SOWERS MIDDLE SCHOOL
HUNTINGTON BEACH CITY SCHOOL DISTRICT

GEOLOGICAL AND GEOTECHNICAL CONSIDERATIONS WITH SCHOOL MODERNIZATION

PRESENTED BY

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May 25, 2021

OUTLINE

- Geological Hazards Review
- Review of Existing As-Built Foundation Plans
- Examples of Ground Improvement Projects
- New Construction vs Existing Structure Rehabilitation
- Decisions/ Guidance Needed from the School Board

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GEOHAZARDS REVIEW FOR SOWER MS

GEOLOGICAL HAZARDS

Primary

- Faults
  - ~~Ground Rupture~~
  - Strong Ground Shaking
- ~~Landslides~~
  - Ground is flat, therefore not prone to landslides
- Subsidence
  - Caused by tectonic movement or by fluid withdrawal

Secondary – Follow On Effects

- Tsunamis
- Flooding from Reservoir Breaks
- Liquefaction
- Lateral Spreading

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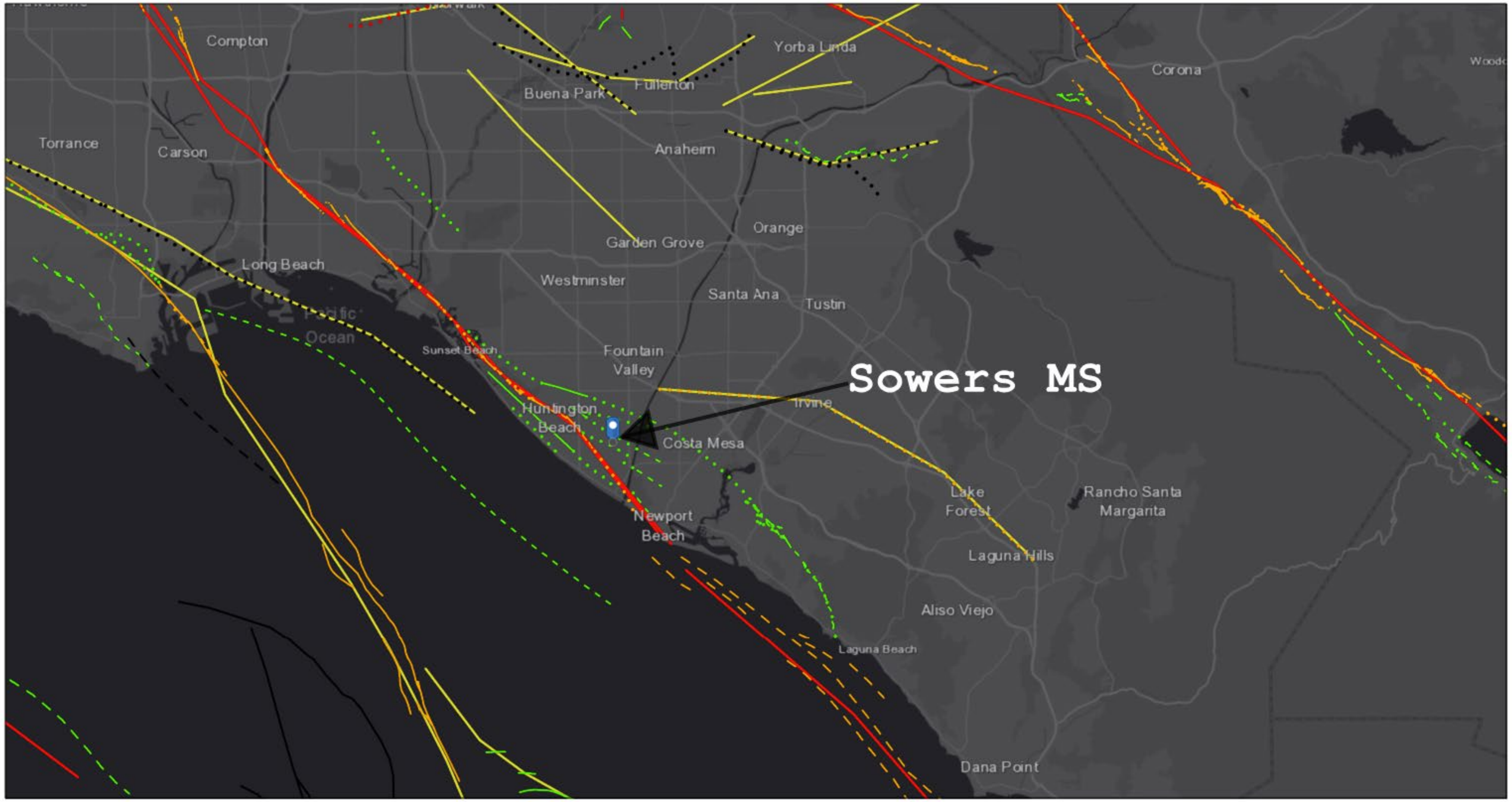
U.S. Geological Survey Quaternary Faults



