Title
Field report of geophysical investigations at the proposed La Purisima Mission Visitor Center

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FIELD REPORT OF GEOPHYSICAL INVESTIGATIONS AT THE PROPOSED LA PURISIMA MISSION VISITOR CENTER

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Geophysical investigations were conducted at the La Purisima Mission State Historic Park to understand potential impacts due to the proposed development of a new visitor's center. The portion of La Purisima State Park studied is located near the park entrance, just north of the intersection of Purisima Road and Mission Gate Road, in Lompoc, California. Field surveys using four geophysical techniques were conducted on September 23-25, 1999 and October 27-29, 2000 to search for buried objects and structures associated with historic occupation of the site. Four geophysical techniques were employed at La Purisima: ground penetrating radar (GPR), electromagnetic conductivity (EM), total magnetic field measurement (MAG), and seismic reflection imaging (SRI).

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GEOPHYSICAL TECHNIQUES

Ground Penetrating Radar

Ground penetrating radar transmits high frequency electromagnetic energy into the ground and measures energy reflected from buried interfaces, such as between soil and rock or wood. GPR is a means for delimiting buried site stratigraphy, and objects or structures that disrupt the natural stratigraphy. At the La Purisima study area, we used a GPR unit manufactured by GSSI (SIR-2000) with a 400 MHz antenna. Data were collected at 16 scans/seconds as the radar antenna was moved along the ground surface at walking speeds. Grids of data were collected with 0.5 m line spacing. A series of maps of radar reflectivity was produced at various depths, called time-slices. Data were collected within a total time window of 30 (ns) nanoseconds from the surface, and were divided into 6 ns time-slices for display (0-6 ns, 6-12 ns, 12-18 ns, and 18-24 ns). The radar data are gridded with a large (approximately 1 m) search radius to filter out clutter and pipes, and to emphasize the largest features.

Electrical Conductivity

Electrical conductivity uses low frequency electromagnetic energy to detect changes in electrical properties. It is an effective means for detecting soil moisture content or buried metallic objects. Instruments for measuring electrical conductivity have a transmitting antenna and a receiving antenna separated by some horizontal distance. The antenna separation sets the optimal depth for detection of buried objects and structures. Metal pipes produce a particularly strong signature, since they are efficient conductors of electrical energy. Moving the instrument parallel to a pipe will produce an enhanced electrical conductivity signal, whereas moving the instrument perpendicular to a pipe will produce a reduced electrical conductivity signal. At the La Purisima study area, we measured electrical conductivity using two different instruments manufactured by Geonics. In 1999, we used an EM-31 with a maximum detection sensitivity for objects and structures at 1.5 m depth. In 2000, we decided that a shallower sensitivity would be most appropriate for the potential targets present at La Purisima, so we used an EM-38 with a maximum detection sensitivity at 0.4 m depth. Data were collected at 0.4 sec intervals at walking speed along survey tracks. The data were corrected for walking speed (shifted backward along track) and then gridded for display.

Total Magnetic Field

Total magnetic field mapping detects changes in the magnetization of subsurface materials. For example, fire produces a strong magnetization in clay and soils, such as the materials comprising a hearth or kiln. Metals are another class of materials that produce a strong magnetic signature. There is a daily variation of ambient magnetic field strength due to the presence of the sun; at local noon an enhanced magnetic field is observed whose amplitude depends on the geomagnetic latitude and on sunspot activity. To remove the solar diurnal variation, a pair of magnetic sensors is used, and data are taken on the difference observed between the two sensors. These data capture the presence of local magnetized materials and remove the fluctuations due to solar activity. This configuration is called a magnetic gradiometer. The magnetic sensors, separated vertically by 1 m, are moved above the site surface, collecting a grid of magnetic field measurements to produce a two-dimensional map. At La Purisima, magnetic survey data were collected only within the 1999 survey grids using a Geometrics 858G cesium vapor total field magnetic gradiometer. During the 2000 field season battery failure kept the magnetic sensors from working properly and no total magnetic field data were collected.

Seismic Reflection Imaging

Only recently has seismic reflection imaging been applied to soils at depths of 10 m or less. Conventional seismic techniques must be modified to account for the properties of shallow soils. Seismic waves used for reflection imaging are sensitive to the elastic properties within the soil. The principal factors effecting soil seismic velocity are its composition (e.g. grain size), water content, and the confining pressure. At La Purisima we used a seismic reflection imaging system with closely spaced geophones, deployed in a line along the surface of the ground, and near these geophones, a series of seismic sources. A digital Geometrics Strataview seismograph allowed large dynamic range signal recordings. With successive shots the geophone array was translated along the line to maintain a constant geometry between the shot and the receiver positions. We used a small hammer to strike a rod that was inserted into the ground, at each shot point

FIELD OPERATIONS

The geophysical survey grids were designed to test for historic structure and objects within or near the footprint of the proposed visitor's center, as well as along the path of the proposed new entrance road. A total of six grids of geophysical data were collected and they are shown in Figure 1, superimposed on the existing buildings, roads and trails in the study area, along with the footprint of the proposed La Purisima visitor's center.

Each grid was marked on the ground with corner stakes, and measurements were made to place the grid relative to a series of datum stakes that had been previously placed on the site (see Figure 1). The primary datum was established along the strike of Building No. 15 (the existing visitor's center) at 300 feet south of the southwest corner of the building. Table 1 gives the geophysical grid dimensions, the grid origin, and the direction for data collection, and their position relative to the primary datum is given in Table 2.

Table 1 Geophysical Grid Dimensions, Origin and Line Direction

Grid	N-S Dimension (m)	E-W Dimension (m)	Origin	Line Direction
99-CEM	30	40	SE	E-W
99-PAL	27	50	NM	E-W
99-ER1	55	20	NE	N-S
99-ER2	25	45	NW	E-W
00-CEM	75	45	NW	E-W
00-PAL	45	40	SW	N-S

Table 2 – Geophysical Grid Coordinates

Grid	NW - east	NW -north	NE - east	NE - north	SW - east	SW -north	SE - east	SE - north
99-CEM	-57.9	26.3	54.3	-41.5	-108.3	-55.4	4.3	-124.4
99-PAL	-6.1	109.8	44	185.5	130.5	18.2	155.5	59.7
99-ER1	-254.9	52.6	-190.2	61.1	-228.8	-126.9	-163.4	-117.3
99-ER2	-382.5	15.7	-253.5	36.1	-370	-64.4	-241.3	-45
00-CEM	-54.3	46.1	72.9	-27.3	-183	-176.6	-55.4	-249.5
00-PAL	32.9	42.2	111.9	179.5	224.5	111.2	144.8	-24.7

Note: These coordinates are given in feet, relative to the primary site datum, with N (+) / S (-), and E (+) / W (-). The designations NW, NE, SW, and SE refer to the corners of the grid.

These data are shown graphically within Figure 1b (1999) and Figure 1c (2000). Within each grid the geophysical data sets were collected along survey lines with a 0.5 m spacing. Survey lines were generally collected parallel to the longest dimension of the grid. The direction of the first line of the survey is shown by an arrow within each grid for 1999 (Figure 1b) and 2000 (Figure 1c). The origin for each grid is taken to be the corner near these arrows. Measuring tapes were placed along the ground surface and control marks were entered into the data at 1 m intervals during the data collection process.

RESULTS

Ground Penetrating Radar

Ground penetrating radar data are shown in map view for the 1999 (Figure 2) and 2000 (Figure 3) field season grids. For each field season, time slice images are shown with increasing depth. All images have red colors for reflective materials and blue colors for non-reflective materials.

The ground penetrating radar results will be discussed as a series of depth (time-slice) sections for each of the two field seasons (1999 and 2000). The uppermost section represents 0-32 cm depth (0-5.8 ns) for the 1999 field season (Figure 2a). These data reveal a highly reflective linear zone associated with the compaction of the existing dirt road which passes through the Palisada (99-PAL) and Cemetery (99-CEM) grids (see red stripe in Figure 2a).

There are also linear reflective features in the 0-32 cm slice within the Entrance Road #1 (99-ER1) and #2 (99-ER2) grids. In the 99-ER1 case these features may be associated with modern utilities (water and sewer pipes). In the 99-ER2 case these features, primarily in the northwest corner of the grid, form a more complex pattern, and are not at the location of any known utilities. Perhaps these patterns may be related to historic architecture or other features. It is proposed that the GPR anomaly in 99-ER2 be tested to investigate what objects or features create these linear reflective patterns (see Table 3 - anomaly 1, for the location of this anomaly).

