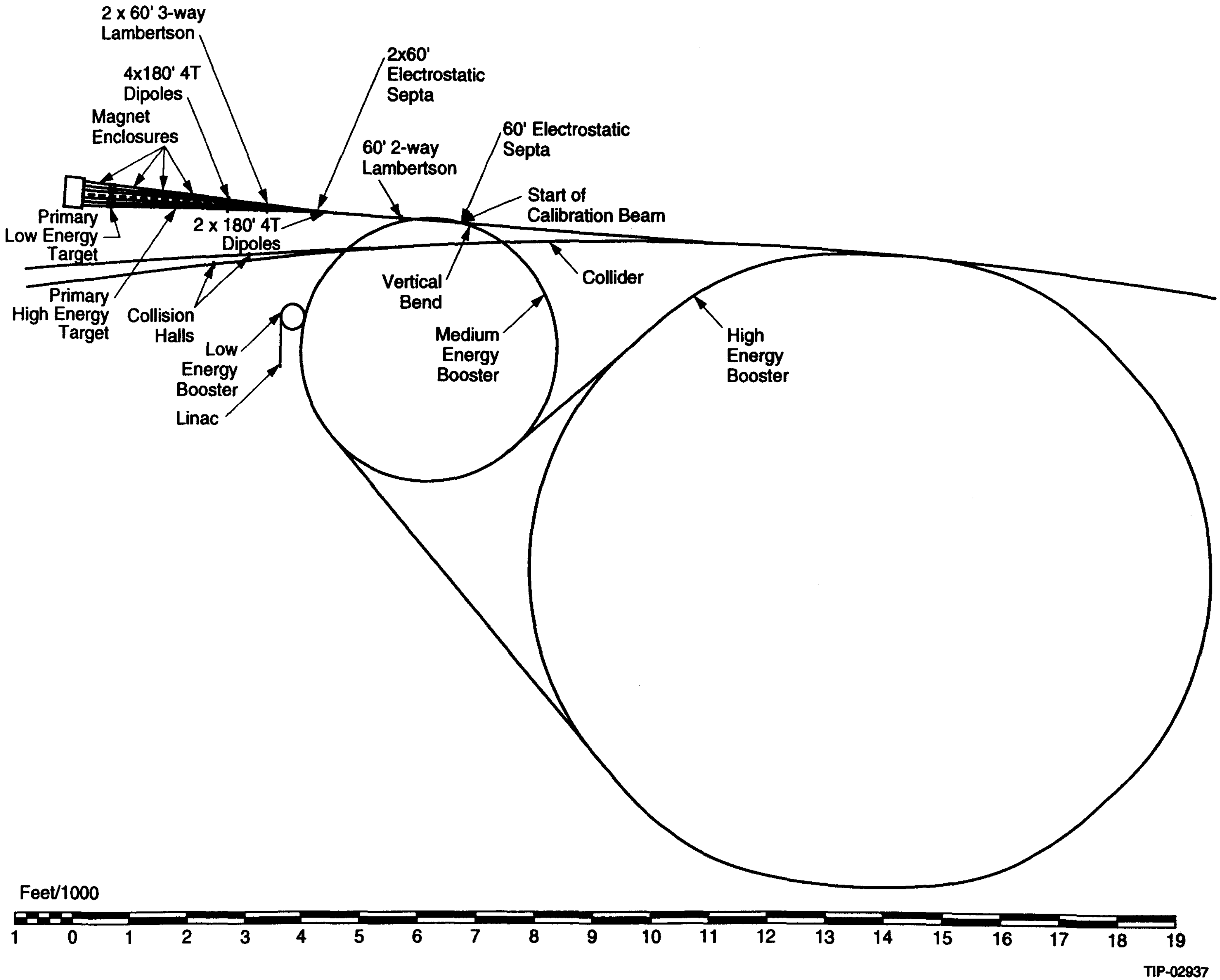


Figure 3.2. Calibration Beams.

4.0 RADIATION PARAMETERS

Annual Radiation Exposure Guidelines

In defining radiation criteria, the DOE distinguishes between criteria for operating a facility and criteria for designing a facility. DOE Order 5480.11 defines the radiation standards for protection of the public in the vicinity of DOE facilities. The permissible level for continuous exposure is limited to 100 mrem/yr of whole-body radiation compared to an average naturally occurring background of more than 170 mrem/yr. This is an operational limit. To ensure that this will in fact be met in operation, DOE specifies that facilities be designed for 20% of the permissible levels. Since the SSC is in the design phase, the relevant DOE criteria are the 20% limits.

The Environmental Protection Agency (EPA) has established limits for radiation exposures to members of the public from radiation in community drinking water supplies and from radiation released into the air. These limits are 4 mrem/yr and 10 mrem/yr for water and air respectively. These two limits are considered to be part of the 100 mrem total annual exposure allowed by the DOE regulation.

In the spirit of maintaining radiation exposures as low as reasonably achievable (ALARA), and in order to remain consistent with other large DOE accelerators, the SSC director has chosen to set a design goal of less than 10 mrem/yr exposure at the boundary of areas controlled by the SSC laboratory. Of this, no more than 4 mrem/yr will be from SSC impact on community drinking water.

Radiation Contours

The land requirements for radiation shielding are dominated by the lengths required to attenuate muons produced at beam interaction points. The distance in earth needed to shield the hadron radiation from the interaction points is typically a few meters transverse to the beam direction, whereas the distance needed for muon shielding may extend a few kilometers in the direction of the beam. The required attenuation length depends on the amount of beam (protons/yr) lost annually at the point in question, on the beam energy, and on the soil density. Density measurements of 86 samples from nine holes average within 2% of the 2.24 g/cm^3 assumed in the determination of the lengths of radiation vectors for the SSC. The density distribution from the samples indicates that the radiation vectors are adequate as given throughout the facility.

Hadron Shielding

Hadron shielding is a consideration throughout the accelerators and external beam lines. The main impact is in the arc regions. For a soil density of 1.8gm/cm^3 a shielding thickness of 30 ft. around the tunnel would be needed for control of hadron radiation which would occur in the case of an accidental beam loss. An additional 15 ft. is required by DOE above the tunnel to ensure the integrity of the hadron shield where the surface is not controlled (owned) by the SSC Lab. This is illustrated in Figure 4.1. The SSC tunnel as situated on the Ellis County site has a minimum cover of 45 feet above the crown with an average cover of approximately 150 feet. Under these circumstances it is not necessary for the SSC Laboratory to control any land above the tunnel except for that required by surface operations.

As shown in Figure 4.2, Collider beam backstops, scrapers and interaction regions will be located on land owned in fee simple because the surface is needed for operational reasons. Thus, the hadron shielding will be provided within the fee simple areas, so there are no additional land acquisition considerations for hadron shielding of these expected beam loss points. Similarly, the HEB ring, backstops, test beam targets and test beam backstops are located in the west area and will require no extra land for hadron shielding. These observations hold true for the other accelerators as well.

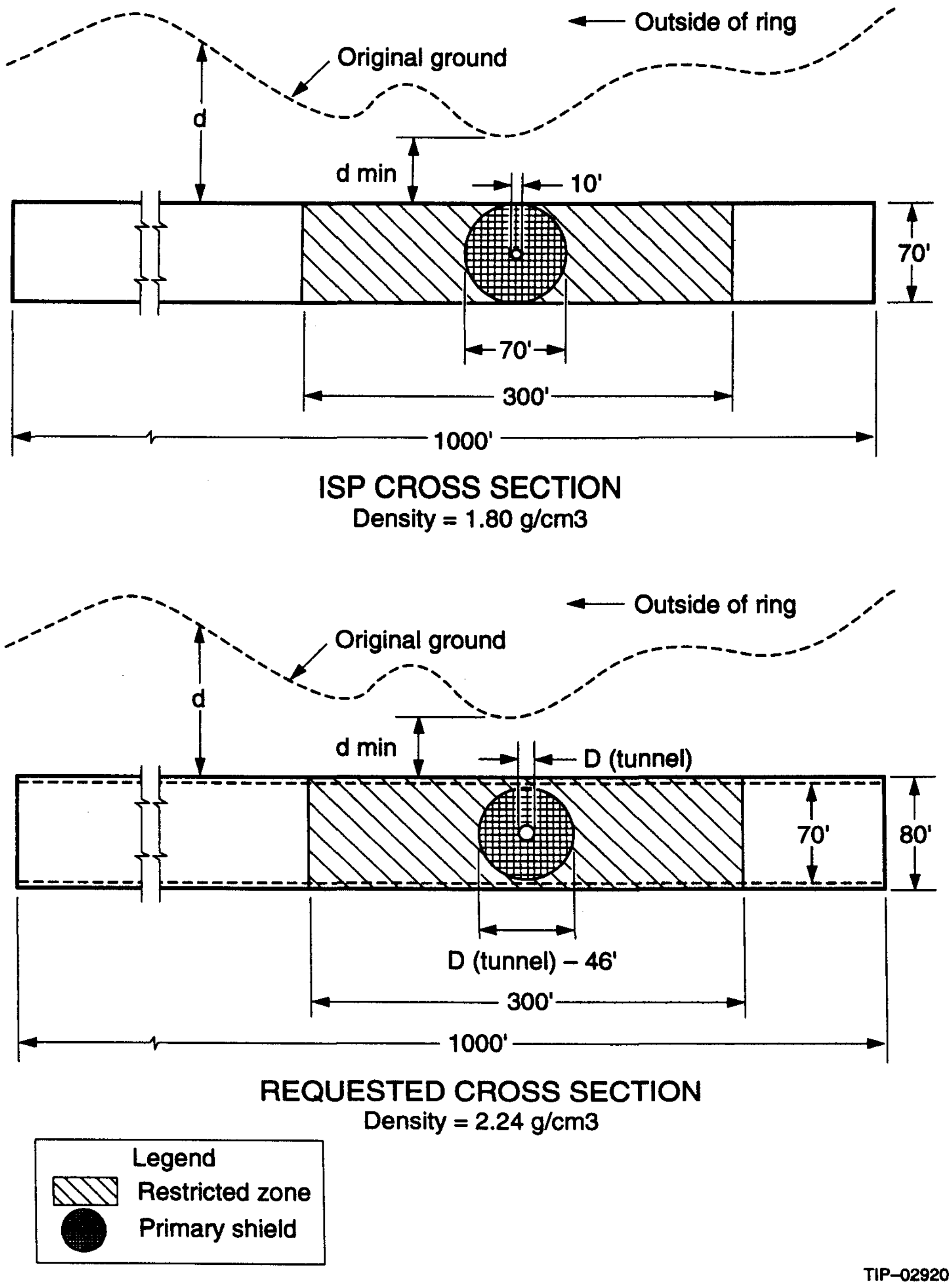


Figure 4.1. Vertical Control Criteria.