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Fault Areas
- Class B
- historic
- late Quaternary
- latest Quaternary
- middle and late Quaternary

National Database
- Historic (< 150 years), well constrained location
- Historic (< 150 years), moderately constrained location
- Historic (< 150 years), inferred location
- Latest Quaternary (<15,000 years), well constrained location
- Latest Quaternary (<15,000 years), moderately constrained location
- Latest Quaternary (<15,000 years), inferred location
- Late Quaternary (< 130,000 years), well constrained location
- Late Quaternary (< 130,000 years), moderately contrained location
- Late Quaternary (< 130,000 years), inferred location
- Middle and late Quaternary (< 750,000 years), well constrained location
- Middle and late Quaternary (< 750,000 years), moderately constrained location
- Middle and late Quaternary (< 750,000 years), inferred location
- Undifferentiated Quaternary (< 1.6 million years), well constrained location
- Undifferentiated Quaternary (< 1.6 million years), moderately constrained location
- Undifferentiated Quaternary (< 1.6 million years), inferred location
- Unspecified age, well constrained location
- Unspecified age, moderately constrained location

1:288,895

0 3 6 12 mi
0 4.75 9.5 19 km

USGS, Esri, HERE, NPS, Esri, HERE, Garmin, USGS, EPA, NPS

USGS
USGS | City of Costa Mesa, City of Irvine, County of Los Angeles, Bureau of Land Management, Esri, HERE, Garmin, USGS, EPA, NPS | Esri, HERE, NPS |

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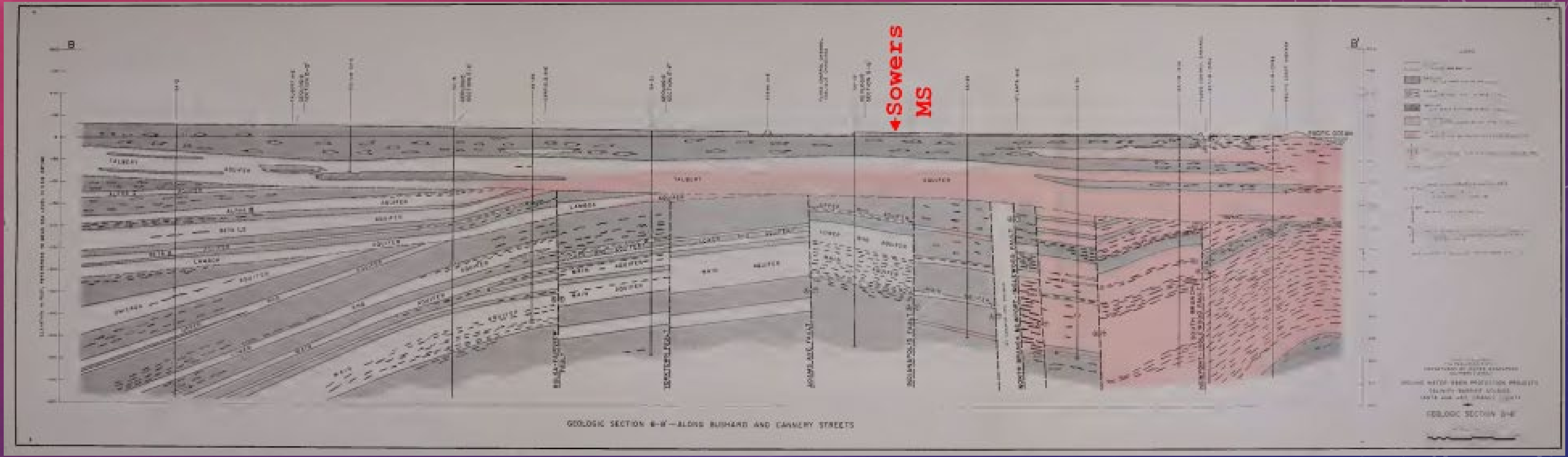
GENERAL GEOLOGICAL CROSS SECTION