The GPR section at 32-64 cm depth (Figure 2b) reveals two linear reflective features in the western half of the 99-PAL grid. The feature that passes entirely through the grid in a north-south direction is probably associated with a known water line. This feature can be seen to match a linear feature in grid 99-CEM and is consistent with the location of a known (abandoned) water line. The more westerly feature in grid 99-PAL, which passes only through the southern portion of the grid may be associated with the historic palisada sturcture, known to extend about 300 feet south from the current visitor's center (building 15 in Figure 2b). The GPR reflection may be related to a hard-packed clay floor or other architectural component of the palisada structure. A third feature seen in the GPR data is located at the southern edge of the grid, almost directly under the existing dirt road. As discussed later, this feature is probably a metallic object (abandoned septic tank?) and we suggest that it should be tested since it is directly beneath the proposed new visitor's center (see Table 3 - anomaly 2 for coordinates within the 99-PAL grid).

The GPR section at 64-96 cm depth (Figure 2c) again shows the water pipe running north-south in the western portion of the 99-PAL grid. Another north-south linear feature, however, appears in the eastern portion of the grid. This feature was previously investigated and found to be an ancient fluvial channel. The existence of this channel was confirmed by auger testing during data acquisition. It is likely that this channel is very old (perhaps at least 10,000 years or more), when a small stream was flowing at this location. Since it is located directly under the footprint of the proposed visitor's center, however, it may be appropriate to further test this feature to confirm that it is of geological, rather than historic origin. (Table 3 lists the feature as anomaly 3 and gives its location for testing within grid 99-PAL.) Also seen in the 64-96 cm GPR section (Figure 2C), is an intense zone of radar scattering in the southeast portion of the 99-CEM grid. This region has been excavated previously, but the zone of radar scattering (60 ft x 60 ft) is somewhat larger than the dimensions of previous excavations (30 ft x 30 ft). These reflections are presumed to be from the historic cemetery. The proposed entrance road to the new visitor's center passes just to the south of this feature. It may be appropriate to conduct test excavations along the path of the proposed entrance road in the vicinity of grid 99-CEM, to better define the boundary of the historic cemetery.

In the deepest GPR section (96-128 cm), the presumed fluvial channel in grid 99-PAL is seen as a distinct feature in the eastern portion of the grid, trending in a north-south direction. Radar scattering is also seen from the presumed historic cemetery in the southeast portion of grid 99-CEM.

Two grids of GPR data were collected in September 2000. Grid 00-PAL (Figure 1c) was coincident with the eastern portion of grid 99-PAL but also included the remainder of the proposed visitor's center footprint to the east, where brush had been recently removed. Grid 00-CEM was coincident with portions of grid 99-CEM, but included areas to the south and east, with the idea of better defining the historic cemetery region. Unfortunately, there were rains just before and during the 2000 geophysical fieldwork, so that the ground was substantially wetter than during the 1999 fieldwork. Overall, there was less radar penetration during 2000 and this resulted in little or no new information on subsurface features. Figure 3a show the upper section (0-44 cm) GPR data for the 2000 – the primary features are linear zones associated with the present dirt road (eastern portion of grid 00-CEM) and with the current paved park entrance road (southwestern portion of grid 00-CEM). The grids produced for later times (Figure 3 b and 3 c), which should have information on deeper objects/structure, instead show multiple reflections from the surface features, an indication of poor radar penetration.

Electrical Conductivity

The electrical conductivity data are shown in map view in for the 1999 (Figure 4) and 2000 (Figure 6) field seasons. Regions of high electrical conductivity are shown with white and red colors, whereas regions with low electrical conductivity are shown with black and blue colors. For the La Purisima survey grids, the EM data primarily show the location of buried pipes, and secondarily the moisture content of the soil. The 1999 field season data (Figure 4) were collected with an EM31, whose sensitivity for buried features and objects is best near 1.5 m depth. In the 99-PAL grid (Figure 4) two pipes are seen running in a north-south direction in the western portion of the grid. The pipes appear as low conductivity features (blue stripes) flanked by zones of high conductivity (red and white). These two pipes continue into the 99-CEM grid, although in this grid the eastern pipe is less well resolved. Pipes are also seen in the 99-ER1 and ER-2 grids; in this case the known utilites map suggests that they are a combination of sewer, water and power lines. The high conductivity zone surrounding these pipes may be influenced by the close proximity to the creek and associated high water content of the soil at depth.

The 2000 field season data (Figure 6) were collected with an EM38, whose sensitivity is best at 0.5 m depth. This instrument is perhaps a better match to the expected depth of historic objects and structures at La Purisima. In the EM38 data, two pipes are again seen in the 00-CEM grid, one of which also cuts across the southwest corner of the 00-PAL grid. At the southern edge of the 00-PAL grid is a linear metallic object, mentioned earlier, which is probably an historic septic tank. This object is designated as anomaly 4 in Table 3 (this is the same as anomaly 2 in Table 3, but listed twice to provide coordinates in each grid system). An approximately square region of high conductivity at the northern edge of the 00-PAL grid may be associated with slightly greater water content – it is unlikely, however, to be associated with a buried object or structure.

Magnetometer

The magnetic field data are shown in map view in for the 1999 field season (Figure 5). No magnetic field data were collected in 2000. Regions of increased magnetic field are shown with white and red colors, whereas regions with low magnetic field are shown with black and blue colors. For the La Purisima survey grids, the magnetic field data primarily show the location of metallic objects such as utilities. The magnetic field data reveal linear magnetic anomalies in the 99-PAL and 99-CEM grids. These anomalies display alternate high and low magnetic field strength. They are associated with two buried pipes running parallel in a north-south direction through the grids. Also in the 99-PAL grid is a magnetic anomaly associated with the metallic tank or (?) septic system at the south edge of the grid (anomaly 2 and 4 in Table 3). An additional zone of high magnetic anomaly is seen in the northwest corner of 99-CEM. This may be another metal water pipe, running as a branch line from those previously mentioned in the 99-PAL and 99-CEM grids. A compact set of magnetic anomalies is also seen in 99-ER2 grid, at the location of the previously mentioned GPR anomaly (see anomaly 1 in Table 3).

Seismic Reflection

Seismic reflection data were collected at La Purisima on a one-meter line spacing, over a 15 m by 15 m grid in the central portion of the 00-CEM grid. We have not yet fully processed these data to convert them into vertical sections, and subsequently into time/depth slices. Our hope is that these data will help to non-invasively confirm the presence of the historic cemetery in this region of the site.

Table 3 Geophysical Anomalies Proposed for Testing

Anomaly Number	GRID	N (+) or S (-) in meters	E(+) or W(-) in meters	Depth (cm)	Feature Type	Anomaly
1	99-ER2	-10	15	0-32	Architectural, Metal	GPR, MAG
2	99-PAL	-25	30	32-64	Metal	GPR, EM, MAG
3	99-PAL	-15	42.5	64-128	Geologic	GPR
4A	00-PAL	3	10	0-100	Metal – West end	EM
4B	00-PAL	5	19	0-100	Metal – East end	EM

Note: these coordinates are relative to the grid origin, shown as an arrow in Figure 1b or 1c.

SUMMARY

At the site of the proposed visitor's center at La Purisima Mission State Historic Park, we have applied ground penetrating radar, electrical conductivity, magnetic and seismic reflection survey techniques to image buried objects and structures. Both known and unknown features have been identified from these data. GPR data revealed the known palisade feature, perhaps due to a well compacted floor, and the historic cemetery, perhaps due to scattering and disturbance due to the burials and associated funeral objects. Many known buried utilities were revealed by all three techniques: GPR, EM, and MAG. However, the EM data had the highest success rate for detecting underground utilities. Magnetic field data were an aid in determining if the detected feature was metallic.

Table 3 lists four geophysical anomalies that may be worthy of further investigation. We list them in order of their relation to the footprint of the proposed visitor's center:

Anomaly 2 and 4a,b) - This is a linear metallic object/structure as much as 10 m in length, buried about 0.5m below the present dirt road, within the footprint for the proposed visitor's center. A suggestion has been made that this is a recent (but now abandoned) septic system.

Anomaly 3) - This is a complex linear GPR anomaly at about 1 m depth, within the footprint of the proposed visitor's center. Previous auger testing suggests that it is a geologic feature, associated with a previous fluvial channel.

Anomaly 1) – This is a GPR and magnetic anomaly, perhaps an architectural feature with associated metallic objects. It is located away from direct impacts due to the visitor's center, but within possible alignments for a new entrance road.