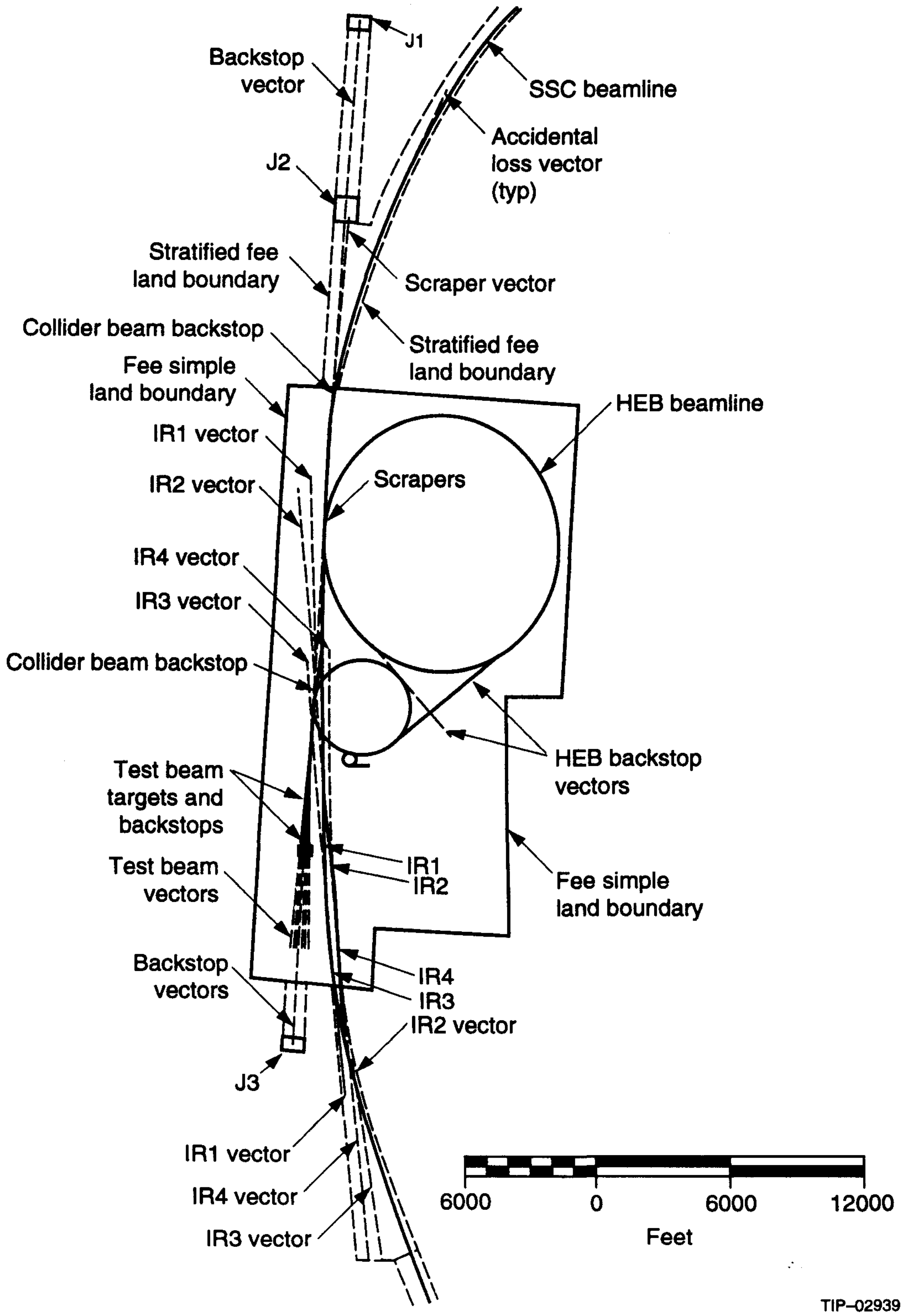


Figure 4.2 Radiation Sources and Land Areas West Cluster.

Muon Shielding

Land control for muon shielding purposes is a consideration for the Collider ring backstops, IR's, beam scrapers, and arc regions. Muon shielding must be considered for the HEB backstops, arcs and external (test) beam targets and backstops.

The shielding to attenuate the forward muon cone is a long narrow strip (a vector), at beam elevation, directly downstream of loss points, pointing in the direction of the beam. This vector is a maximum of 30 ft. in radius and long enough to enclose the entire volume in which the annual muon dose may exceed the design goal of 10 mrem. Since the depth of the accelerator tunnel will everywhere be equal to or greater than 50 ft. to tunnel center, no land needs to be purchased in fee simple for muon shielding purposes. Outside of the regions purchased in fee simple for operational reasons a stratified fee will satisfy the radiation criteria.

Utilizing the operating assumptions described above in Section 2, the following table of required muon vector lengths can be generated. (The calculations for these vector lengths are described in detail for the higher energies in the task force report, "SSC Environmental Radiation Shielding," ed J. D. Jackson, SSC–SR–1026, July, 1987. The lower energy vectors are obtained from experience and calculations at Fermilab, CERN, and Serpukhov. (See "SSC Workshop on Environmental Radiation," 14–18 October 1985, SSC–SR–1016, 9 January 1986.)

TABLE 4.1 RADIATION SHIELDING: MUON VECTORS FOR 10 MREM/YR CONTOURS.

ACCELERATOR	LOSS POINT	BEAM ENERGY	PROTONS PER YEAR	MUON VECTOR (Km)
Collider	Backstop	20 TeV	2E17	5.2
	IR	40 TeV (CM)	2E16	4.3
	Scraper	20 TeV	4E16	3.6
	Accidental Loss	20 TeV	4E14	0.165**
HEB	Backstop	2 TeV	1.5E19	2.0
	Accidental Loss	2 TeV	1E14	0.097
	Test Beams	2 TeV	1.5E19	2.0
MEB		0.2 TeV		0.5

* Density = 2.2 4 gm/cm^3

** The muon vector is actually 1.9 km long. If a tangent vector 1.9 km long is drawn at the loss point on the arc, the point of the vector will be 0.165 km away from the nearest point on the Collider ring. Thus, 0.165 km is the width of the band around the Collider ring which represents the 10 mrem/event line. (See also page 45 of the ISP.)

Muons from the 2 TeV test beams require a 1.6 km vector for shielding. That is not shown here because it is less than the 2.0 km needed for the 2 TeV proton beam backstops.

Muons of 0.2 TeV of energy, the energy of the MEB, are ranged out in 0.5 km of soil. Therefore, since the MEB and all external beams of 0.2 TeV are at least 0.5 km from the site boundary, the muon vectors from the MEB backstop, from accidental loss in the MEB, or from fixed target areas of the MEB will not impact the footprint size.

Figures 4.2 and 4.3 show the various vectors described above superimposed on the proposed SSC footprint. As shown all the vectors are included in either fee simple areas or stratified fee areas. It should be noted that within ± 1,000 ft. of the ends of the backstop vectors for the Collider ring are small, fee simple land areas labeled M4 and M8 in Figure 4.2. Those areas will be used for the installation of permanent muon monitors to verify that the radiation criteria are met. Monitors will also be installed at locations about half way along the length of the vectors. The north backstop vector thus requires another small piece of fee simple land, labeled M3, as shown. The corresponding location on the south backstop vector is on the campus and thus does not show. The west IR vectors are monitored at M7. Similarly, on the east side, M5 and M6 represent muon monitoring locations for muons from the east IR's. On the east side IR vectors are also shown originating from the utility straight section. These muon vectors are indicated for the possible future use of this straight section for colliding beams or for extracting low intensity, 20 TeV beams here.

