CHAPTER 2

SITE SELECTION

2-1. General. The most effective precaution that can be taken to assure a mark's stability and survival is to choose an appropriate location. Since there are a wide variety of possible situations that may be encountered when setting a mark, it is virtually impossible to address them all in this manual. Therefore, the ultimate selection of a site is necessarily left to the discretion of the mark setter; however, it is imperative that good judgment be exercised. The resultant accuracy of any survey will be determined in part by the stability of the marks. A mark setter exercising good judgment is defined as an individual who thoroughly evaluates the security, utility, stability, environment, and safety of the mark and its site before establishing the marks. The most important site selection parameters are discussed in the following sections.

2-2. Security. Foremost on the list of evaluation considerations is the mark's susceptibility to damage or destruction. In view of the great expense involved in establishing a mark and the data associated with it, time spent in preservation is worthwhile. It is necessary to anticipate any construction that might occur at the proposed mark location. Is the site selected for marks in the path of a future highway, waterway, ditch, or pipeline? Will an adjacent shopping center or parking lot be expanded in the foreseeable future? Is the prospective mark site near a potentially active mine or quarry? Highway maintenance often involves the widening of the road surface and the straightening of curves. Marks set near the edge of the right-of-way and on the outside of a curve increase their chances for survival. Conversely, the outside of a river bend is not an appropriate site for marks because the effects of erosion may lead to undercuts in the bank. The effects of undercutting may also occur on shoreline scarps where stormy waters slowly erode the embankment. Floodplains should be avoided when otherwise comparable sites are available. Marks located in floodplains may be buried in sediment or washed out due to erosion. Often, sites may be located in areas that provide natural protection for the mark. Locations near the edge of the right-of-way, well away from a highway surface, provide protection for marks. Property fence lines and utility poles usually remain in place for many years and afford good protection for marks. Structures that are of themselves not suitable for mark settings prevent vehicles and equipment from damaging marks that are set adjacent to them. In addition, from a standpoint of survival, Federal, state and local public areas, as well as private property and cemeteries, provide excellent sites for marks.

2-3. Utility. Accessibility of the marks by users should be evaluated in selecting the mark's site. If the mark cannot be found or if the site cannot be conveniently occupied, its worth is questionable. Are there nearby objects that can be used to reference the mark? Are these objects fairly permanent? Can suitable measurements define a precise point where a hidden mark can be found? To enable the mark setter to establish a mark where its position can be accurately described, familiarity with referencing techniques is required. Marks are usually described in the following manner: Directions are given to the general area in which the mark is located. Normally, this puts the individual within 100 meters (328 feet) of the mark. Then the mark is located by distances and directions from prominent reference objects. These distances and directions establish lines of position (LOP). The prominent objects are referred to here as "origins." At least two LOPs are required to define a point, but additional LOPs are desired in case some reference objects are destroyed. Also, the more nearly perpendicular the angle at which LOPs intersect, the more accurately a position may be determined and the easier it will be to locate the mark. Consideration should be given to the ease with which the location of a mark may be established from reference measurements. It is important that this information be included on the mark documentation as discussed in paragraph 6-1.

2-4. Stability. All marks are subject to the effects of geologic and soil activity. Vertical control marks (bench marks) are particularly vulnerable because this activity results in vertical movements much more so than horizontal motion. Therefore, the following environmental effects should be evaluated when considering a mark site.

a. Advantageous Topographic Features. Crests of hills are good places to set bench marks for three reasons. First, the problem of slope instability is eliminated. Even though the neighboring hillside might be sliding, the summit will generally remain stable. Second, frost heave is less likely with the increased separation from the water table. And third, the consistency of the soil will tend to be more firm.

b. Effects of Soil Grain Size. Whenever soil types can be ascertained, it is preferable to choose a site with coarse-grained soils rather than one with fine-grained soils. Most of the problems associated with soil movements are attributable to the fine particles it contains. The fraction of grain sizes less than 0.02 millimeter governs whether or not a soil is frost susceptible. Soils susceptible to high volume change due to variation in moisture content are normally clays, which are very fine-grained. In addition, poorly drained clays provide environments conducive to corrosion. If an alternative is available, avoid sites with fine-grained soils, especially clays.

c. Effects of Vegetation. The presence of vegetation, particularly trees, has marked influence on the stability of the upper layers of a soil mass. Trees, underbrush, grass, and moss act as insulation, reducing the depth of the active frost zone and thus reducing frost heave. However, the problems associated with expansive soils (clays) are aggravated by vegetation. In seasons of abundant rainfall, vegetation exerts very little influence on soil volume change. However, when the weather is dry and there is little free water available in the soil, trees and other plants will draw more water out of the soil than is normally lost through evaporation. The result is a lowering of the water table and even greater soil shrinkage. With trees, this effect occurs within a radial distance from the trees roughly equal to their heights. Areas covered with thick vegetation should be avoided even where expansive soils do not exist. Dense vegetation may conceal a monument, making it of much less value than one that is open to view. Marks should not be located near lone trees due to potential disturbances from growing roots.