Although not listed in Table 3 as a separate anomaly for testing, some effort should be expended in defining the extent of the historic cemetery. The GPR data suggest an intense zone of scattering at the southeast portion of grid 99-CEM, which may be associated with this feature. The cemetery is located close to possible alignment for the new entrance road.

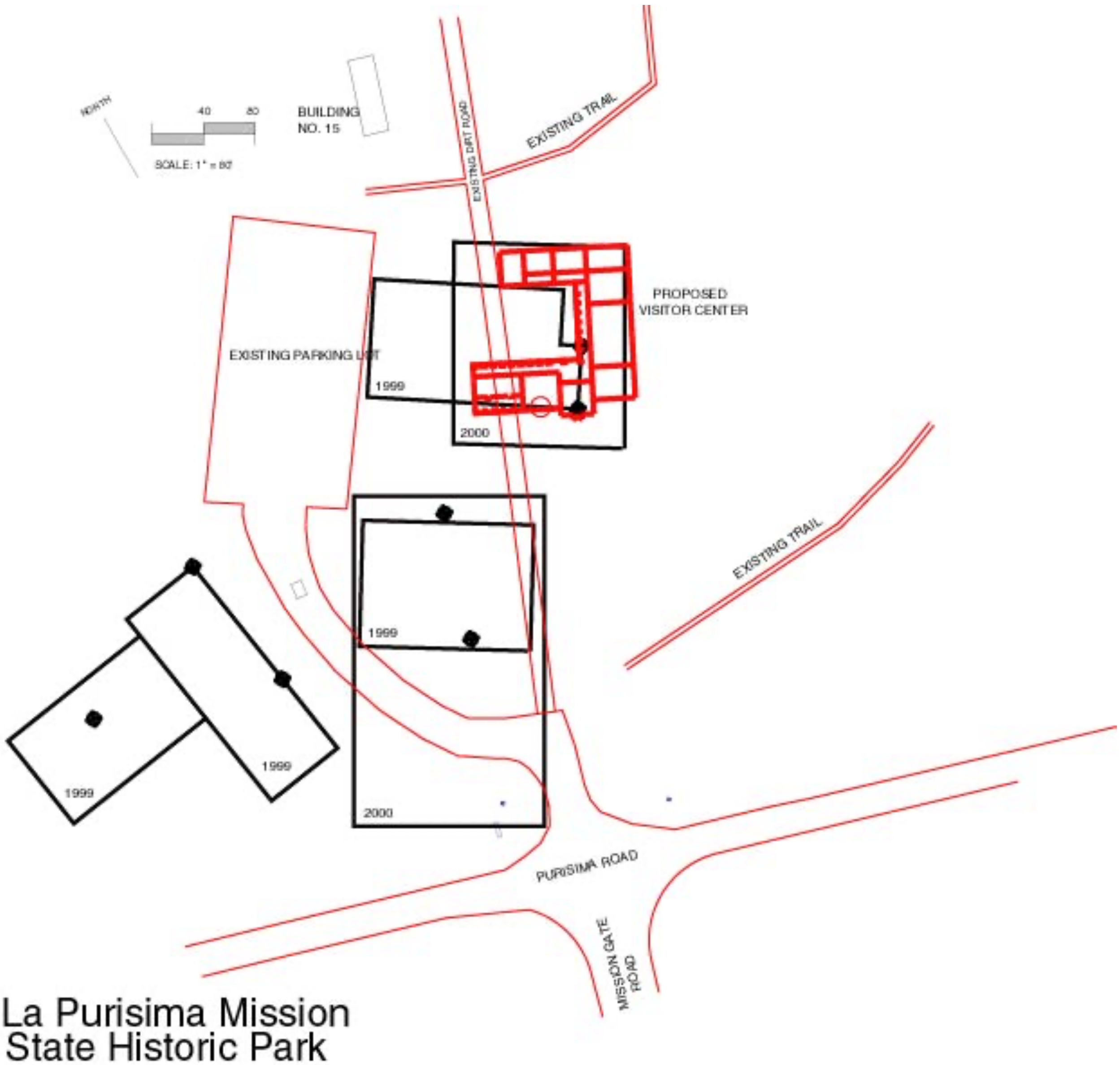

Figure 1. Proposed visitor's center (bold-red) and geophysical survey grids (balck).

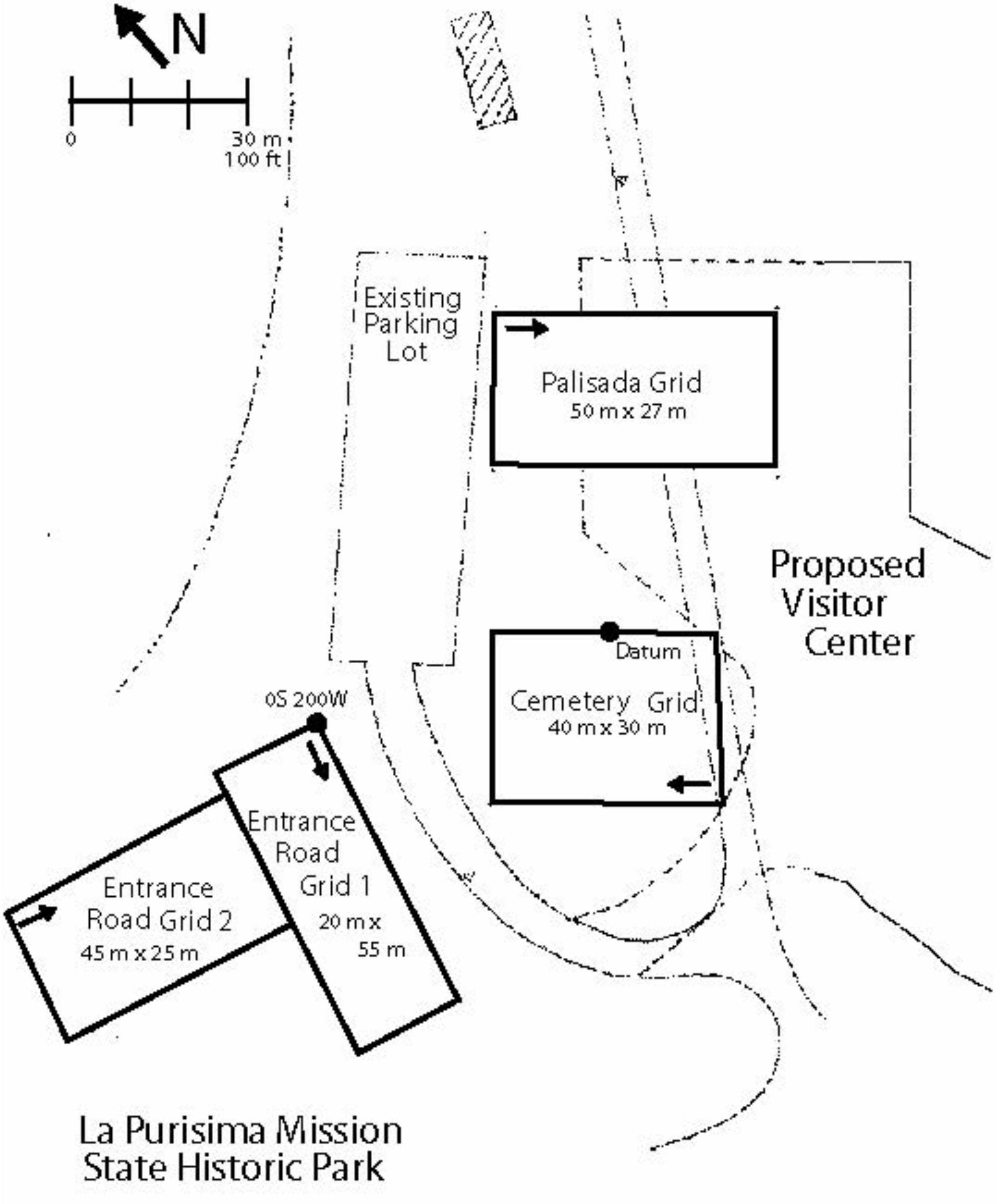

Figure 1 b) Geophysical survey grids for 1999 field season. Grid origin and survey direction indicated by an arrow.