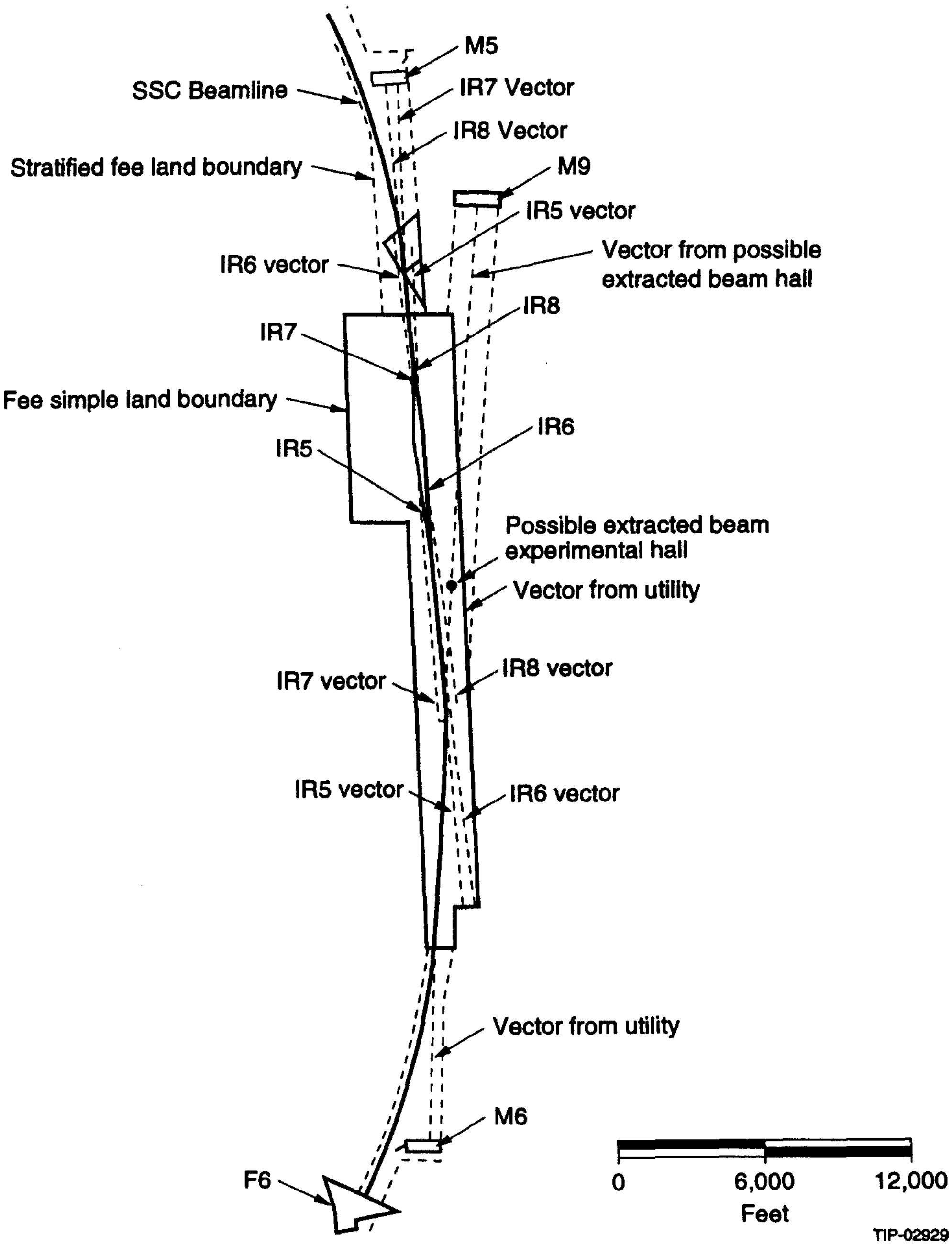


Figure 4.3. Radiation Vectors in East Cluster.

Ground Water Protection

As indicated above, the design criterion used to protect ground water is that no member of the public receive in excess of 4 mrem/yr from drinking water. The task force report, SSC–SR–1026, shows that the 20 TeV backstop design in the Conceptual Design Report (CDR) is sufficient to meet this radiation protection criterion. The beam extraction line and backstop as designed will be accommodated on the fee simple land as shown in Figure 4.2. With designs appropriately scaled for beam energy and intensity, similar observations hold for the backstops for each of the injector accelerators. Therefore, ground water protection around beam backstops is not a factor in land purchase.

The same reference (SSC–SR–1026) discusses ground water protection in the case of accidental beam losses around the Collider ring. It is shown that even if the Collider ring were in an aquifer, wells more than 100 ft. from the tunnel would satisfy the ground water criteria. The nearest aquifer at the Texas site is the Woodbine, located 600 ft. below the Collider ring. Wells closer than 150 ft. already fall within the restricted zone and thus are controlled by the SSC. Additionally, this footprint places the Collider ring in impervious material which further reduces the impact of accidental losses. Therefore, the ground water protection criteria for accidental beam loss do not impact the footprint.

5.0 THE FOOTPRINT

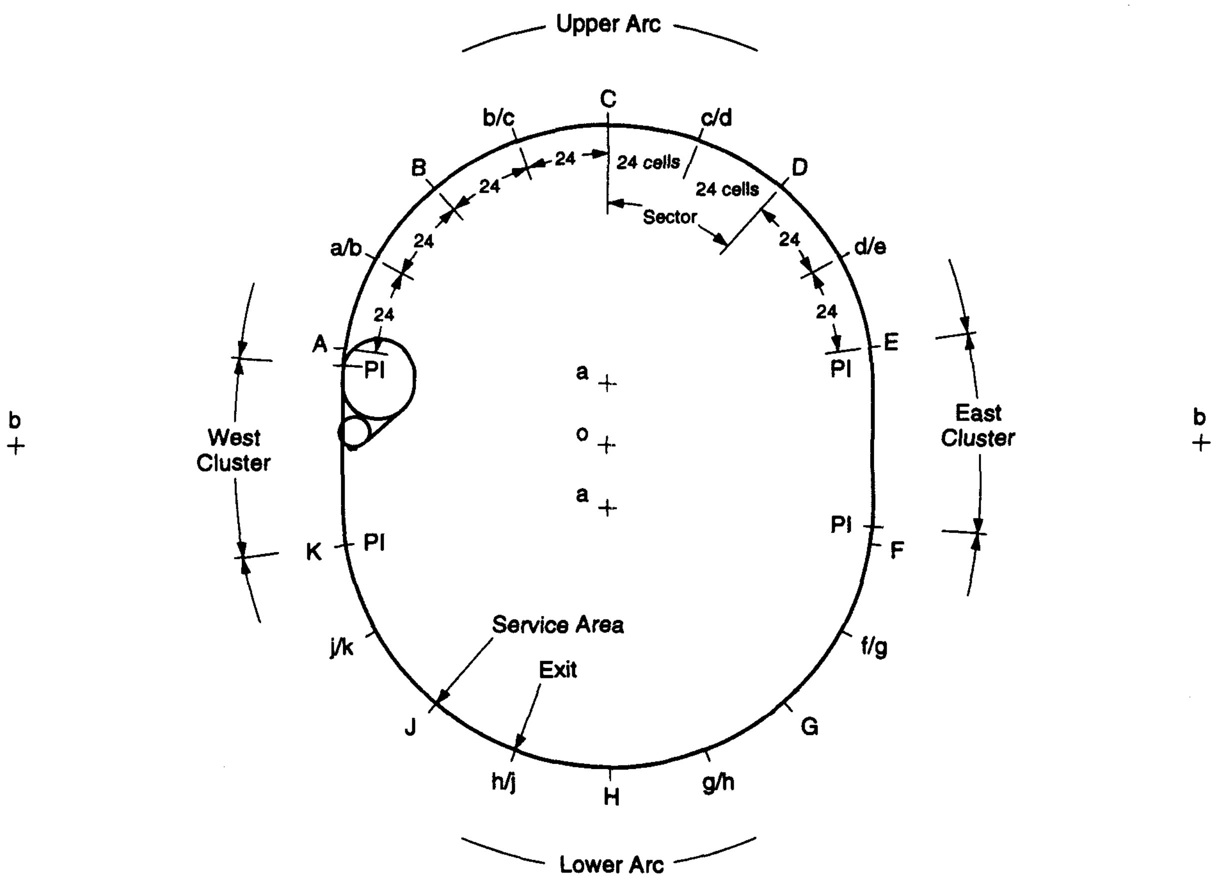
Definition

The definitive update of the "footprint" of the SSC Laboratory is presented in Figure 1.1 of this document. This figure reflects developments in the design of the accelerator and of the requirements of the experimental program that have occurred since the release of the ISP by the DOE in April 1987. These design developments are embodied in lattice calculations which lead to a graphic representation of the revised lattice. This digital representation is the basis upon which the environmental and operating requirements of the SSC facility are superimposed to define the spatial and land area requirements constituting the "footprint."

The current design of the accelerator facility is described in Chapters 2 and 3, above. The North and South arcs are divided into 3 full sectors and 2 half–sectors as defined by the cryogenic and power supply circuits. This is illustrated in Figure 5.1. Each full sector consists of 48 magnet cells centered on a Service Area where a shaft connects the surface facilities to the accelerator tunnel. A schematic illustration of this arrangement is given in Figure 5.2 . The limits of a sector are defined by the exit areas called out as x/y in Figure 5.1.

The extent of radiation patterns resulting from accelerator operations in this configuration is detailed in Section 4, above. The "footprint" is constructed by analysis of the potential radiation patterns which might be generated during operations or during upset conditions. Such considerations taken together with operational requirements determine the widths, lengths, and depths of land needed around the accelerator tunnels and operational areas and thus provide the dimensions given in the footprint drawing, Figure 1.1 From these are derived the acreage requirements for the SSC facilities. These parameters determine the dimensions of the footprint drawing, Figure 1.1. The manner in which these considerations are folded together to define the footprint on the land is presented below, along with other dimensioning arguments.