Reference: Section B-B' from Department of Water Resources, Bulletin No. 147-1, Santa Ana Gap Salinity Barrier, Orange County, December 1966

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STRONG GROUND MOTIONS

TABLE 1

Seismic Design Input Parameters (2% in 50 yr Return Period)	
Distance (km)	1.2
Magnitude (Mw)	7.2
PGA_m (g)	0.58

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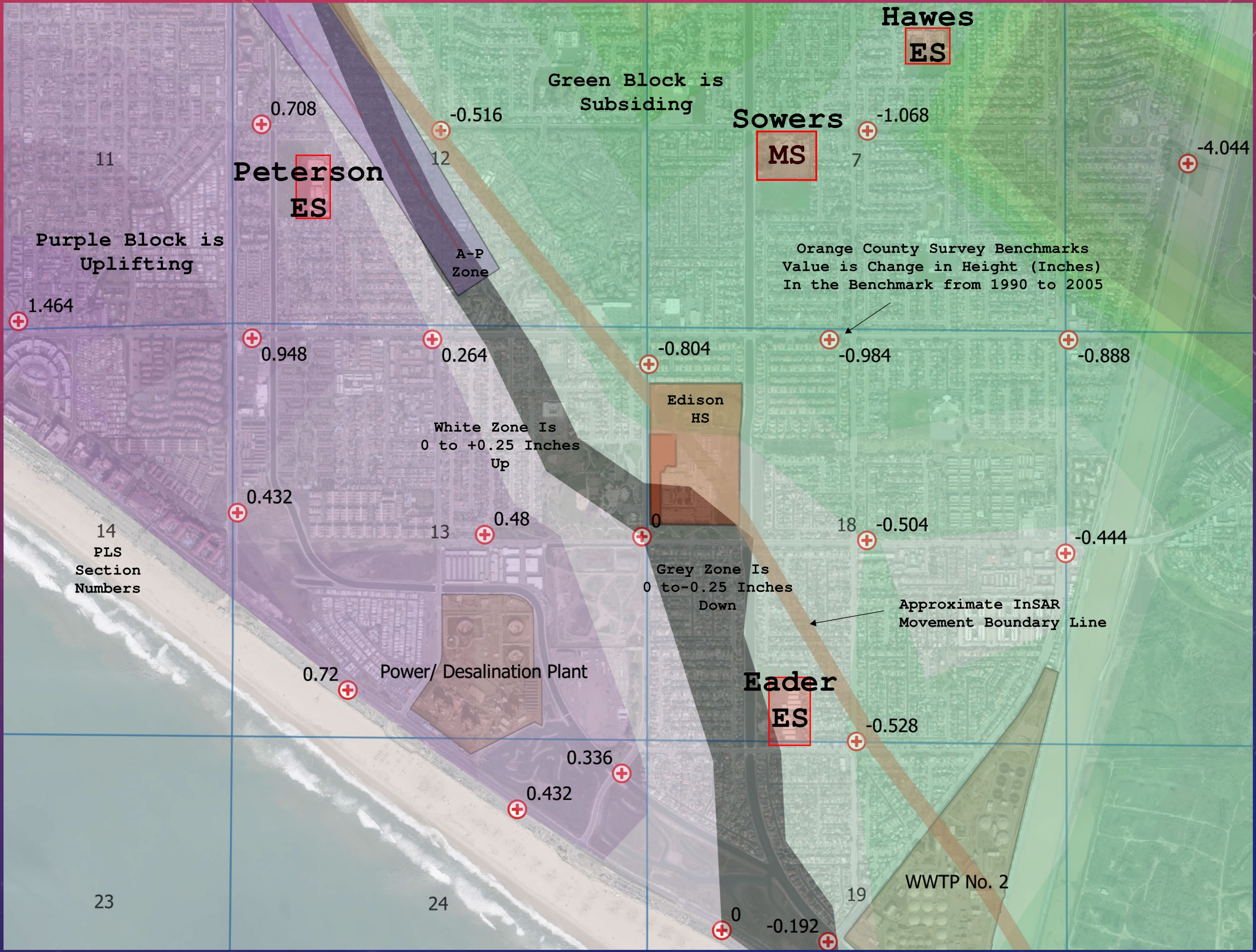
SUBSIDENCE MAP

