GEOVATION

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3 December 1996

Mr. Dave Worrell
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RE: *Report on Fracture-Trace Analysis Study*: NAWC and Delphi properties, Trenton NJ.

Background/Introduction

Based on the findings of the hydrogeologic investigations conducted by the U.S.G.S. on behalf of the NAWC, bedrock ground-water flow is interpreted to be primarily through vertical fractures. As the U.S.G.S. reports that (i) the major fracture/joint orientation is N20°W-to-S20°E and (ii) the secondary fracture/joint orientation is N50°W-to-S50°E, there is a well-founded concern that such fractures could transmit TCE and related contaminants from Site 1 at the NAWC to downgradient locations on the Delphi (GM) property. Based on these concerns, Delphi requested that Geovation perform a fracture-trace analysis survey of the area encompassed by the NAWC and Delphi properties using stereo pairs of aerial photographs.

Fracture-Trace Methods

Geovation's senior staff recently completed a fracture-trace analysis of the area encompassed by the NAWC and Delphi properties under the direction of Dr. Donald Groff, Geovation's Director of Geological Sciences. Two (2) sets of stereo pairs of aerial photographs from 1940 and 1959, respectively, were used in the fracture-trace study. The objective of the fracture-trace work was to delineate bedrock fractures in the area of concern relative to known and/or historical features, such as the area identified as "Site 1" on the NAWC property, the Delphi (GM) building and Gold Run. Geovation employed standard methods for the fracture-trace study as described by Blanchet (1957), Lattman (1958) and others with respect to the analysis and interpretation of stereo-pairs of aerial photographs.

Results

The results of the fracture-trace analysis of the above-referenced aerial photographs are shown on Figures 1, 2 and 3. Figure 1 provides an interpretation of the fracture-trace data from the 1940 stereo pair whereas Figure 2 depicts the data from the 1959 stereo pair. Figure 3 illustrates the combined data from the 1940 and 1959 photographs. Each of these figures provides a plan-view interpretation of the fracture-trace data relative to known features on the NAWC and Delphi (GM) properties at an approximate scale of 1 in. = 750 ft.

Several "sets" of bedrock fractures were delineated within the study area based on the stereographic analysis of the aerial photographs. At least three significant fractures or fracture "swarms" were identified which originate at the NAWC property and "propagate" along the major fracture orientation (approximately N20°W-to-S20°E as reported by the U.S.G.S.) to downgradient locations across the Delphi (GM) property (Figure 1, Figure 3). In addition, several fracture traces were observed which are oriented along the secondary fracture orientation reported by the U.S.G.S.--i.e., approximately N50°W-to-S50°E (Figures 1-3). A third set of lineaments was observed which are oriented roughly parallel to the strike of the bedrock (N70°E-to-S70°W; Figure 1, Figure 3). Analysis of the 1959 stereo pair also indicates that Gold Run originates from and/or follows a significant fracture system (Figure 2, Figure 3).

A major fracture swarm was identified which originates in the vicinity of Site 1 on the NAWC property and which extends downgradient across the Delphi (GM) property (Figure 3). This fracture swarm has well-defined lineaments which correspond to both the major and secondary fracture orientations reported by the U.S.G.S. as described above. It is important to note that the downgradient expressions of this fracture system are near the UST-area wells on the Delphi (GM) property--these wells have historically exhibited among the highest levels of TCE-related contamination found in monitor wells on the Delphi (GM) property.

Conclusions

The results of the fracture trace study are consistent with the findings of the U.S.G.S. with respect to the orientation of the major and secondary fracture systems in the area. A number of bedrock fractures of significant scale were delineated as a result of this fracture-trace study which have the potential to transmit TCE and related contaminants from the source areas identified at the NAWC (e.g., Site 1) to downgradient locations on the Delphi (GM) property (e.g., the UST-area wells). Comparison of these fractures with the locations of the existing monitor wells on the Delphi (GM) property indicates that the installation of additional deep bedrock monitor wells would be required to fully assess the impact(s) of the historical releases of TCE from Site 1 at the NAWC on the Delphi (GM) property.