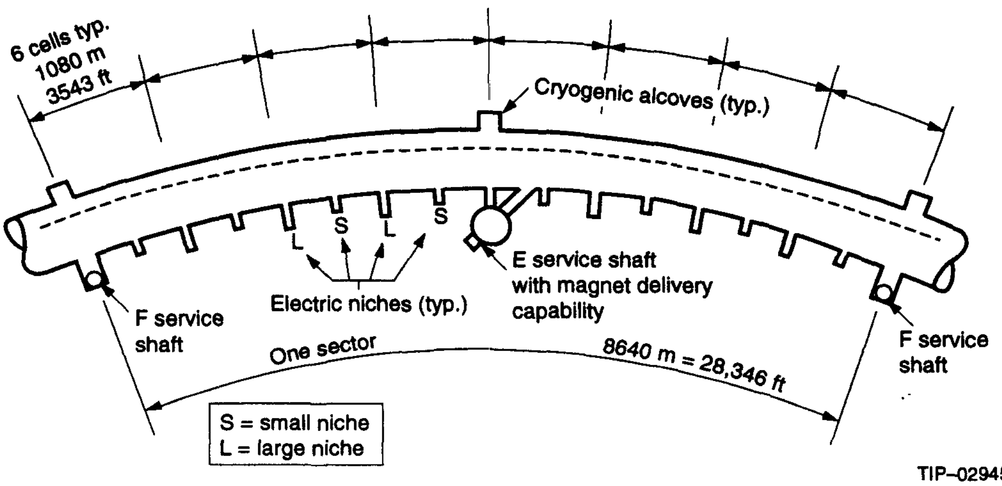
First of all, it should be noted that a rectilinear coordinate system has been adopted with vertical and horizontal axes meeting at the center of the diagram. The units used are ft. and the center is defined as x = 100,000 ft. and y = 100,000 ft. in order to avoid negative numbers for the coordinates of features around the footprint. Note that the turning points A, for the elliptical figure approximately the lattice, lie near the x = +100,000 ft. vertical axis at x = 100,329 ft., y = + 90,574 ft., and x = 99,671 ft., and y = +109,426 ft. The corresponding B turning points are near the y = +100,000 ft. horizontal axis at x = +10,321 ft., y = 96,868 ft., and x = +189,679 ft., y = 103,132 ft.



Arc Length	115,747 ft
Cluster Length	27,165 ft
Circumference	285,823 ft

TIP-02934

Figure 5.1. SSC Service Areas and Exits.



TIP–02945

Figure 5.2. Typical Sector Schematic.

The Arcs

For the diagram in Figure 1.1, the radii used from the above turning points are based upon the ones used in the "simplified template" of Figure 5.1. However, for the footprint there are now two radii for each turning point, one used to define an inner boundary and the other for an outer boundary of the land. The width of land so defined is 1,000 ft. in the arcs and provides adequate space for the Collider tunnel, a surrounding restricted zone, and some allowance for flexibility in final positioning of the ring. In order to provide protection in the case of an accidental loss of beam, more shielding is needed towards the outside of the ring as noted in Section 4, above. Within the 1,000–ft. width the inner boundary of the land is assumed to be 250 ft. from the lattice points. Consequently, the arc radii are:

R (inner) = 39,475 – 250 ft. = 39,225 ft.

R (outer) = 39,475 + 750 ft. = 40,225 ft.

The Clusters

In the west (near) cluster the configuration and width of the required land relative to the lattice position are determined by the presence of the calibration and test beam facility, by the beam backstops, by the experimental areas, by the Injector, and by radiation considerations in regard to these facilities. The east (far) cluster is somewhat less complicated, since there are no test beams on this side. However, the possibility exists of using the utility straight section on this side for very high beta experiments by use of a "kissing" scheme (*i.e.*, one in which the counterrotating beams are deflected such as to come in gentle contact without actually crossing), or for external beams. The configuration and width of the land on this side relative to the lattice location is determined by these radiation considerations. The overall length of land in the east cluster is determined by the need to provide adequate distances for the attenuation of muons arising from the interaction regions or the possible future external beams from the utility straight section. In the west cluster the lengths are derived from calculations on muon attenuation from the beam absorbers in addition to those from the IR's and the beam scrapers in the west utility straight section. An allowance is also made for absorption of the muons arising from interaction of the 2 TeV protons in the test beams facility. On both east and west the land areas must provide for operations, administrative and support functions in addition to radiation requirements.

The Service Areas

The azimuthal positions of the service areas (marked "E" on the drawing) were determined at the below–ground location of the center of each sector. As described in the CDR and the SCDR, this allows for the electrical and cryogenic connections to be routed from the service building to the Collider tunnel at the point of attachment which is assumed to be at the midpoint of the sector. Measured along the Collider ring alignment the circumferential distance from a service area to an exit is 14,173 ft. When measured along the inner boundary of the arc the distance of the service area is 14,083 ft.

This pattern is followed for the five areas on the upper arc and the five areas on the lower arc. Coordinate values have been calculated for the location of the service areas and exits as measured along the nominal lattice. The x,y values above the lattice at the service areas and intermediate exits are displayed in Table 5.1.

Provided that the tunnel centerline is 50 ft. or more below the surface of the ground in accessible areas, the land for the tunnel arcs can be acquired in stratified fee estate. This means that, except at the service areas (E) or exits (F), current surface land usage and ownership can continue. For the cluster areas, the surface land is to be acquired in fee simple. This will permit the development of the central laboratory, support buildings, injector complex, and experimental areas. A table of the required acreage compared with the ISP example is shown in Table 5.2 and the land represented in Figure 5.3.

TABLE 5.1 LAND AREAS: COORDINATES OF POINTS ON LATTICE.
(x = 100,000 ft., y = 100,000 ft. at center of ellipse.)

ISP DESIGNATION	SSC DESIGNATION	X	Y
Upper Arc			
E1	Service Area A	60613	114723
F1	Exit a/b	64969	128130
E2	Service Area B	73759	139151
F2	Exit b/c	85861	146382
E3	Service Area C	99731	14889
F3	Exit c/d	113602	146382
E4	Service Area D	125704	139152
F4	Exit d/e	134493	128130
E5	Service Area E	138850	114723
Lower Arc			
E6	Service Area F	139387	85277
F6	Exit f/g	135031	71870
E7	Service Area G	126241	60848
F7	Exit g/h	114139	53618
E8	Service Area H	100269	51101
F8	Exit h/j	86398	53618
E9	Service Area J	74296	60848
F9	Exit j/k	65507	71870
E10	Service Area K	61150	85277
Near Cluster			
K1	IR1	60075	99258
K2	IR2	60239	98677
	IR3	60612	91009
	IR4	60698	91607
Far Cluster			
K3	IR8	139302	108393
K4	IR7	139388	108991
K5	IR6	139761	101323
K6	IR5	139925	100742
External Area			
J1	J1	62193	133873
J2	J2	61455	125196
J3	J3	58218	87098
J4	J4	138281	122996
J5	J5	138319	75563

TABLE 5.2. SSC LAND AREAS.

FUNCTIONAL AREA	ISP REQUEST (ACRES)	SSC REQUEST (ACRES)
Fee Simple		
West Campus	5510[1]	7382
East Campus Area	1980[2]	1868
Service Areas & Access Points	200[3]	1048
Subtotals	**7690**	**10298**
Stratified Fee		
Arcs (2)	3750[4]	4701
East Campus Area	4390[5]	1607
Subtotals	**8140**	**6308**
TOTALS	**15830**	**16606**

1 A + B + C + G
2 H
3 E + F + (J + 80)
4 D − (E + F)
5 I − (J − 80)

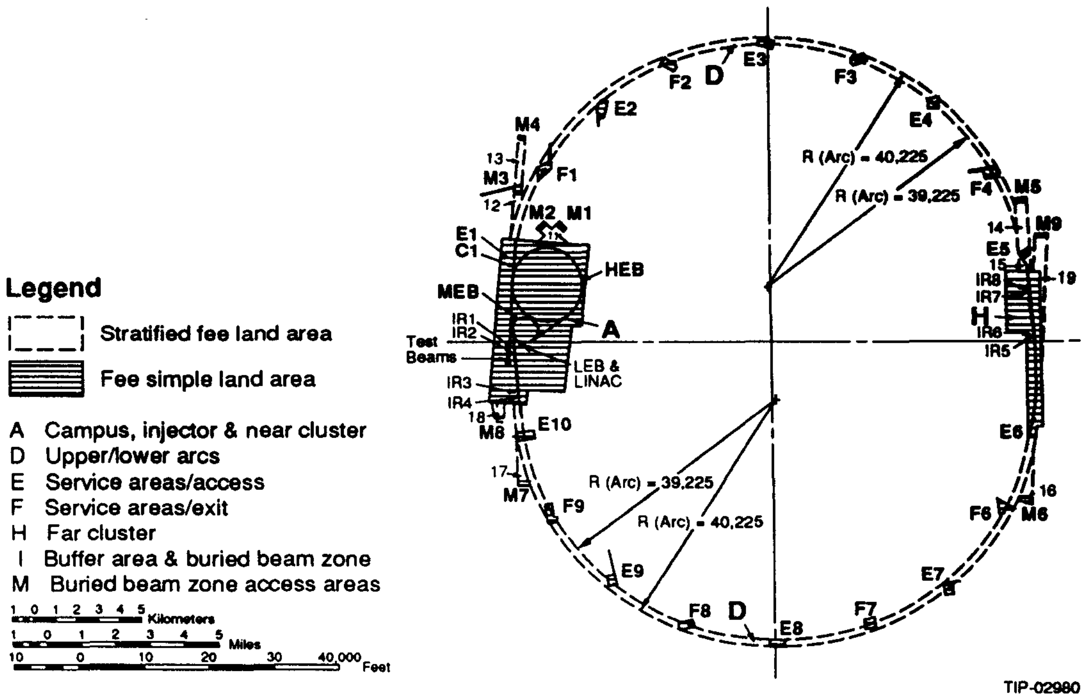


Figure 5.3. Land Areas Classification.