Benchmark Data Collected from OC Survey Shows Change in Benchmarks Over 15 Years



TSUNAMI HAZARD MAP

New design requirements in effect with 2019 CBC/ ASCE 7-16

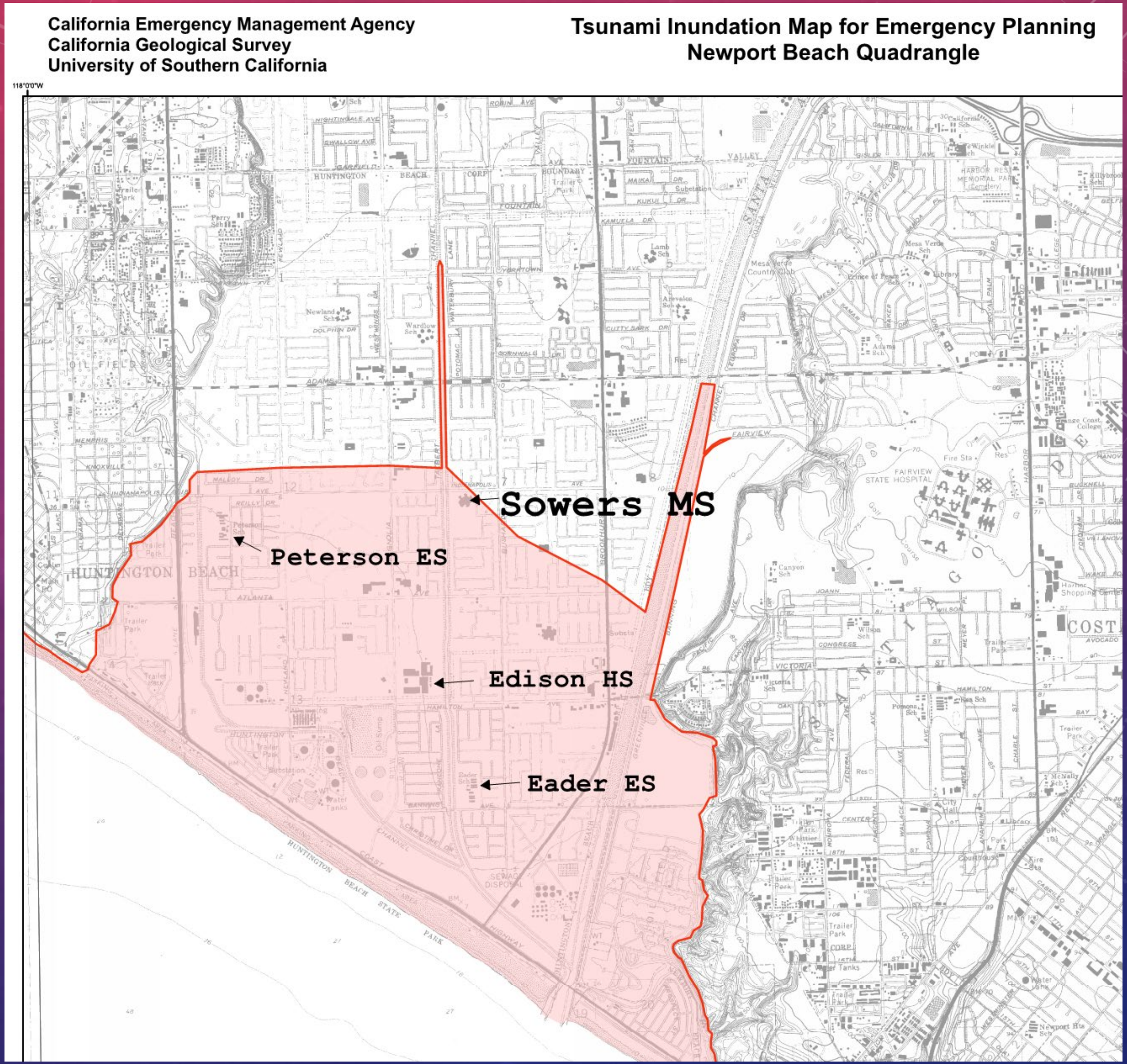


Figure 4.68: Aerial view of liquefaction manifestation at the Blenheim Rowing Club looking east (18 Nov 2016, approx. centre of image: S41.4883, E174.0096, Marlborough Regional Council, 2016).

LIQUEFACTION HAZARD

- Groundwater pressures build up during strong earthquake shaking. Soil grain to grain contact is lost. This causes the ground to turn from a solid to a semi-liquid state.
- Photo showing ground cracks and sand ejected from liquefaction in a New Zealand Earthquake in 2016.
- Reference: Geotechnical Reconnaissance of the 2016 Mw7.8 Kaikoura, New Zealand Earthquake, Cubrinovski & Bray, Editors, {GEER (2017)}