Recommendations

Geovation strongly recommends that the NAWC install a number of deep-bedrock monitor wells downgradient of Site 1 at locations selected so as to intersect the key bedrock fractures and fracture swarms identified as a result of this study. As the U.S.G.S. has already recommended the installation of eight (8) additional on-site wells to further characterize the deep bedrock beneath Site 1, Geovation recommends that the NAWC install a minimum of eight (8) additional downgradient wells to place equivalent emphasis on the characterization of areas downgradient of Site 1. Geovation recommends that the NAWC first install a subset of these wells so as to allow the U.S.G.S. to verify the depth and thickness of the previously identified "bedding units" in the bedrock at downgradient locations via the use of borehole geophysical methods. Subsequently, the remainder of these wells should be installed so as to optimize their locations and depths based on the results of the borehole geophysics.

Figure 4 illustrates a number of prospective drilling locations selected so as to intersect key fractures or fracture swarms at locations downgradient of Site 1 on the NAWC property. The locations of these wells are approximate in that they would need to be verified in the field using standard surveying techniques. In addition, the stratigraphic interval(s) to be monitored by these downgradient wells should be selected so as to coincide with the U.S.G.S.'s interpretation of the key stratigraphic units identified in the bedrock aquifer as described above.

References

Blanchet, P. H., 1957. Development of Fracture Analysis as an Exploration Method. *Bull. Am. Assoc. Petrol. Geol.*, v. 41, #8, pp. 1748-1759.

Lattman, L. H. 1958. Technique of Mapping Geologic Fracture Traces and Lineaments in Aerial Photographs: *Photogrammetric Engineering*, v. 84, pp. 566-575.

Lattman, L.H. and R. R. Parizek 1964. *Journal of Hydrology*, v.2, pp. 73-91

Meiser and Earl, 1982. Use of Fracture Traces in Water Well Location, A Handbook; Office of Water Research and Technology Report TT/82 1. U.S. Department of the Interior, Washington, D.C. 20240

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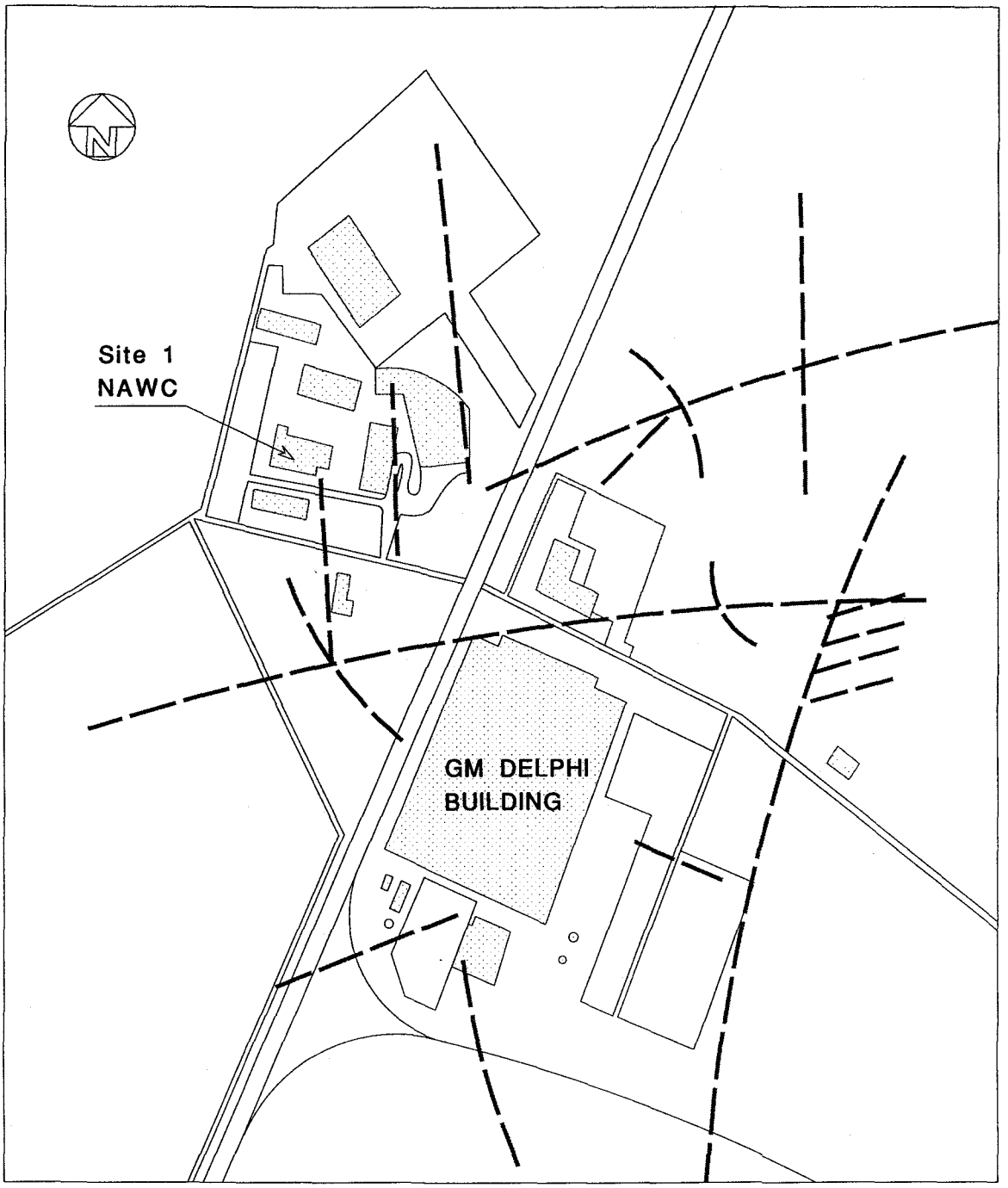
Thank you for this opportunity to serve Delphi Interior and Lighting Systems. Please do not hesitate to contact us at (914) 782-5890 should you have any questions concerning this report.