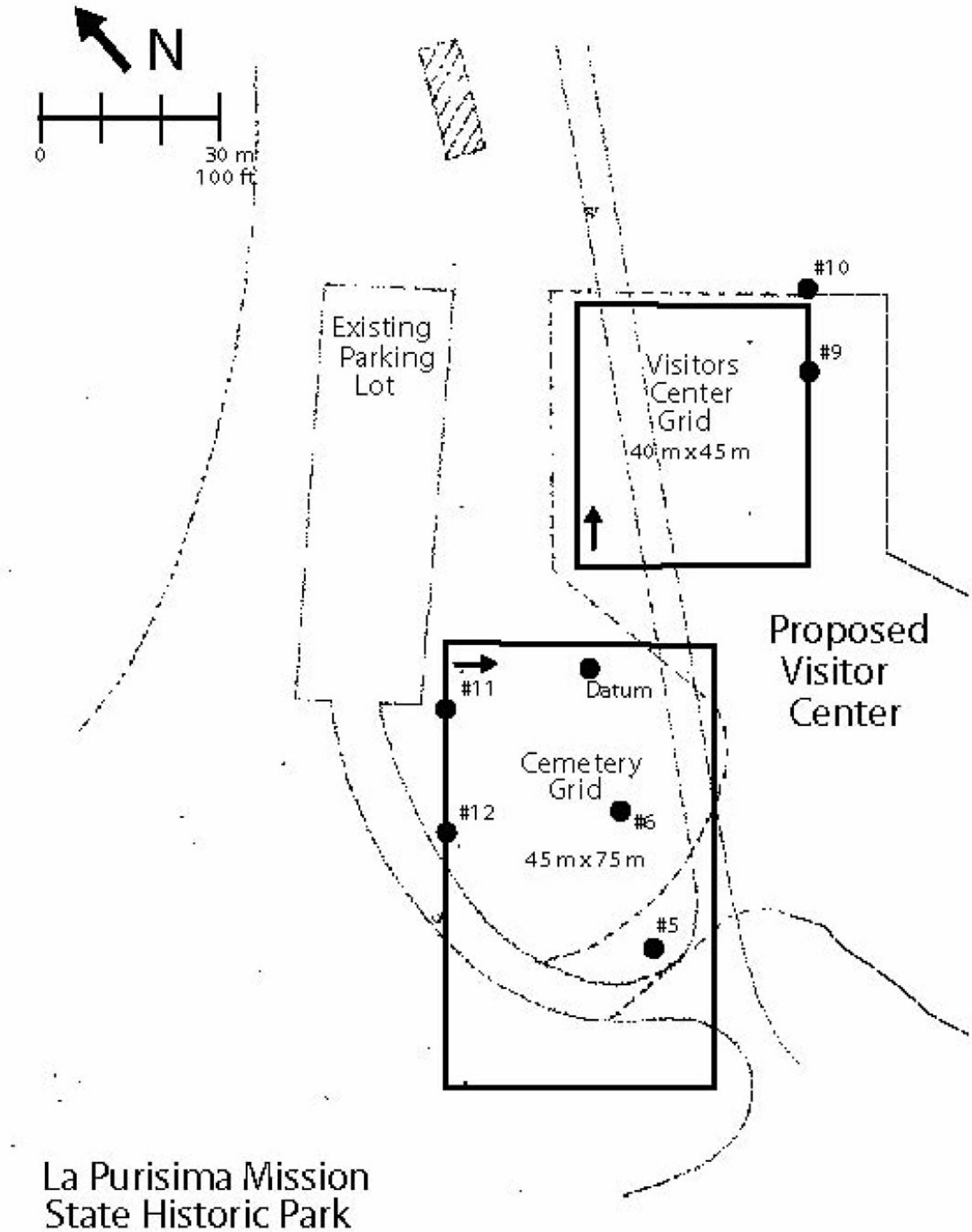

Figure 1 c). Geophysical survey grids for 2000 field season. Grid origin and survey direction indicated by an arrow.

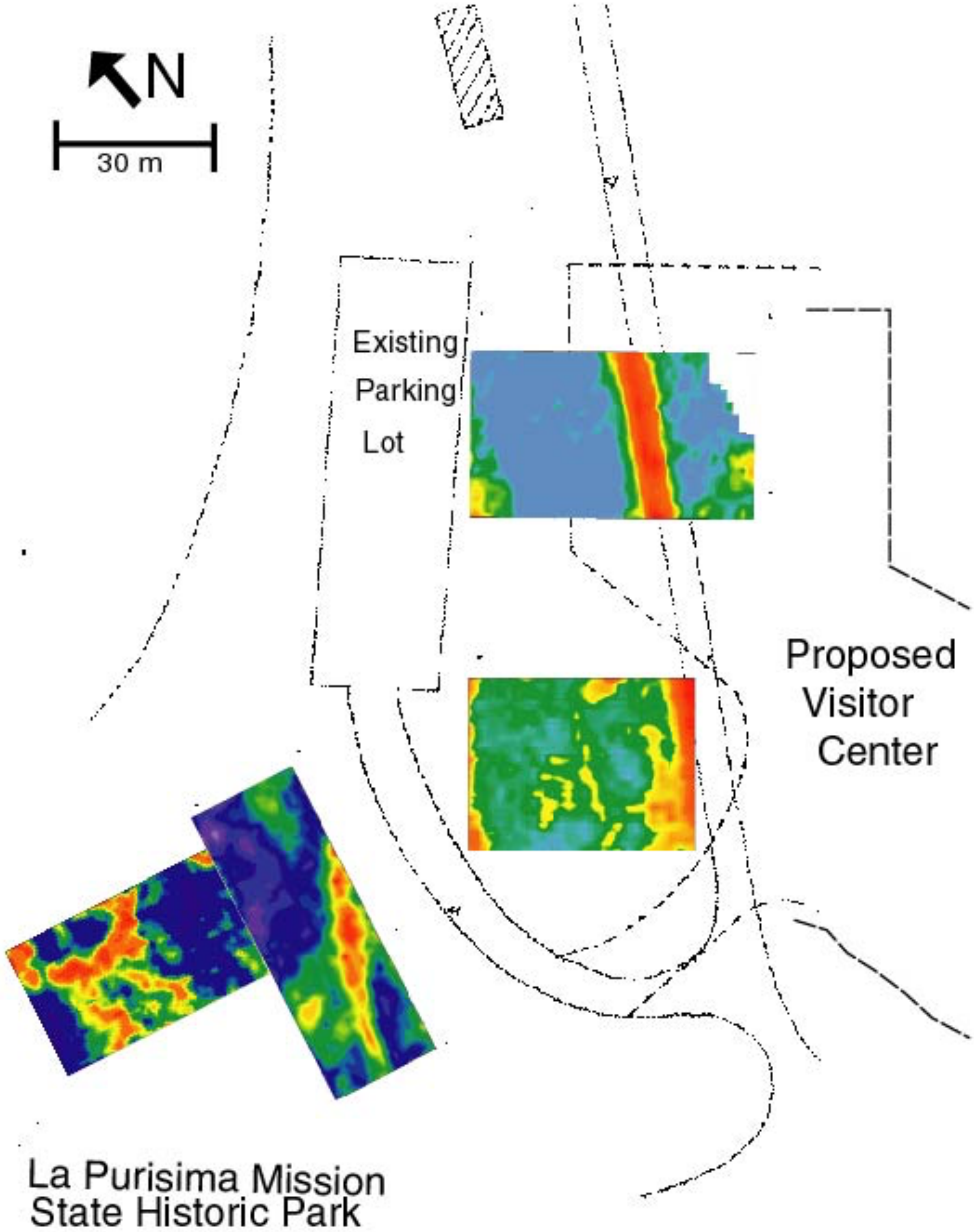

Figure 2 a) Ground Penetrating Radar 0-32 cm collected in 1999.