6.0 THE TOPOGRAPHICAL AND GEOLOGICAL SETTING FOR THE SSC FACILITY

The Collider footprint described above has been adapted to the topographical and geological setting proposed by the State of Texas as the site of the facility. This adaptation involves geotechnical evaluation of the site, followed by subsequent adjustment of the placement of the Collider ring as dictated by the geotechnical information. This section summarizes the topography and geology of the Ellis County site, factors determining the detailed physical location of the ring, the resulting overall siting parameters as well as certain details pertaining to elevations of interaction regions (experimental halls) and tunnel shafts. Presentation of land requirements to the TNRLC, in a computer data form, is also discussed.

Topography

The site selected for the SSC lies entirely in Ellis County. Ellis County is on the northwestern margin of the Gulf Coastal Plain, on the gentle eastern slope of the Austin Chalk surface, known as the White Rock Prairie. The topography of the site is gently rolling, generally sloping toward the southeast. Topographic relief is about 350 ft. across the site, with elevations ranging from 400 ft. to 750 ft. above mean sea level (MSL). The site is crossed by a number of creeks and streams, all flowing toward the south and east to join the Trinity River. Waxahachie Creek has been dammed south of the site to form Bardwell Lake near the city of Ennis. The southeastern portion of the Collider ring will pass under the upper reach of Bardwell Lake.

The site is in a semi–rural area. Near the center of the site area is the city of Waxahachie, and immediately to the east of the site is the city of Ennis. Several railroads and major roads, including Interstate Highway 35E, cross the site, as well as a complex of farm–to–market and local roads. The siting in the Texas Proposal was chosen to minimize the interference between these existing geographical features and the surface manifestations of the Collider.

The physical features of the site are displayed in Figure 1.2.

Geology

Characteristics of Geologic Units

The area proposed by the State of Texas for the Collider ring is underlain by three rock units, the Austin Chalk (AC), the Taylor Marl (TM), and the Eagle Ford Shale (EFS). All of these are classified as soft rock. The AC is the most competent of the three rocks. It has standup time of a few months. There are inactive faults in the AC in the site area, most of which are minor. Taylor Marl is less competent than AC in that it is weaker and is susceptible to alteration if exposed to air or moisture. It has a standup time of the order of several weeks to several months. Eagle Ford Shale is very susceptible to alteration when exposed to air or moisture. Standup times are of the order of hours or days, so that exposed surfaces in a tunnel or excavation must be immediately sealed or protected in some way. All three rock bodies have very low permeabilities, less than 10^{-7} cm/sec, which is conventionally classified as impermeable. Water encountered in excavating these formations will be perched water from surficial alluvial deposits, or water trapped in faults.

SSC–Specific Geological Characterization

The specifications for the Collider ring constrain it to lie in or slightly out of a plane with a maximum inclination to the horizontal of 0.55, to have a minimum earth cover of 30 ft. (or 45 ft. where the federal government will not own the surface area), and to be situated as far as possible in a uniform environment. The extent of the lattice coupled with the slope and thickness of the rock strata in the vicinity of the site mean that, to meet the site requirements, the ring must intercept at least two of the three rock masses.

The geological database for setting the ring is drawn from 38 borings made by the Texas proponents in preparing the site proposal, and additional borings made by the SSC Laboratory to improve coverage, particularly for definition of the AC/EFS interface on the West side of the site area. The overall borehole pattern is shown in Figure 6.1 with the West side borings detailed in Figure 6.2.

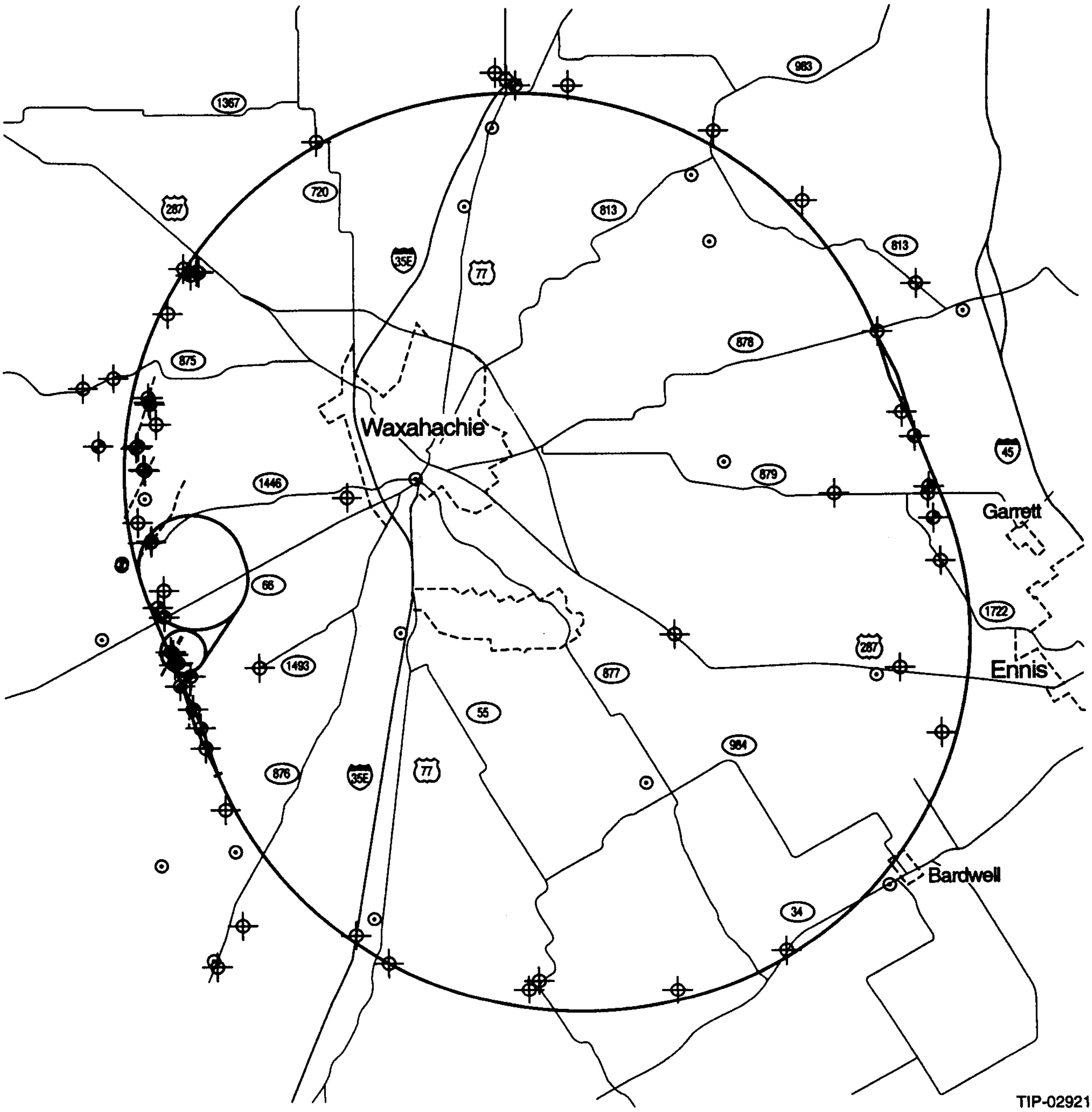


Figure 6.1. Boring Plan—Overall.