Sincerely,

Eric Christian Hince, P.G., CPG
President

cc: Lou DeStefano, Esq.; Carpenter, Bennett & Morrissey
Michelle Fisher, Esq.; GM Legal

Enclosures



SCALE: 1" = 750'

LEGEND

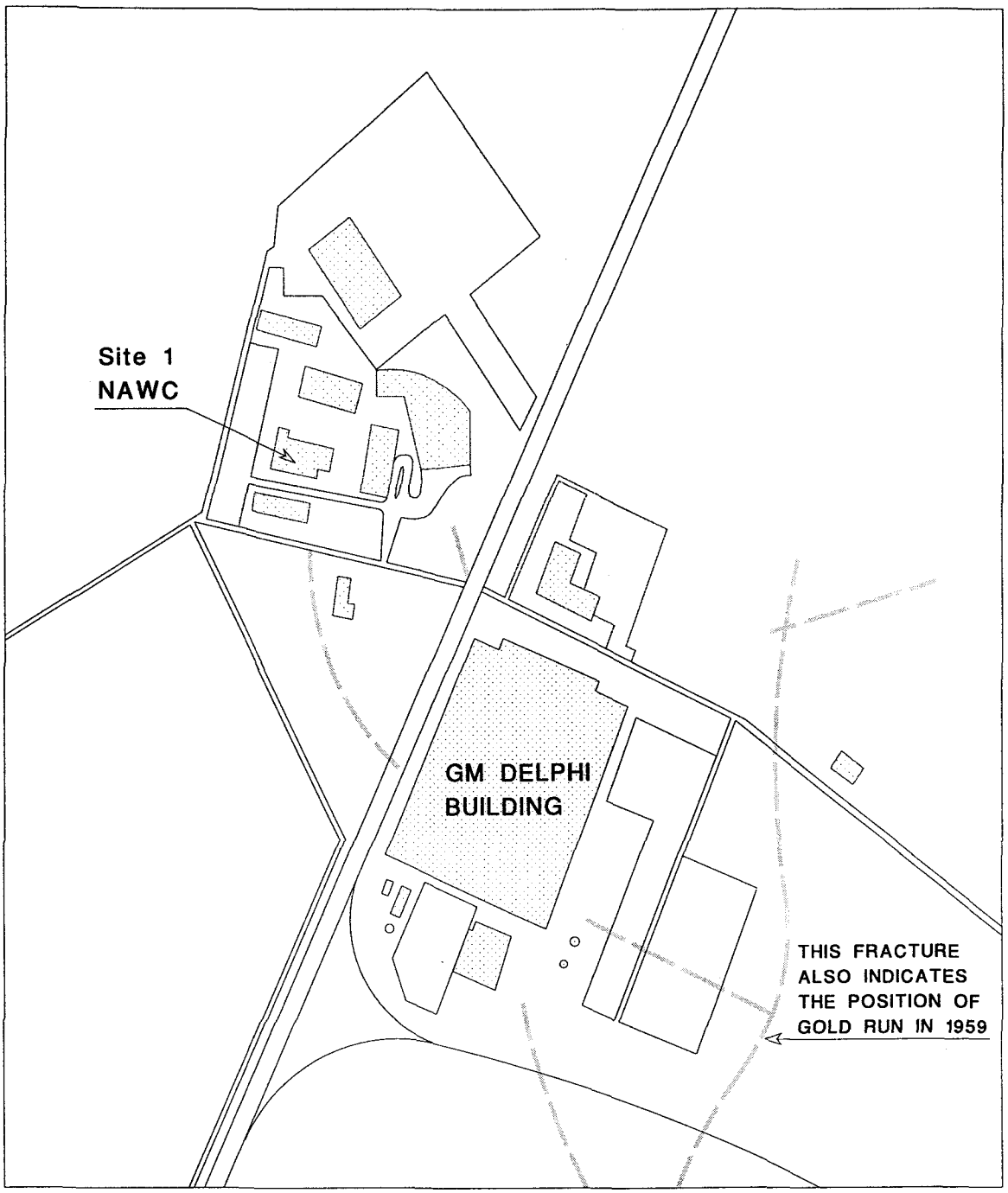
STRUCTURES

FRACTURE TRACES IDENTIFIED BASED ON 1940 AERIAL PHOTO

FRACTURE TRACE ANALYSIS
NAWC/DELPHI (GM) PROPERTIES
TRENTON, N.J.

Results of analysis of 1940 Aerial Photograph

DATE: 11/15/96	RLZ	FIGURE
GEOVATION CONSULTANTS Inc. (914) 782-5890		1



SCALE: 1" = 750'