d. Geological Effects. It is generally not feasible to determine the nature and extent of subsurface geological activity. Nevertheless, it is an important consideration that should never be overlooked when the information or a means of obtaining the information is available. Detailed geological data are very important in locating pockets of unstable ground within a generally stable area. Caverns and underground mines, as well as water and oil-bearing strata subject to pumping, are especially prone to cause significant subsidence. Marks established strictly for geodetic control should not be set in these areas. Whenever possible, sound bedrock should be used for a mark setting. However, it is often difficult to determine whether or not an outcrop is indeed sound bedrock, especially when the decision is based mainly on visual evidence obtained from an exposed portion of the formation. Where a large portion of the outcrop is exposed, try to insure that the section of rock in which the mark will be set is essentially intact with the rest of the outcrop. Carefully examine the surface of the bedrock to insure that it is solid and not in a state of deterioration. The margin of weathered rock can be surprisingly thick. If its surface has begun to crumble or contains deep fissures in close proximity, the outcrop is probably unsound and should not be used as a mark site. In this case, another type of mark or another location may improve stability. Some sedimentary rock, such as montmorillonite, contains detrimental clay minerals. Geological maps or expert advise may help determine if a sedimentary outcrop is expansive and therefore unsuitable as a mark setting. In this case, a site should be located in a structure or another rock outcrop. If this situation is not practical, a rod-type mark should be used. The effects of expansive bedrock due to variations in moisture content is not a problem if there is a sufficient overburden.

e. Man-made Structures. Since structures are subject to movements, fixing a mark on a structure does not assure that it will be a good geodetic control point. Before setting a mark it should be determined whether or not the structure will be as stable as a Type A rod mark (see Table 3-1). If not, use a Type B (see Table 3-1) or any other suitable rod mark. The stability of a large structure may be related to a Type B rod mark by comparing the depth of the structure's foundation to the required depth of the rod mark sleeve. In addition, the structure should be a multistory design constructed of concrete, masonry, or steel. The Type B rod mark sleeve is set to a depth below that affected by expansive soils and frost heave. For a structure to be of comparable stability, the foundation need not be as deep as the rod mark sleeve. This is attributed to the weight of the structure, which can resist some of the expansive forces exerted by the soil. Also, the structure itself will have a shielding effect on the soil below, making conditions such as temperature and moisture content less variable. If the foundation of a structure is at least a quarter of the specified sleeve depth of a Type B rod mark, the structure is considered stable. Small structures, such as concrete culverts, platforms, retaining walls, bridges, etc., shall never be used for permanent monumentation. Very large bridges can be used if the structural member in which the monument will be set rests directly on bedrock, deep piles, or piers. Most structures are expected to settle both during and after construction. A structure less than 5 years old shall not be considered for vertical control marks unless its foundation is on bedrock. In general, a structure with a long life expectancy should be selected. Modern buildings will probably remain undisturbed for a long time. Older buildings of historical significance may provide a good site for a permanent monument. Caution should be taken to assure that the monument is placed in a location that is an integral part of the structure's foundation or fixed rigidly to it. Placing a permanent monument on an appendage, such as steps entering a building, is unacceptable unless the appendage has its own foundation of sufficient depth. Avoid sites that might be damaged or covered during any additional construction on or near the structure.

f. Miscellaneous Areas to Avoid. Sites near water reservoirs and large rivers, where the water level is variable, can rise and fall due to rebound and compression of the soil. This type of movement can have a significant effect on the precision of geodetic measurements. If possible, marks should be established a few hundred meters from the boundaries of these sources of ground activity. Permafrost has a stabilizing effect on marks anchored to a sufficient depth. Significant expansion and contraction of frozen ground due to temperature variation can occur to a depth of about 10 meters (33 feet). A permanent monument anchored below this depth can be expected to be quite stable. In regions where permafrost normally exists near the surface, sources of thawing can keep the ground in an unfrozen condition to a greater depth than expected. Any body of water, such as a pond, lake, or river, will have this effect. Other influential thawing sources include buildings, roads, pipelines; in short, any mark of civilization.