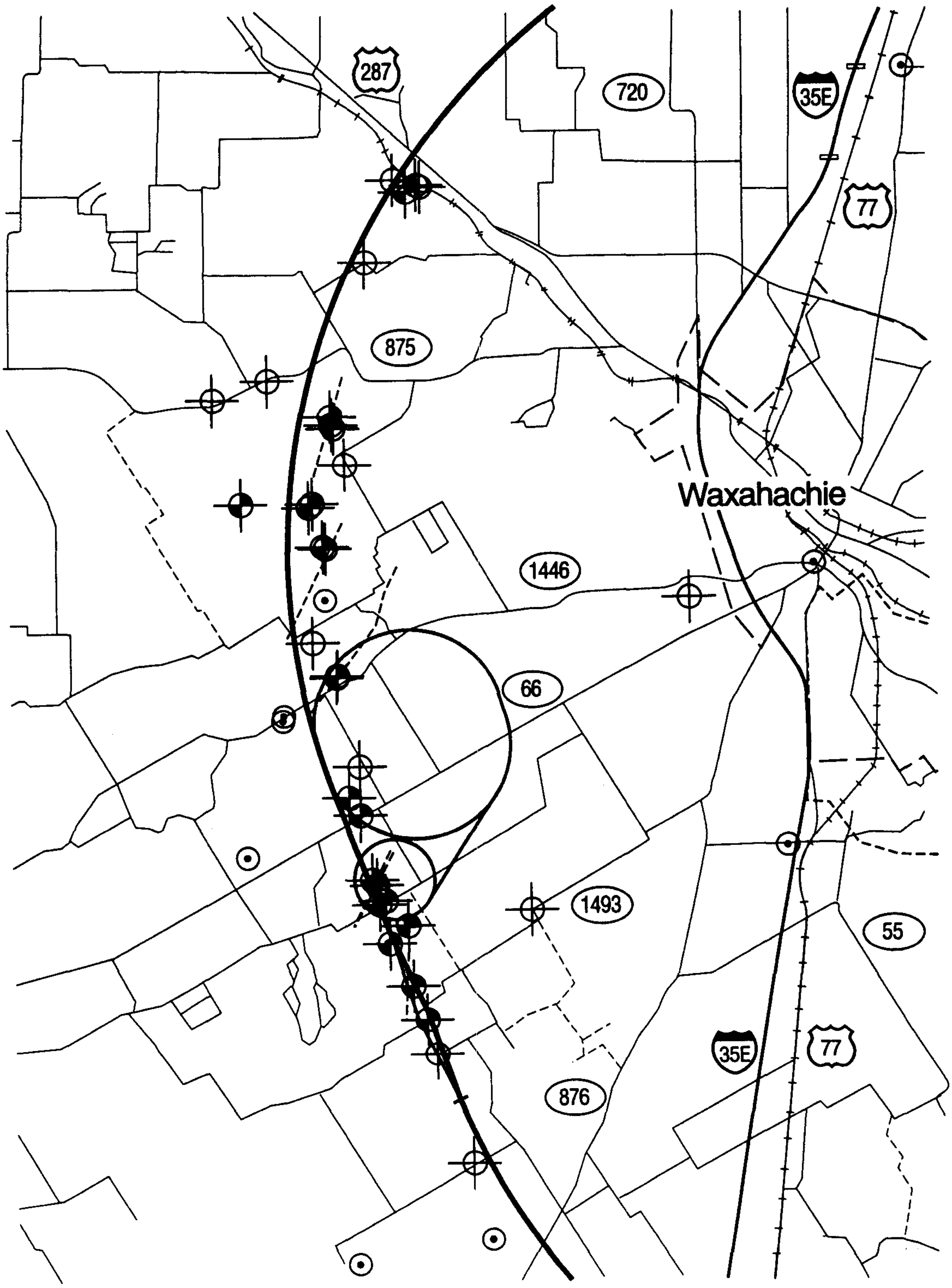


Figure 6.2. Boring Plan—West Cluster.

In general, the borings encountered a 1 to 1.5 ft. thick bentonite seam approximately 80 ft. above the base of the AC. A number of thinner bentonite seams, marl beds, and clay seams are also present, which provide useful markers for identification of strata. The recovery of cores and RQD measurements made on them, along with gamma and resistivity measurements made with downhole logging instruments, indicate uniform geotechnical characteristics in both the AC and TM.

The ring center coordinates locate the ring in the State Plane coordinates (North, East, and elevation). The orientation of the ring is determined by its obliquity, defined as the angle between the major axis of the ring and grid north. The grid is the Texas State Plane Coordinate System, North Central Zone. The plane of the ring is defined by the strike and dip, see Figure 6.3. Strike is the bearing of a line of constant elevation in the plane, and dip is the angular rotation about the strike axis. The coordinates of the center of the ring siting and the obliquity can be considered relatively independently of strike and dip.

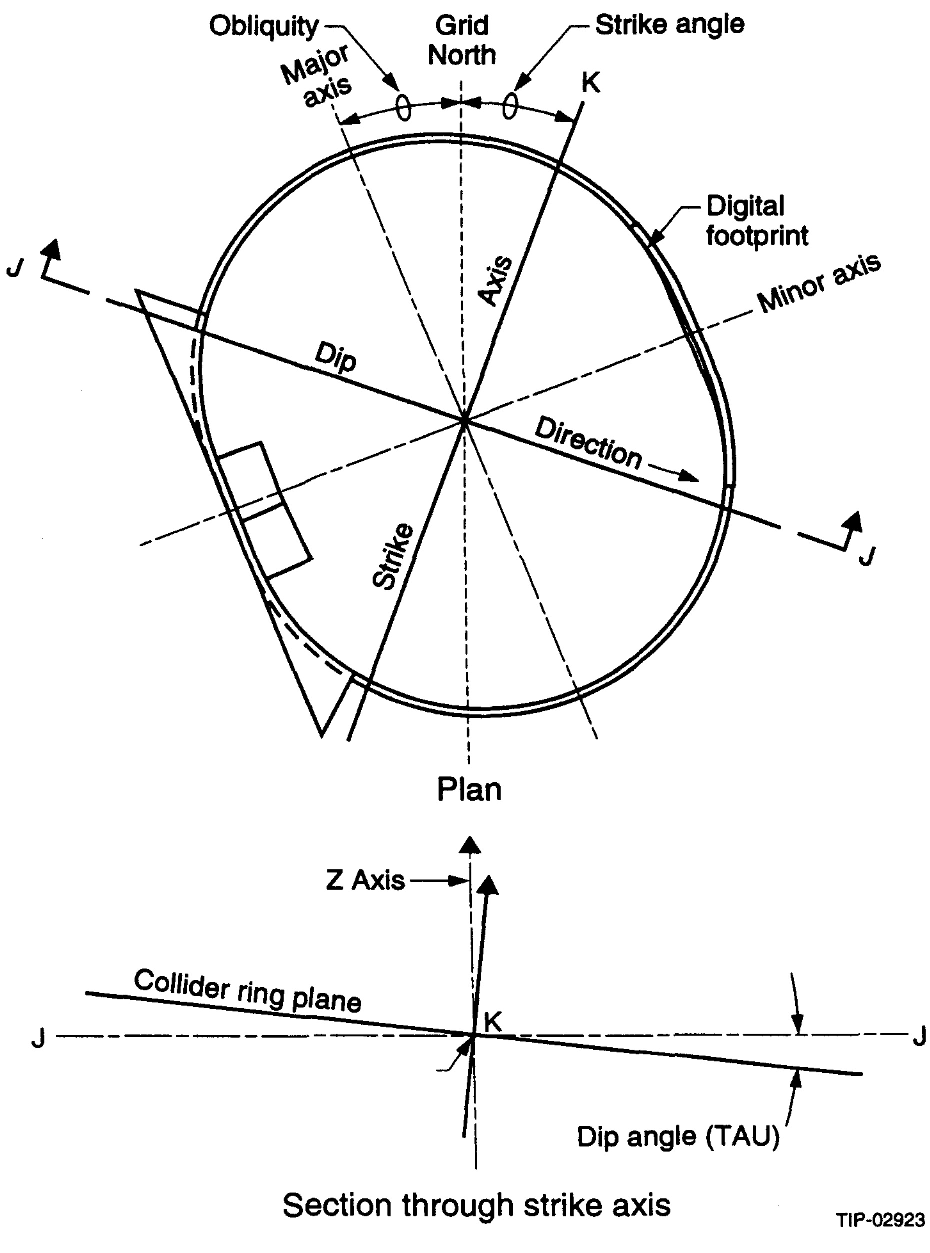


Figure 6.3. Strike and Dip Definitions.

Initial attempts at adjusting the ring siting to improve its geological setting focused on maintaining the ring center and obliquity as given in the Texas proposal, and on varying the strike and dip. Final adjustments involved some translation of the ring center, rotation of the ring about its center, and a rotation about the west cluster experimental halls (which affected the ring center coordinates). Factors considered in adjustment of the ring location were:

Geology, Environmental Considerations and Land Features, Constructibility, Real Estate, and Costs.

Under each heading were several considerations:

Geologic Considerations

- Locate the west cluster experimental halls in chalk if at all possible
- Minimize hall excavation requirements (keep less than 200 ft. if at all possible)
- Maximize tunneling in chalk
- Minimize tunneling in shale

Environmental Considerations & Land Features

Minimize impacts on:

- Surface Water Resources (lakes, streams, flood plains)
- Roads and Railroads
- Developed Areas
- Cultural Resources
- Campus Area Aesthetics (conservation of scenic character)

Constructibility

Consider:

- Site Access
- Access Shaft Locations
- Spoils Disposal
- Construction Staging Areas

Real Estate

- Adhere to the Texas Proposal insofar as possible, maintaining consistency with the physics, geologic, environmental, and constructibility factors presented above.

Ring Orientation

As noted above, ring orientation is defined by obliquity, the angle of rotation of the major axis with respect to grid north. The obliquity of the Texas proposal was 13.27° counterclockwise, that is, the bearing of the major axis was N 13.27° W.

Extensive investigations of the ring location in the Texas Proposal were made before considering changes to the center coordinates or obliquity. Then, with the goals of siting the west experimental halls in Austin Chalk and avoiding a fractured fault zone, changes in obliquity and center coordinates were studied. Obliquity studies ranged from the N 13.27° W in the Texas proposal to an additional 16° rotation (N 29.27° W).

Strike And Dip

The strike and dip of the ring may be considered separately, *i.e.*, various strike angles can be examined, then dip. Alternatively, since three points determine a plane, three control points can be set, then both strike and dip may be readily calculated. Examinations utilizing both approaches indicate:

- Construction costs, driven by the east experimental halls, increase as the dip increases, until the tunnel is deep enough on the east side for the east side halls to be caverns in chalk, rather than open cut excavation in marl. This occurs at a dip of about 0.35 degree for the selected strike.
- Cost savings at the 0.35 dip are potentially offset by complications in the technical systems.

For the strike chosen, three creeks control the elevation of the minimum dip ring, since they are low points in the surface topography. The three are: Waxahachie Creek in the northwest quadrant of the ring; Red Oak Creek in the northeast quadrant; and the north tributary to Chambers Creek in the southwest quadrant. Minimum clearances to these three points were established using the criteria illustrated in Figure 4.1, to set control elevations.

It should be noted that the dip represents the maximum slope; when the tunnel direction is parallel to the strike, the tunnel slope is zero. Thus, with the proposed footprint, the longitudinal slope near the experimental halls is nearly zero. The cross–slope, however, is nearly equal to the dip, 0.17°.

Curvature Correction

The Collider ring is so large that the curvature of the earth introduces significant deviation between the geometrical plane constituted by the Collider ring and the elevation as determined by mean sea level. This is illustrated in Figure 6.4 .