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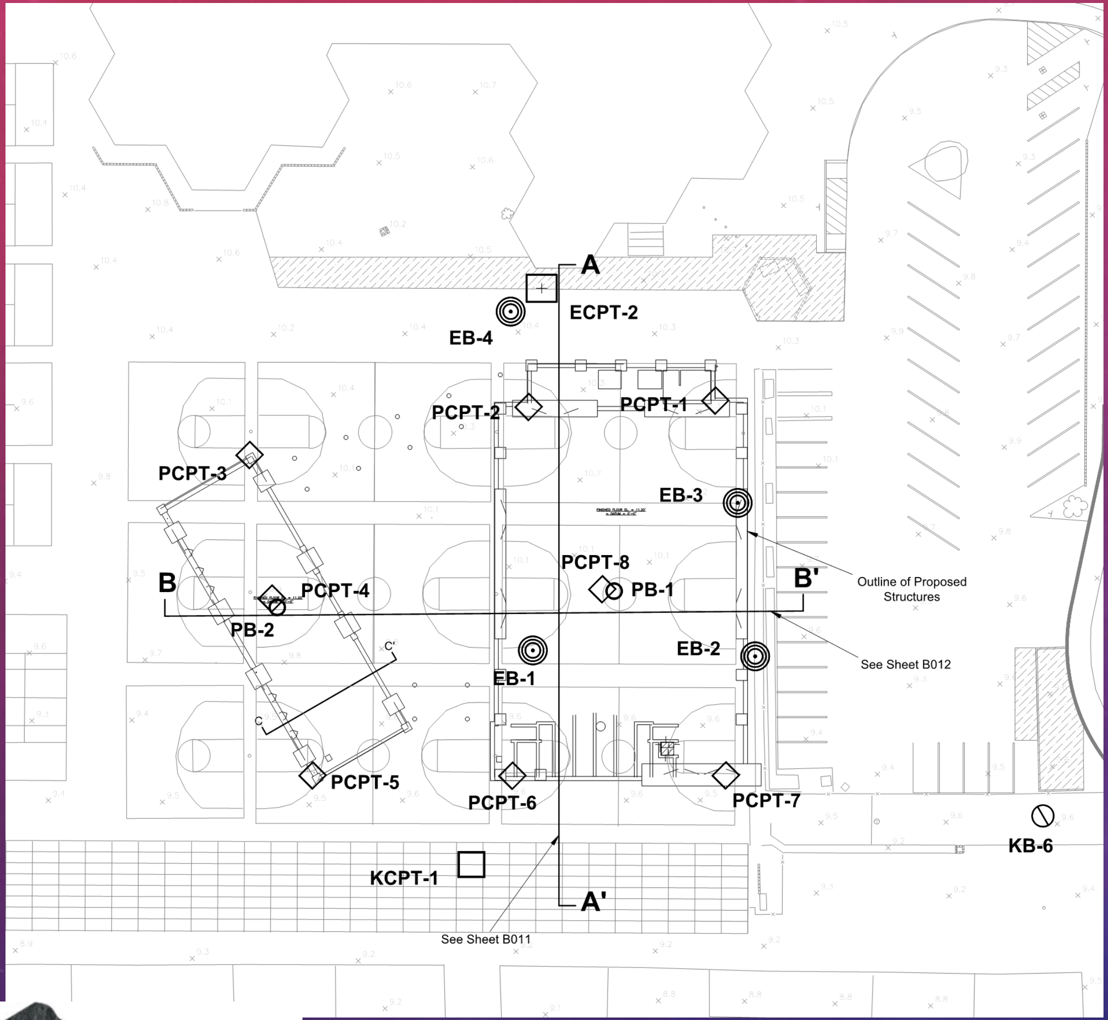