2-5. <u>Corrosive Environment</u>. The rate at which a material will corrode or deteriorate is affected by its environment. There are two conditions necessary for corrosion to occur. First, the metal being corroded must be in contact with an electrolyte or a liquid capable of conducting electric current. Electrolyte composition may vary widely, ranging from a minute amount of nearly pure water formed by condensation to seawater. Secondly, there must be a dissimilarity in two areas of the surfaces being corroded. This could result from the presence of strains or inclusions in an alloy, the contact of dissimilar metals, or a variety of possibilities between these two extremes. The most important environmental factors governing the corrosive character of a soil are the degree of aeration and the presence of any water-soluble salts. Aeration is an important soil characteristic because many metals need exposure to oxygen in order to form a dense, tough layer of metallic oxide on their surfaces. The oxide coating prevents further corrosion by isolating the remaining metal from any electrolytes. Aluminum and steel protect themselves in this manner. Water-soluble salts have an influence on corrosion in two ways. First, the ions that form when salts dissolve improve the capability of the electrolyte to carry current. The greater the ability of the electrolyte to carry current, the faster corrosion will occur. Water with dissolved salts is a better electrolyte than pure water. A second effect of water-soluble salts is the influence they have on the formation of the dense, tough protective oxide layer that forms on the surface of certain metals. Rod marks will at times unavoidably be placed in corrosive soils. As a protective measure, rod marks placed in corrosive soils should be Type B made of Type 316 stainless steel. This material is more resistant to corrosion than other affordable alloys in nearly all environments. Nonetheless, steps may be taken to increase its life span. Stainless steel is most susceptible to corrosion in poorly aerated environments and those in which chlorides are present. Well-aerated soils are generally recognized by their red, yellow, or brown colors resulting from the oxidation of iron compounds commonly found in soils. Sites with this type of soil characteristic provide a good location for permanent monument setting. Poorly aerated soils are usually gray in color due to the lack of sufficient oxygen to oxidize the iron compounds. Soils of this type may also be identified by their poor drainage characteristics. Avoid areas where there is a high concentration of chlorides. Rod marks set along highways, where heavy salting might be done in winter, should be located at least 10 meters (33 feet) from the road surface. In general, setting marks along the edge of the right-of-way is a good practice. Although it will sometimes be impossible, due to project requirements, try to avoid saltwater shorelines. When the purpose of a project is to provide shoreline control, stay off the beach when possible. Another good indication of the corrosive character of a soil may be obtained if one has the capability to measure soil resistivity. The more resistant a soil, the poorer the electrolyte and, consequently, the less corrosive it will be.

2-6. Safety. If a mark extends below ground level, there is a chance of encountering underground cables or pipes during installation. This is especially a concern when drilling a hole for marks requiring sleeves or casings. This situation is more critical in urban areas than in rural areas. Evidence of underground utility lines often can be observed at the surface. Water lines are marked by valve boxes at most street intersections. Avoiding the area between valve boxes will decrease the chances of hitting a pipe. Fire hydrants are a good indicator of the location of water mains. Hydrants usually are placed within a meter (40 inches) of the line and to the side away from the street centerline. Most water and sewer lines lie under the road surface, but some are placed adjacent to it. Therefore, avoid the area between the street and the sidewalk. Telephone and electrical cables are normally laid from 0.5 to 1 meter (1.6 to 3.3 feet) below the surface. Housing developments built in the 1960s and later are much more likely to have underground cables than those built before that time. The absence of telephone and power poles is conclusive evidence that there are underground cables in the area. However, the presence of utility poles does not necessarily indicate the lack of underground cables. Buried telephone lines usually run directly between junction box pedestals or between telephone poles. Electrical cables may run adjacent to telephone lines. When an electric appliance, such as an air conditioning unit or floodlight, is located apart from other structures, an underground cable to it would probably run directly from a metering device. Gas lines are generally harder to detect. Meters and valves are helpful in locating buried gas lines if they are not situated too far apart. As with telephone cable pedestals, do not drill or drive monuments in an area between visible gas devices. If circumstances permit, the best way to avoid problems is to contact the local metropolitan utilities commission. A utility locator service will locate underground utilities by painting the ground. Do not drill or drive monuments within 60 centimeters (2 feet) of either side of the painted line. In addition, it is wise to develop a habit of looking for "Buried Cable" signs. In conclusion, if other considerations in the site selection will allow, monuments may be set near utility poles, for greater security, avoiding the areas between adjacent poles.

2-7. Satellite Visibility. In addition to permanence, utility, and stability, satellite visibility must also be considered when selecting sites for monumentation for Global Positioning System (GPS) type surveying. The proximity of existing bench marks should also be considered when performing dynamic surveying. Sites that provide maximum visibility above the horizon, plus 15 degrees, should be selected. Any obstructions above 15 degrees will potentially block satellite signals. The site ideally should have visibility in all directions above 15 degrees; however, in some locations at specific times, an obstruction in one or possibly two directions may not affect the ability to use the site for GPS surveying. Existing bench marks should be utilized as often as possible as GPS monuments, or new marks should be located as close as possible to known vertical control. For maximum utility and economical use, maximum effort should be made to locate all GPS type monuments within 100 feet of easy access to vehicular ground transportation.

2-8. Cost Comparison. Experience has shown that the earth's crustal movement is dynamic in both the vertical and horizontal directions to various degrees at different sites. This is caused by a combination of several factors such as regional crustal plate movements, removal of subsurface fluids, soil shrinking and swelling, soil freezing and thawing, growth of vegetation, construction of new structures, and settlement of old structures. When developing a monumentation plan, a comparison should be made between the cost of additional monument installation and additional leveling to more stable areas that require less costly monuments. The average cost of second-order and third-order leveling per mile is presently $800 and $480, respectively. The average cost to install a Type A rod monument to 50 feet of depth is presently $280. Additional depth beyond 50 feet will average $3 per foot. In developing the cost comparison, future uses of the mark must be considered; e.g., if marks will be used frequently, there will be an additional future cost of leveling in locations where marks are constructed away from the immediate site where they are needed. In most cases, the cost of repeated or additional leveling will far exceed the extra cost required to install the most stable monument at the site where needed.