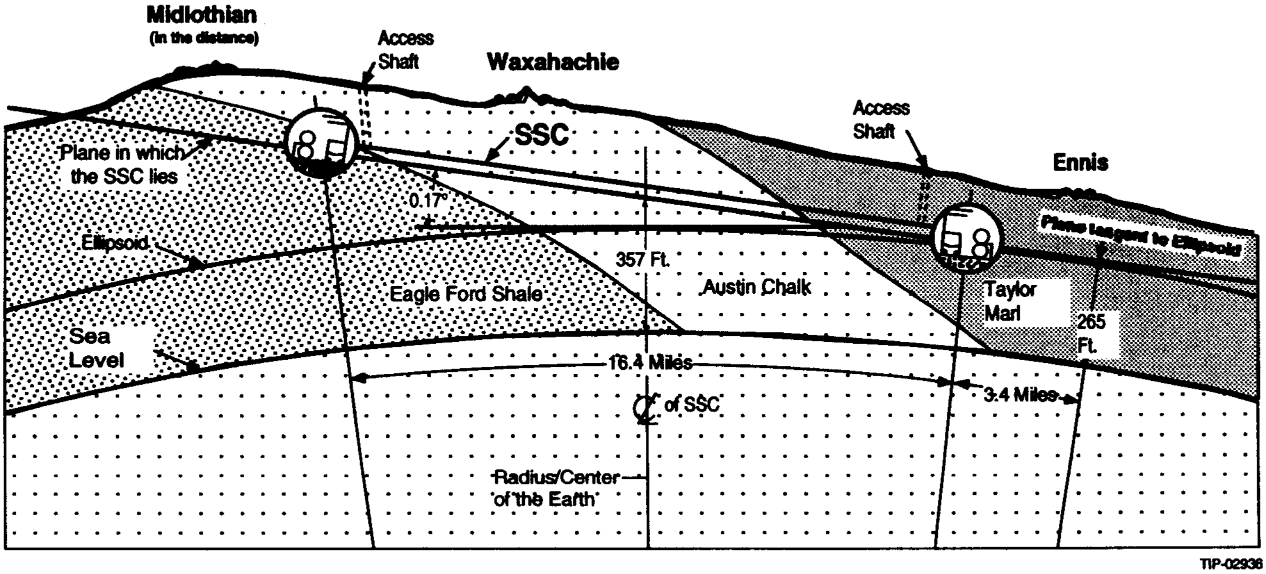


Figure 6.4. Effects of Earth's Curvature on the SSC.

Figure 6.5 shows the curvature correction isocontours in feet compared to the Collider ring center. While curvature correction relative to the ring center exceeds 50 ft., the relative correction varies about 20 ft. Curvature correction numbers were calculated at 10,000 ft. intervals.

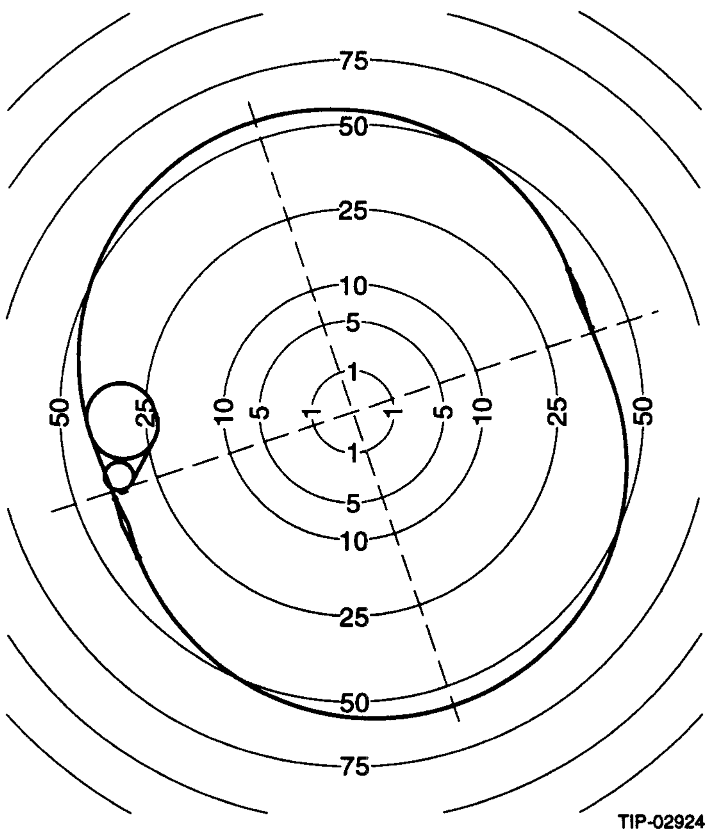


Figure 6.5. Curvature Correction—Plan View.

Constructibility

Selected ring profiles were evaluated based on four considerations: tunnel length in each material type, service area shaft depths, experimental hall depth, and experimental hall foundation requirements. Rough order–of–magnitude costs were assigned to each item for purposes of comparison.

Digital Footprint

A detailed description of the techniques and calculations for determining the footprint is contained in "Computer Aided Design of the Digital Footprint" Rev. 1, dated March 1990. (SSC–SR–1049).

In this system a lattice conversion program is used to convert an input point file (consisting of enumerated x, y, z lattice points in a cartesian grid coordinate system) into Texas state plane coordinates in the CAD system. To confirm the accuracy of the conversions the Texas State Plane coordinates may be reconverted into corresponding geodetic coordinates in the NAD27 system and the NAD83 system. Output from the lattice routine is directly uploadable to Intergraph CAD using COGO (coordinate geometry) programs to enter the numbered lattice points entered into the active database for graphic presentation and manipulation.

Proposed Ring Location

The final location of the footprint was set by making use of the data from the geotechnical investigations and applying the considerations described above. The geometric parameters of the proposed ring are as follows:

Orientation:	S18.77° E, (grid bearing, Texas Coordinate System)
Strike:	North 13.7° East
Dip:	0.17°
Center Coordinates:	x = 2,213,072, y = 252,561, Center Elevation 357 ft.

Texas Coordinate System, NAD27.

Based on the geometry, the distances and percentages of tunnel length in the various materials is roughly estimated to be as follows:

Austin Chalk	155,000'	55%	29 miles
Taylor Marl	95,000'	33%	18 miles
Eagle Ford Shale	35,000'	12%	7 miles

Elevation data for the experimental halls are given in Table 6–1: shaft depths around the ring are given in Table 6–2. An overall topographic and geologic profile along the ring circumference is shown in Figure 6.6

TABLE 6.1 INTERACTION REGIONS[1]

DESIGNATION	USGS GROUND ELEVATION (FT)	ROCK CONTACT	CONTACT ELEVATION (FT)	FINISHED FLOOR ELEVATION (FT)	TUNNEL[3] CENTERLINE ELEVATION (FT)
IR1	675	AC/EFS	454*	472	494
IR2	665	AC/EFS	453*	463	492
IR3	616	AC/EFS	448–452*	429	481
IR4	620	AC/EFS	443*	460	480
IR5	450	TM/AC	259*	262/282	296
IR6	450	TM/AC	259	Unknown	298
IR7	440	TM/AC	255	Unknown	310
IR8	450	TM/AC	310*	289	312

*Confirmed by drilling

1. Based on the following Collider ring location:
   a. Center coordinates
      (Texas Coordinate System, North Central Zone, NAD 27):
      X= 2,213,072.33; Y= 252,561.30
   b. Center elevation: 357.00 ft.
   c. Orientation: N 18.77° W
   d. Strike: N 13.7° E
   e. Dip: 0.17°
2. Numbered counterclockwise beginning at northernmost hall on west side.
3. Assumed to be approximately equal to elevation of center of beamlines.

TABLE 6.2. SHAFT DEPTHS.

POINT	USGS TUNNEL CENTERLINE ELEVATION[1] [ft(ms1)]	USGS SURFACE ELEVATION[2] [ft(ms1)]	SHAFT DEPTH
E1	521.6	765	243.4
F1	537.8	710	172.2
E2	538.3T	648	109.7
F2	522.6	675	152.4
E3	492.7	683	190.3
F3	452.7	530	77.3
E4	407.5	528	120.5
F4	362.8	496	133.2
E5	324.5	455	103.5
E6	277.2	494	216.8
F6	272.8	456	183.2
E7	282.2	460	177.8
F7	304.00	480	176.0
E8	335.6	425	89.4
F8	373.7	509	135.3
E9	411.5	512	100.5
F9	446.1	538	91.9
E10	472.1	552	79.9
IR1	493.9	675	181.1
IR2	492.3	665	172.7
IR3	480.7	615	134.3
IR4	480.3	620	139.7
IR5	296.4	450	153.6
IR6	297.4	450	152.6
IR7	310.9	440	129.1
IR8	311.8	450	138.2

1. Obtained from USGS 7.5 minute quadrangle maps.
2. Computed based on a center elevation of 357 ft., a strike of N 13.7°, and a dip of 0.170°.

TABLE 6.2. SHAFT DEPTHS.