LEGEND

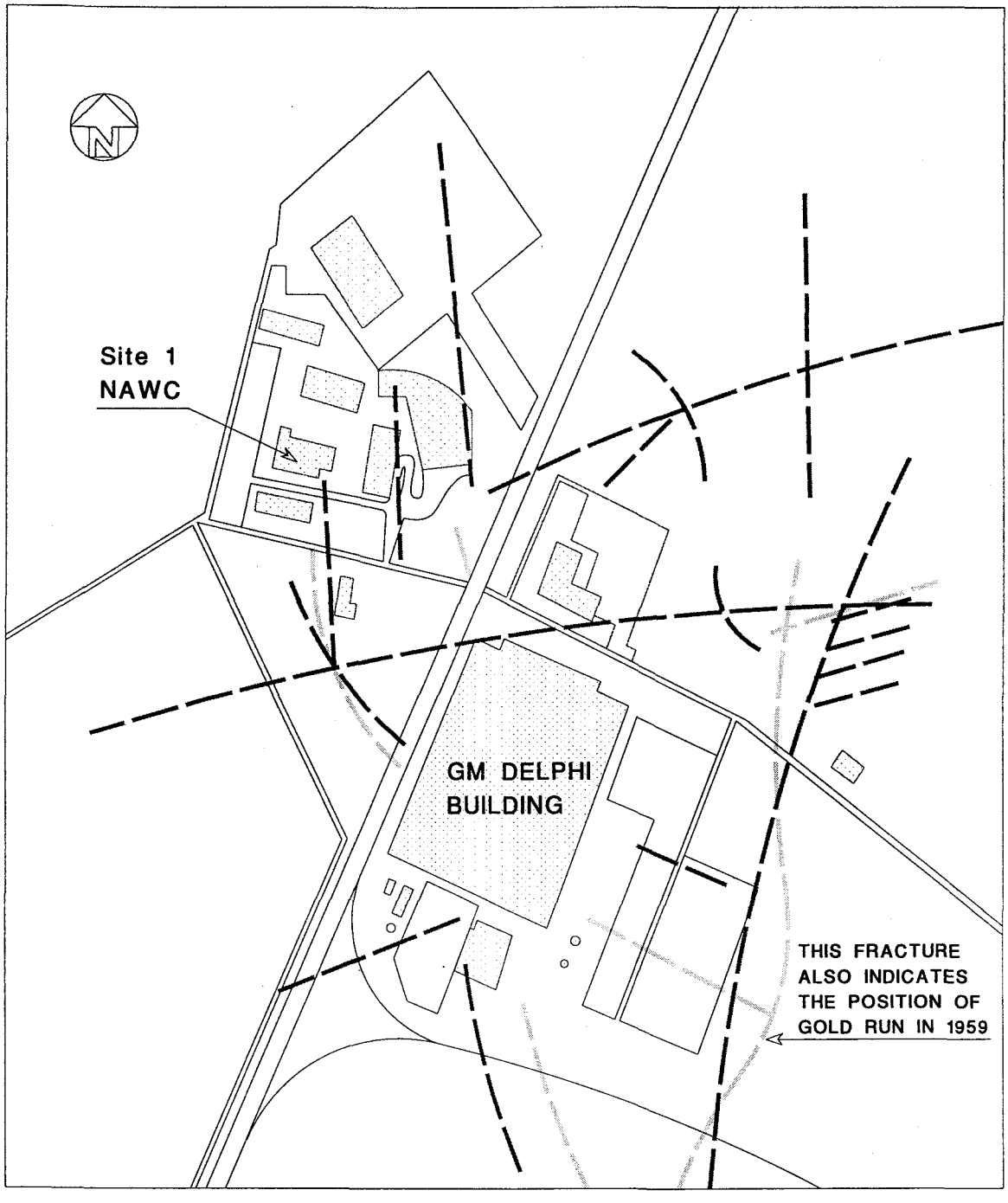
STRUCTURES

FRACTURE TRACES IDENTIFIED BASED ON 1959 AERIAL PHOTO

FRACTURE TRACE ANALYSIS
NAWC/DELPHI (GM) PROPERTIES
TRENTON, N.J.

Results of Analysis of 1959 Aerial Photograph

DATE: 11/15/96	RLZ	FIGURE
GEOVATION CONSULTANTS Inc. (914) 782-5890		2



SCALE: 1" = 750'