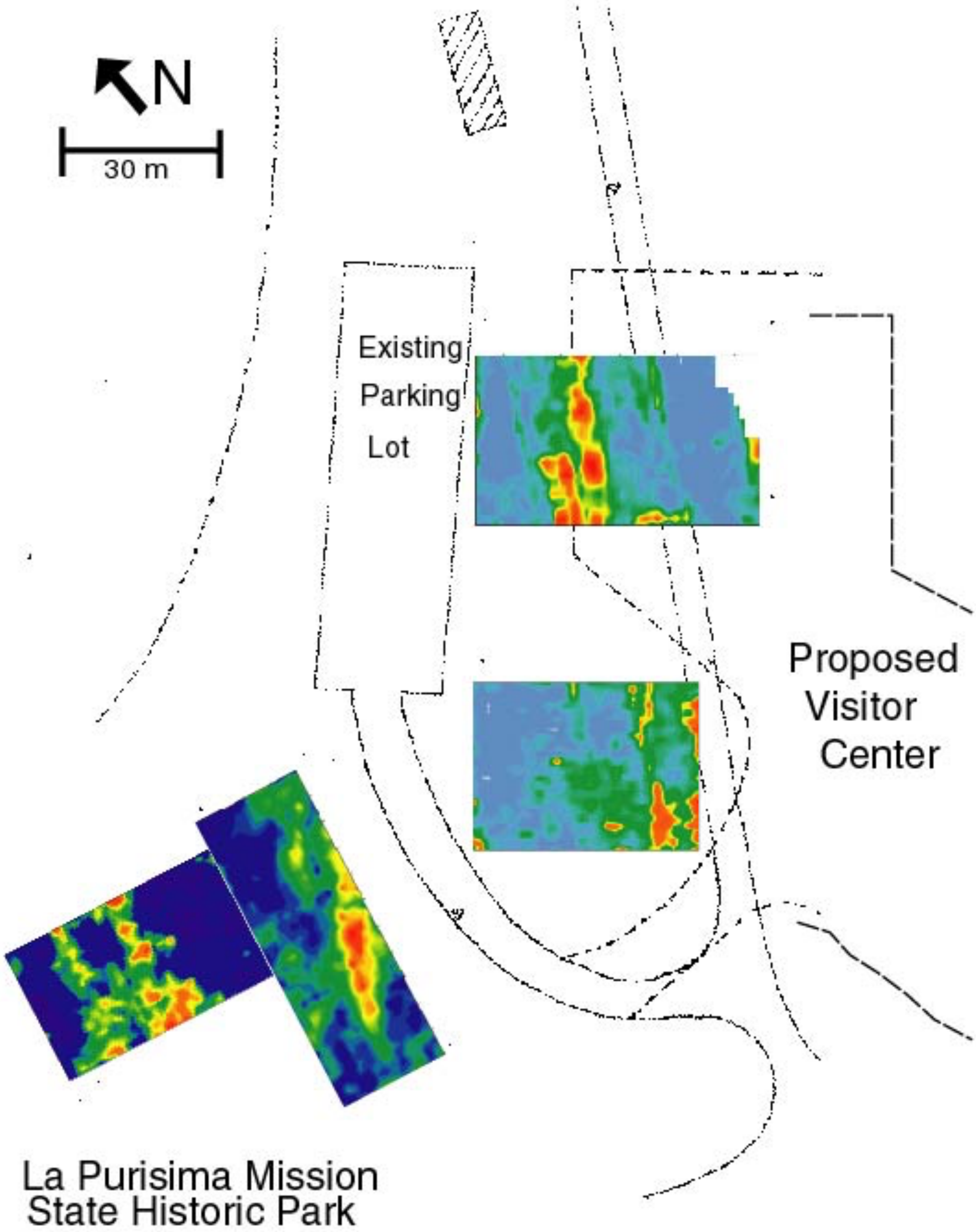

Figure 2 b) Ground Penetrating Radar 32-64 cm collected in 1999.

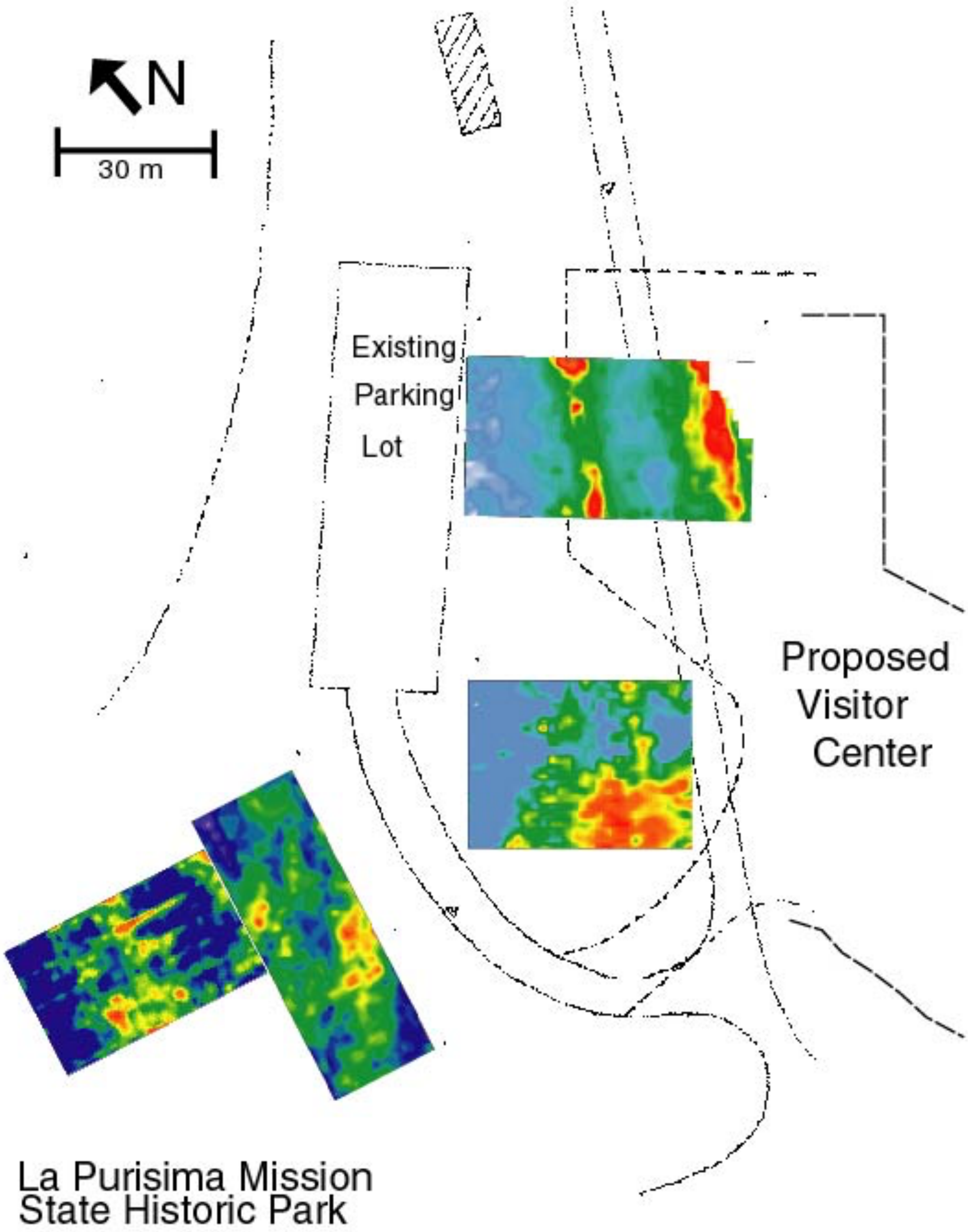

Figure 2 c) Ground Penetrating Radar at 64-96 cm depth, collected in 1999.