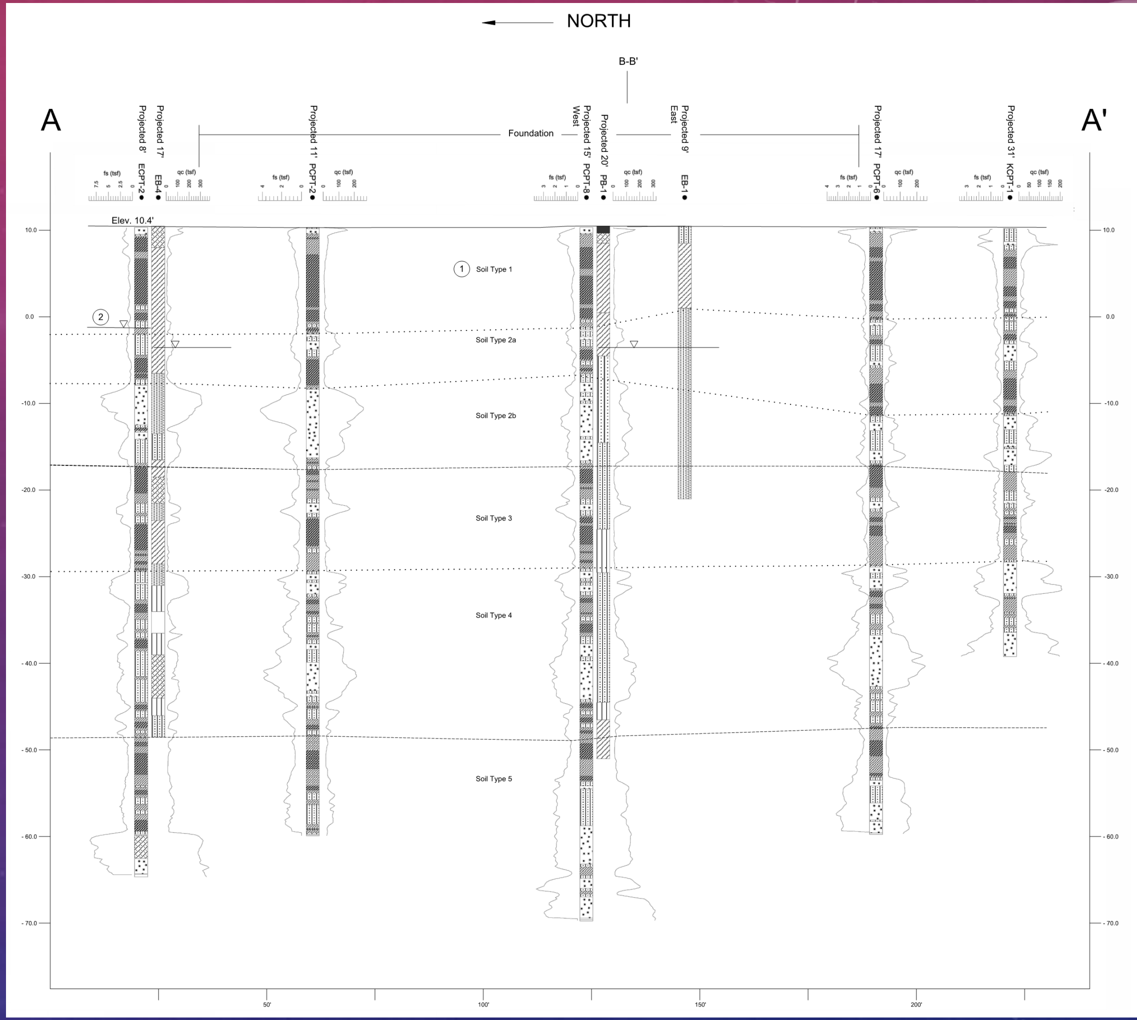
SAND BOILS