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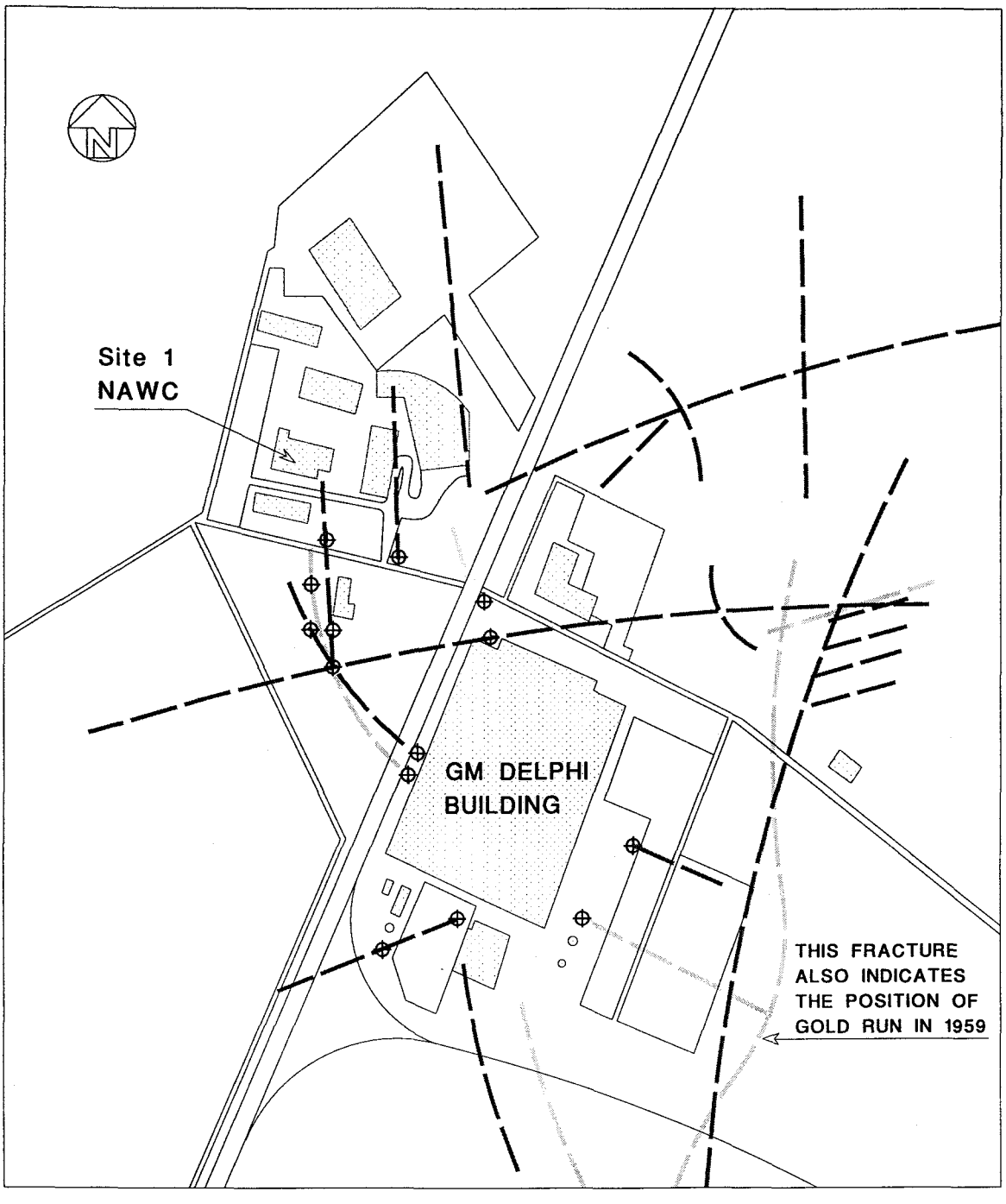
- STRUCTURES
- FRACTURE TRACES IDENTIFIED BASED ON 1959 AERIAL PHOTO
- FRACTURE TRACES IDENTIFIED BASED ON 1940 AERIAL PHOTO

FRACTURE TRACE ANALYSIS
NAWC/DELPHI (GM) PROPERTIES
TRENTON, N.J.

Combined Results of Analysis of 1940 & 1959 Photos

DATE: 11/15/96	RLZ	FIGURE
GEOVATION CONSULTANTS Inc. (914) 782-5890		3



SCALE: 1" = 750'

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- STRUCTURES
- FRACTURE TRACES IDENTIFIED BASED ON 1959 AERIAL PHOTO
- FRACTURE TRACES IDENTIFIED BASED ON 1940 AERIAL PHOTO
- APPROXIMATE LOCATION FOR RECOMMENDED DEEP BEDROCK MONITOR WELLS

FRACTURE TRACE ANALYSIS
NAWC/DELPHI (GM) PROPERTIES
TRENTON, N.J.

Recommended Locations for Deep Bedrock Monitor Wells

DATE: 11/15/96	RLZ	FIGURE
GEOVATION CONSULTANTS Inc. (914) 782-5890		4