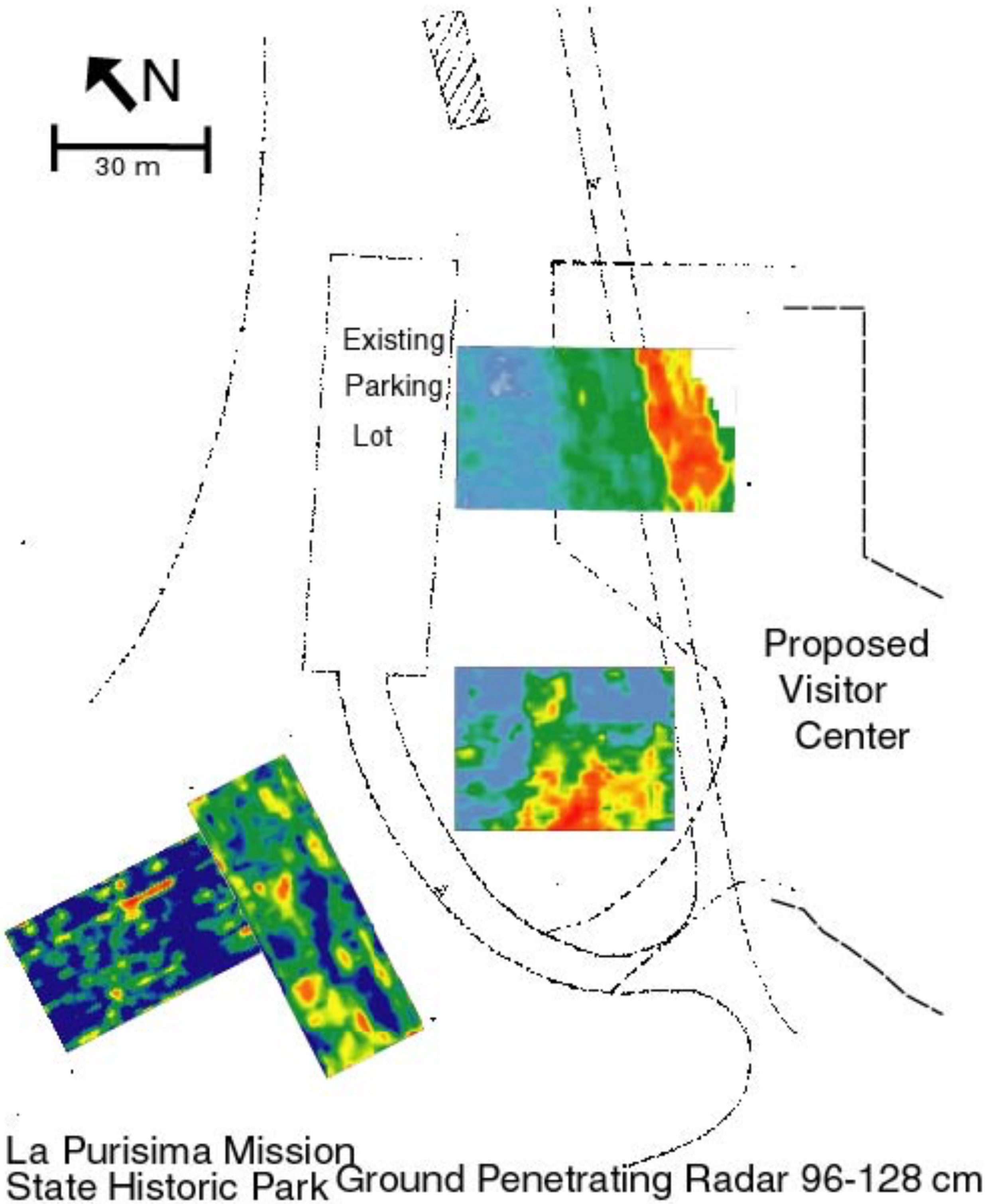

Figure 2 d) Ground Penetrating Radar at 96-128 cm depth, collected in 1999.

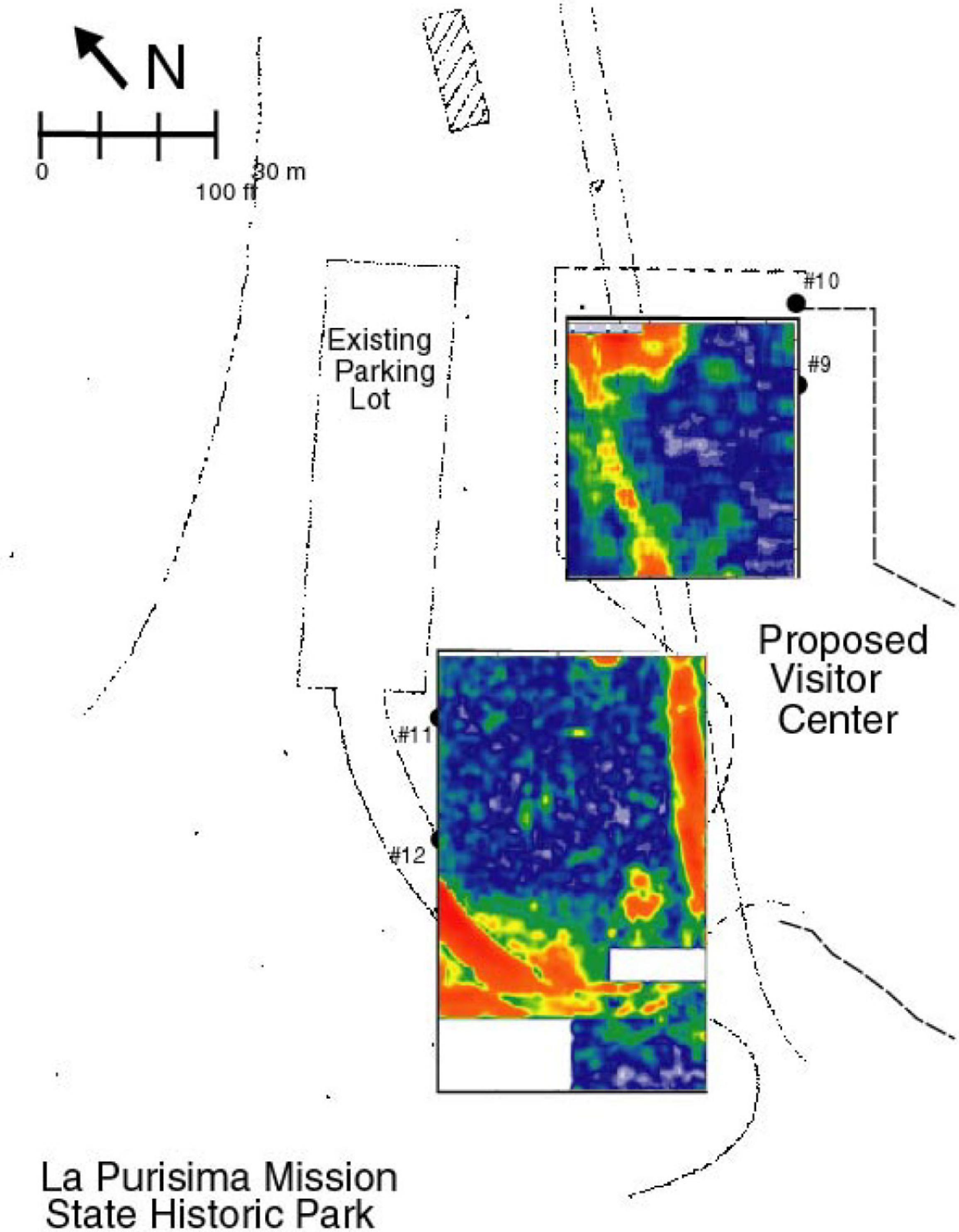

Figure 3 a) Ground Penetrating Radar at 0-44 cm depth, collected in 2000.