- Christchurch New Zealand Earthquake produced these sand boils. Sand boils generally occur when the liquefiable layers are close to the ground surface. Picture from Wikipedia

SUBSURFACE PROFILE – GYM/ STEM BUILDING





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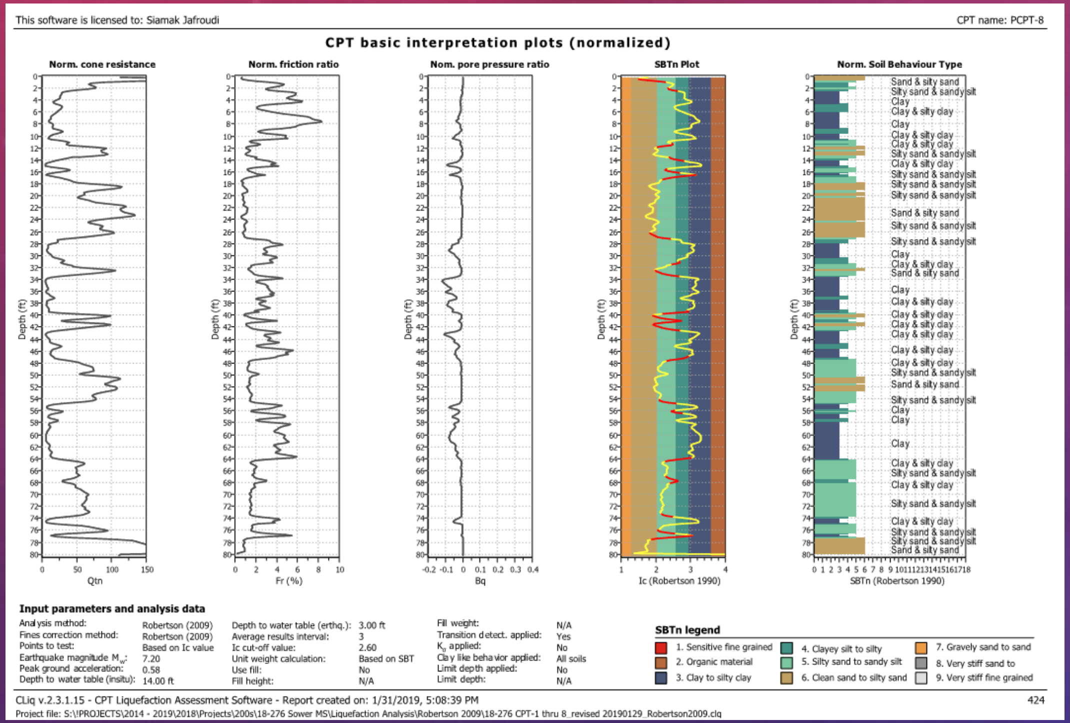