POINT	USGS TUNNEL CENTERLINE ELEVATION[1] [ft(ms1)]	USGS SURFACE ELEVATION[2] [ft(ms1)]	SHAFT DEPTH
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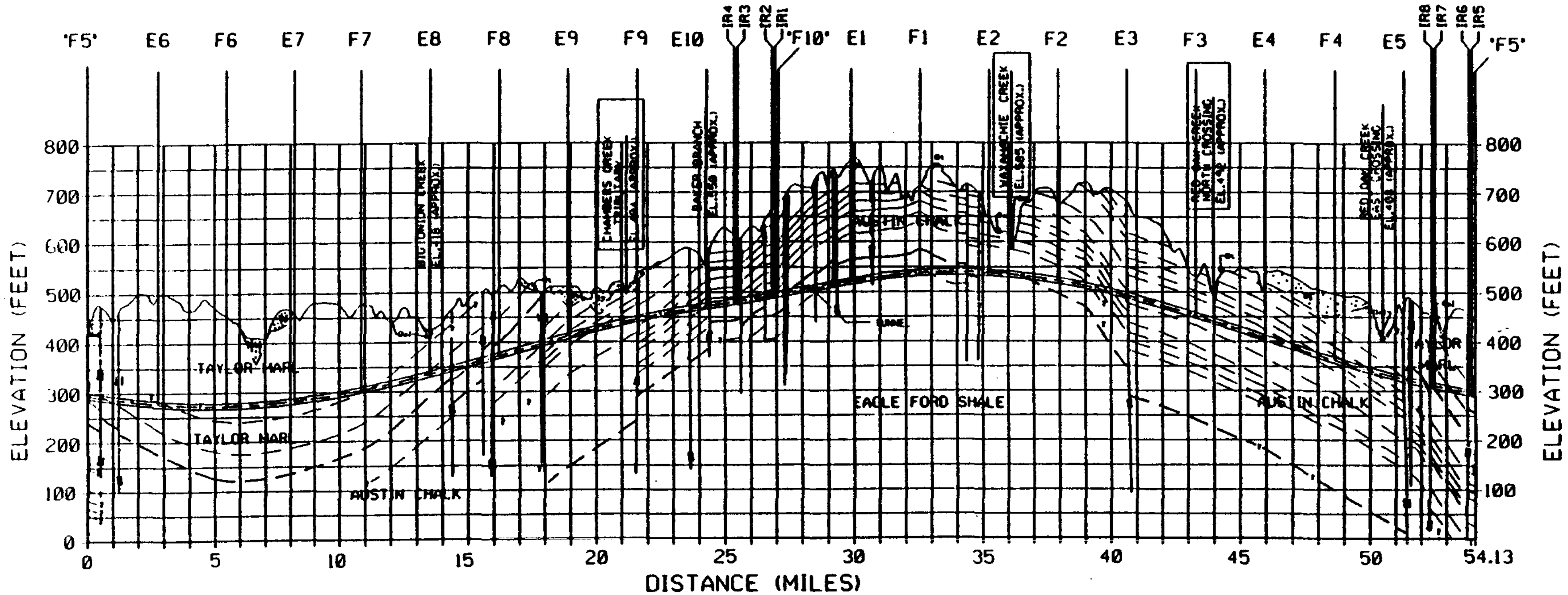
F3	452.7	530	77.3
E4	407.5	528	120.5
F4	362.8	496	133.2
E5	324.5	455	103.5
E6	277.2	494	216.8
F6	272.8	456	183.2
E7	282.2	460	177.8
F7	304.00	480	176.0
E8	335.6	425	89.4
F8	373.7	509	135.3
E9	411.5	512	100.5
F9	446.1	538	91.9
E10	472.1	552	79.9
IR1	493.9	675	181.1
IR2	492.3	665	172.7
IR3	480.7	615	134.3
IR4	480.3	620	139.7
IR5	296.4	450	153.6
IR6	297.4	450	152.6
IR7	310.9	440	129.1
IR8	311.8	450	138.2

1. Obtained from USGS 7.5 minute quadrangle maps.
2. Computed based on a center elevation of 357 ft., a strike of N 13.7°, and a dip of 0.170°.



LEGEND

TUNNEL PROFILE

APPROXIMATE BASE OF EXPERIMENTAL HALL

GROUND ELEVATION DETERMINED FROM USGS TOPOGRAPHIC MAPS

CREEKS AT WHICH 50 FT. MINIMUM DISTANCE TO TUNNEL CENTERLINE OCCURS

CONTACT

INFERRED CONTACT

FAULT

GEOLOGY BASED ON 1989-1990 GEOTECHNICAL INVESTIGATIONS.

Figure 6.6. Geologic Profile—Overall.

7.0 SEIS CONSIDERATIONS

Prior to selection of the Texas site for the SSC the DOE undertook to prepare an Environmental Impact Statement (EIS) for the project based on the CDR of May 1986, as updated and reflected in the ISP. This investigation treated exhaustively all seven finalist sites recommended to the DOE by the advisory site evaluation panel convoked by the U.S. Academy of Sciences at the behest of DOE. This process, including public hearings at each of the finalist sites, resulted in an Final Environmental Impact Statement (FEIS) (DOE/EIS–0138, December 1988) which was the basis of the Record of Decision (ROD) used in siting the project. Since the conceptual design upon which the FEIS was based would need to be adapted to the final site, a Supplementary Environmental Impact Statement (SEIS) was undertaken to encompass any significant deviations between the conceptual design as treated in the FEIS and the specific adaptation to the Texas site.

The effects of the revised footprint on the environmental assessments being performed as a part of the development of the Site–Specific SSC SEIS are minor in nature. The biggest change, perhaps, from the configuration considered in the siting FEIS is the shift from a 1 TeV to a 2 TeV injector. However, this change had been anticipated, and a commitment to assess a 2 TeV injector was made a part of the SEIS development.

The biggest change from the FEIS in the service areas is the increase in fee–simple acreage to a uniform size of approximately 50 acres each for the E and F areas. Although this increase requires a new assessment relative to that performed in the FEIS, the result of the change is positive from an environmental point of view. This is because the increased land at the service areas allows the shaft and tunnel spoil to be disposed of on site in gentle berms rather than being trucked to a remote location. This reduces impacts on traffic, noise, dust, *etc.* The additional land areas also allow the use of cooling ponds rather than cooling towers. These cooling ponds provide a means of controlling the quantity and quality of runoff water, and a potential for creating artificial wetlands to provide a habitat for migratory birds, and waterfowl. Finally, the additional acreage affords greater flexibility in the actual siting of service area facilities, allowing mitigation by design to be implemented where warranted.

As with the earlier footprint, the revised version has two service areas (now E8 and F6) located in the vicinity of wetlands or floodplains. However, as indicated above, there is considerable flexibility in the final siting of these facilities, and every effort will be made to minimize any negative environmental impact. Alternatives, such as locating the surface facilities out of the floodplain and making a subsurface connection to the main tunnel ring, will be considered and assessed in the SEIS. As with all other E and F service areas, the SEIS will contain a complete assessment of proposed conceptual designs for E8 and F6.

Formal consultation with the Corps of Engineers (wetlands, floodplains), U.S. Fish and Wildlife Service (threatened and endangered species, habitat, pond management), U.S.D.A. Soil Conservation Service (prime farmland) are taking place as a part of development of the SEIS. There is also communication with the Texas State Historical Preservation Office (SHPO), Texas Department of Parks and Wildlife, Texas Department of Highways and Public Transportation, and other state and local agencies regarding the SEIS assessments. Among the extensive field work accompanying development of the SEIS are archaeological surveys of all land areas not assessed as part of the FEIS, a paleontological assessment of the entire project region, an historical architecture survey of all of Ellis County not previously surveyed, a background acoustic characterization of the entire project area, a survey of the shallow ground–water resources in the vicinity of the ring, etc. An ecological walkover of all land in the revised footprint that was not assessed in the FEIS will also be performed, including conceptual infrastructure rights–of–way (*e.g.*, access road alignments, utility line corridors, water and sewer lines, natural gas lines).

Typical of the revised information generated by the SSC Laboratory for use in the SEIS assessment are locations of noise sensitive receptors near the final locations of the service areas (*e.g.*, schools, churches, residences), revised estimated quantities of spoils materials and conceptual disposal plans, estimated waste generation rates and conceptual disposal options, estimated water requirements and sewage generation rates, projected water and sewage treatment plant requirements and options for management of the residue from these plants, estimated power requirements, and the like.

8.0 SAFETY CONSIDERATIONS AND ACCESS SPACING

A Working Group of safety professionals has studied egress spacing for the Superconducting Super Collider (SSC) accelerator tunnel, with regard to life safety. The study, based on the SSC Conceptual Design, used three approaches: searching for applicable codes; extrapolating from a similarly configured "model" facility having a statistically relevant injury history; and constructing a Preliminary Hazard Analysis. The Working Group was unable to find codes, standards, or regulations dealing specifically with egress requirements for accelerator tunnel facilities. An OSHA standard dealing with underground mines was found prescribing egress requirements that are satisfied by the SSC. Hazards to which SSC workers are to be exposed are seen as less profound than those for the mining case. Thus it would be expected that SSC injury rates should be less than the 7.4 cases per 2×10^5 man–hours of exposure currently accepted as the level prevalent in the mining industry. The Fermi National Accelerator Laboratory was used as a model for injury rate studies. Fermilab, with an 18–year operating history, has a well–kept injury database and a long–term injury rate below the national average for industry at large. Of all accelerator tunnel injuries experienced over that period, there were no cases for which probability of occurrence or severity of outcome would have been affected had egress spacing been increased to several miles from the present 800 ft. The upper limit of probability for such a case, or of a fatality, is 0.13 per 100 man–years of exposure within a confidence interval of five percent. This compares with the construction industry, with a fatal accident rate slightly greater than 0.13 per 100 man–years. If the injury history experienced at Fermilab is acceptable, and if the fatal accident rate within the construction industry is a tolerable upper limit, there should be no reason to alter SSC egress spacing from the nominal five–mile intervals now planned. However, to accommodate uncertainties in the acceptable level of risk, exit stairways will be provided in the ventilation shafts in place of the emergency evacuation provisions and breathing air supplies will be stocked in electronic niches at 2500 ft. intervals. Finally, the Preliminary Hazard Analysis has produced a document useful as a global inventory of system hazards throughout system life.