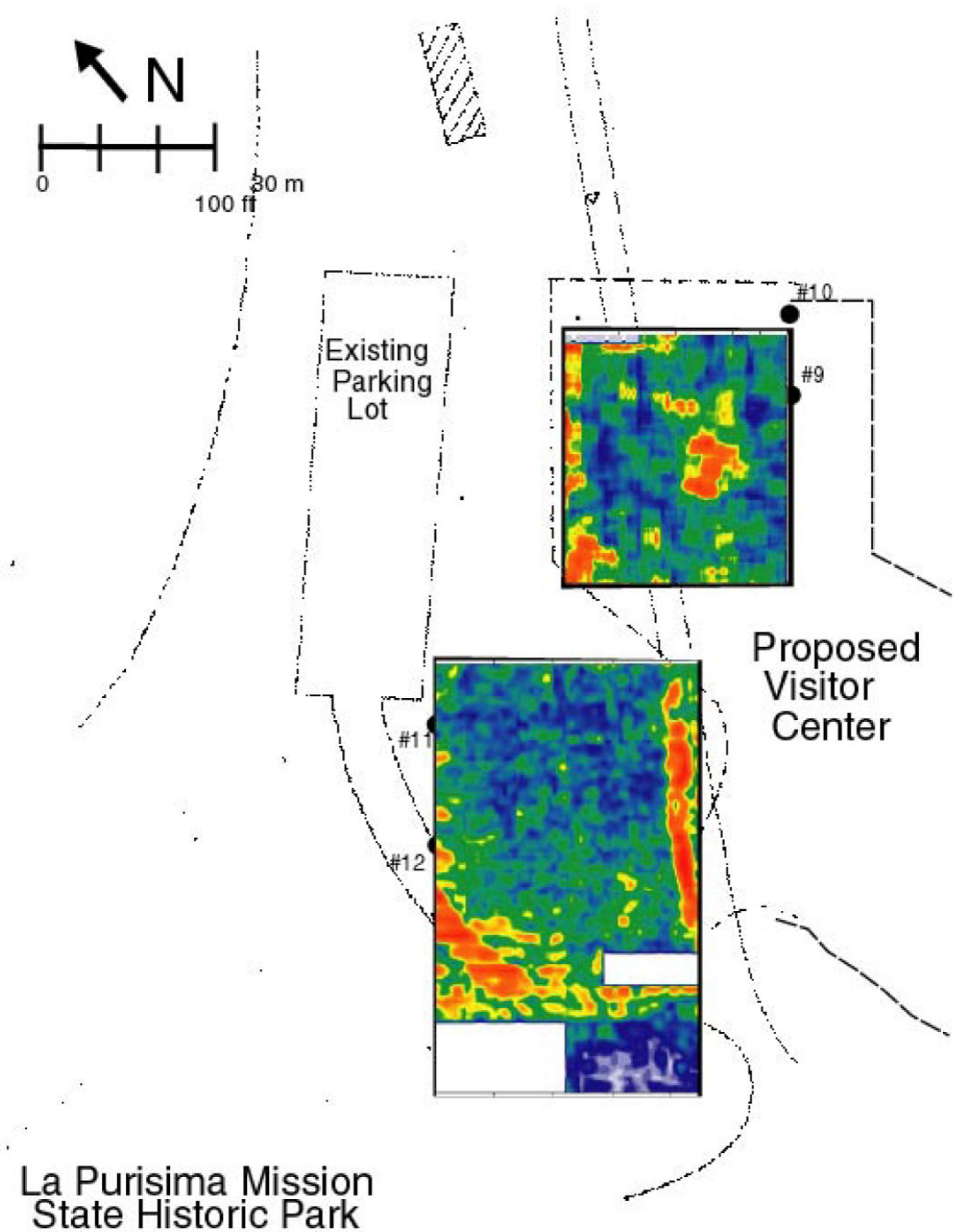

Figure 3 b) Ground Penetrating Radar at 44-88 cm depth, collected in 2000.

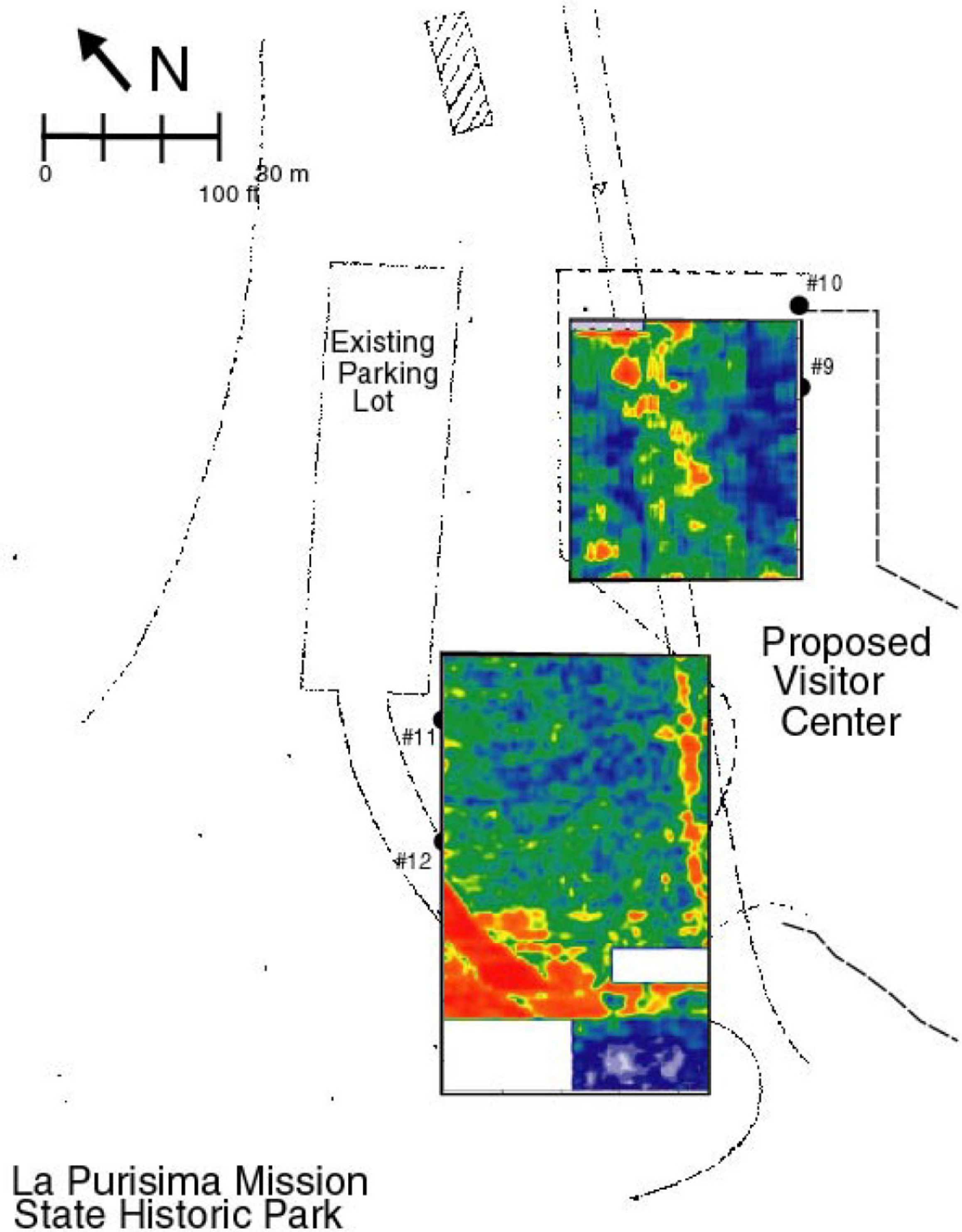

Figure 3 c) Ground Penetrating Radar at 88-132 cm depth, collected in 2000.

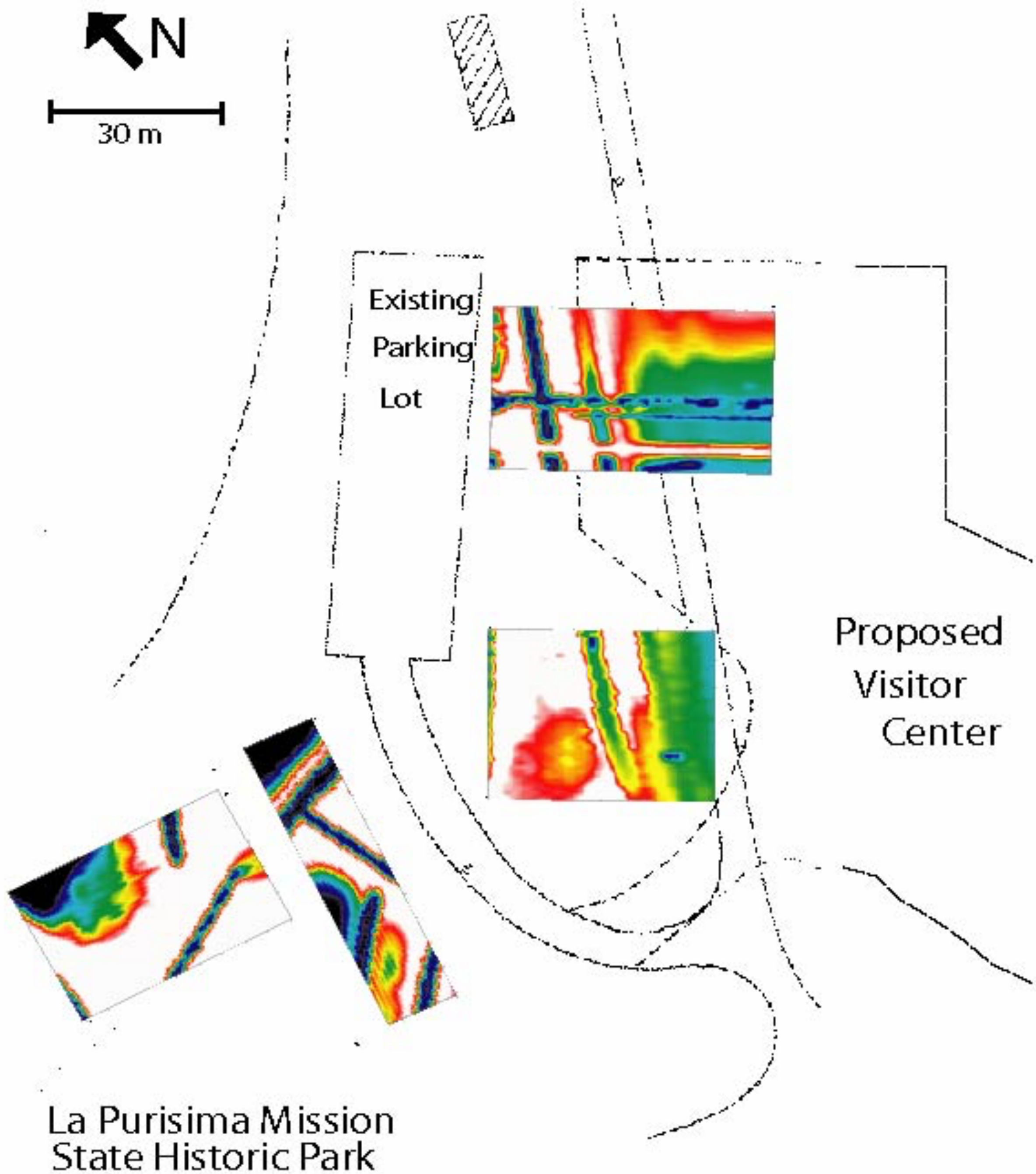

Figure 4 Electrical Conductivity using the EM31, collected in 1999.

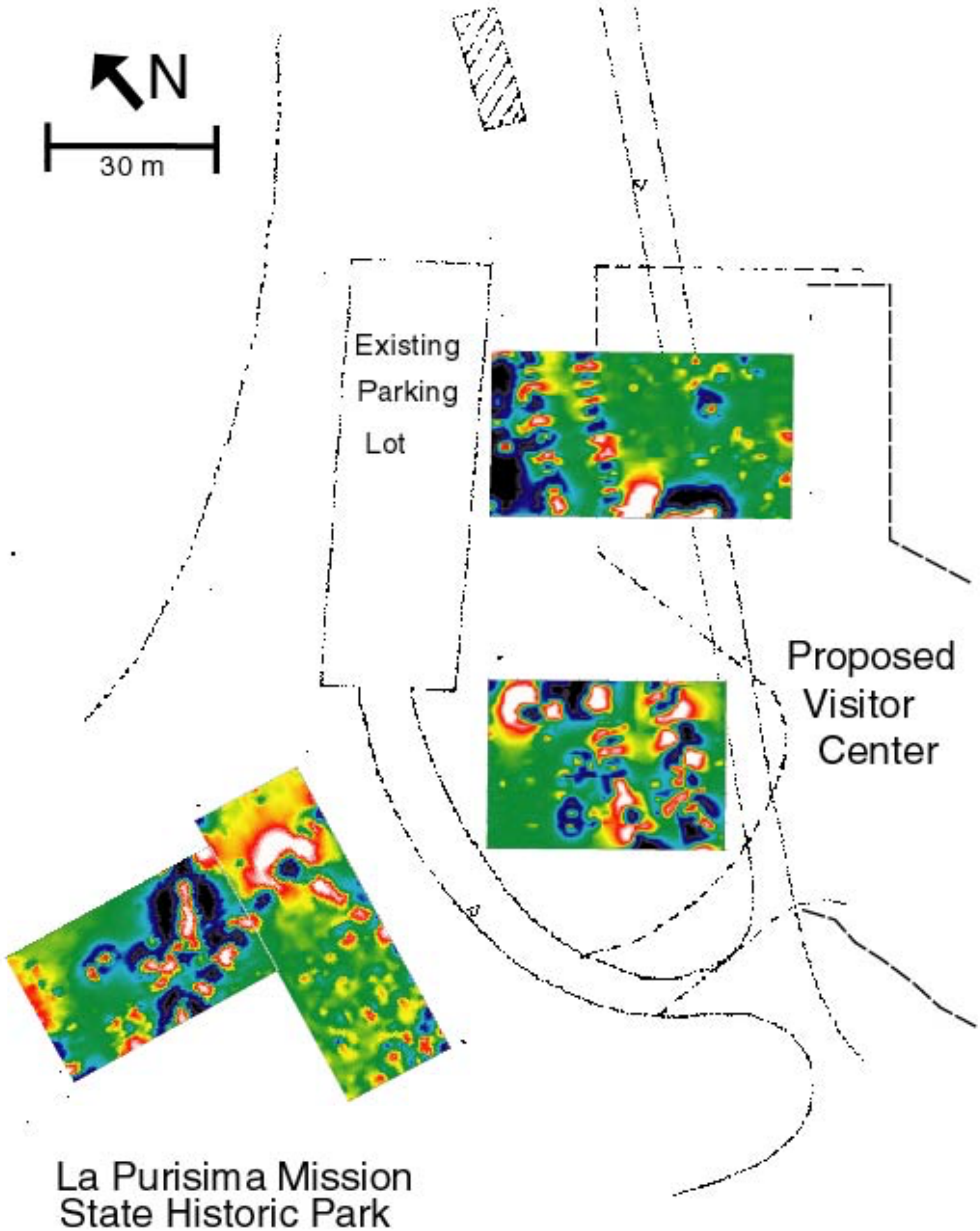

Figure 5 Total magnetic field vertical gradient using Geometrics 858G, collected in 1999.

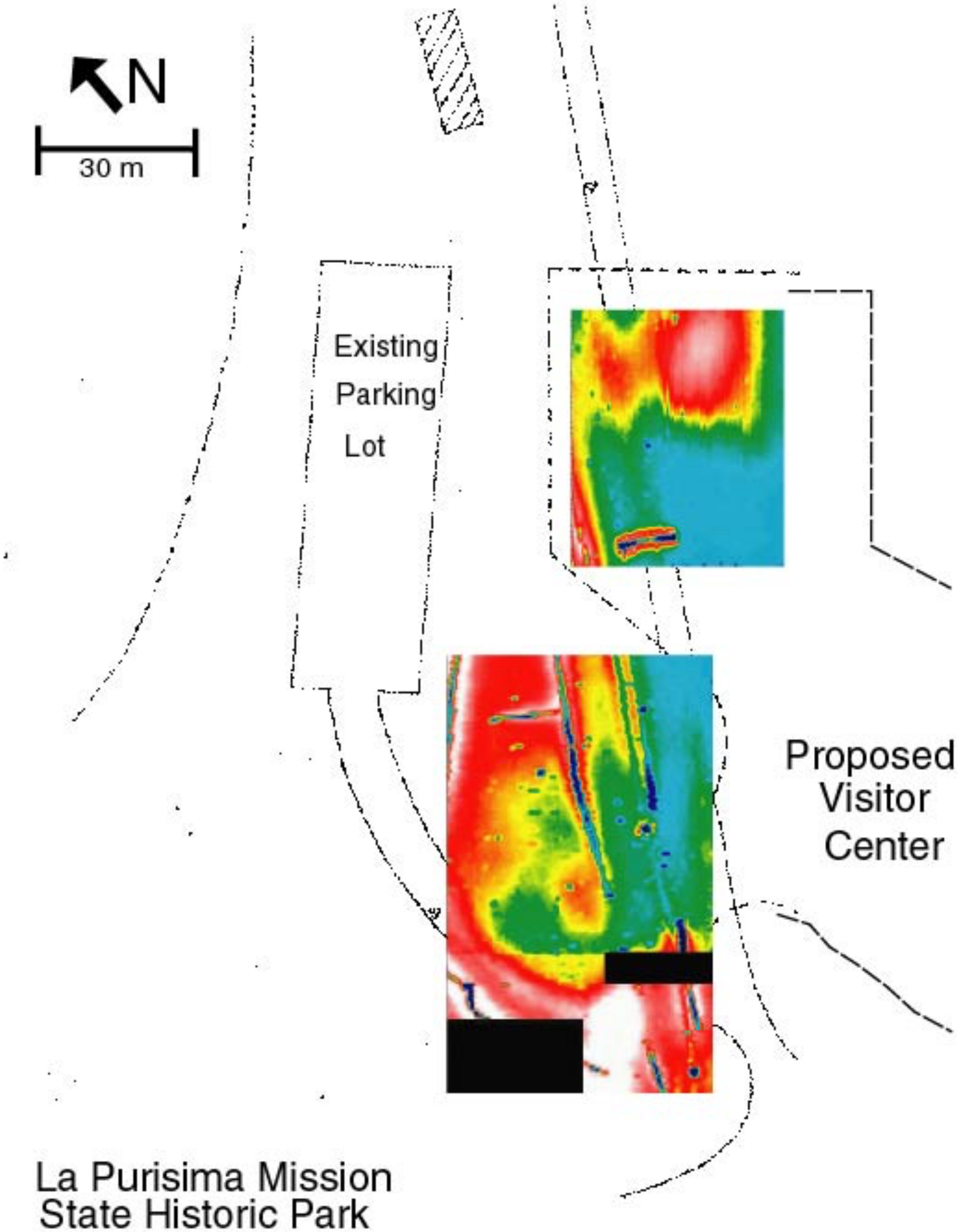

Figure 6 Electrical Conductivity using the EM38, collected in 2000.