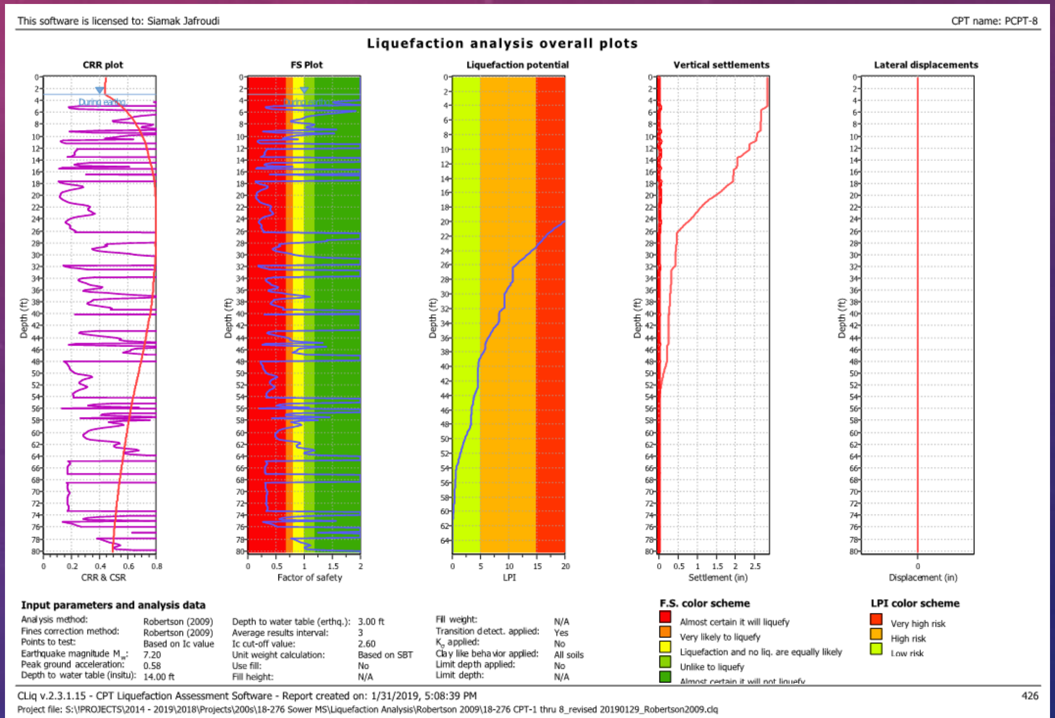
LIQUEFACTION ANALYSIS EXAMPLE FROM GYM/ STEM PROJECT

TYPICAL SOIL PROFILE



TYPICAL LIQUEFACTION ANALYSIS



Most damaging liquefaction concentrated approximately in the upper 25 to 30 feet of site profile.

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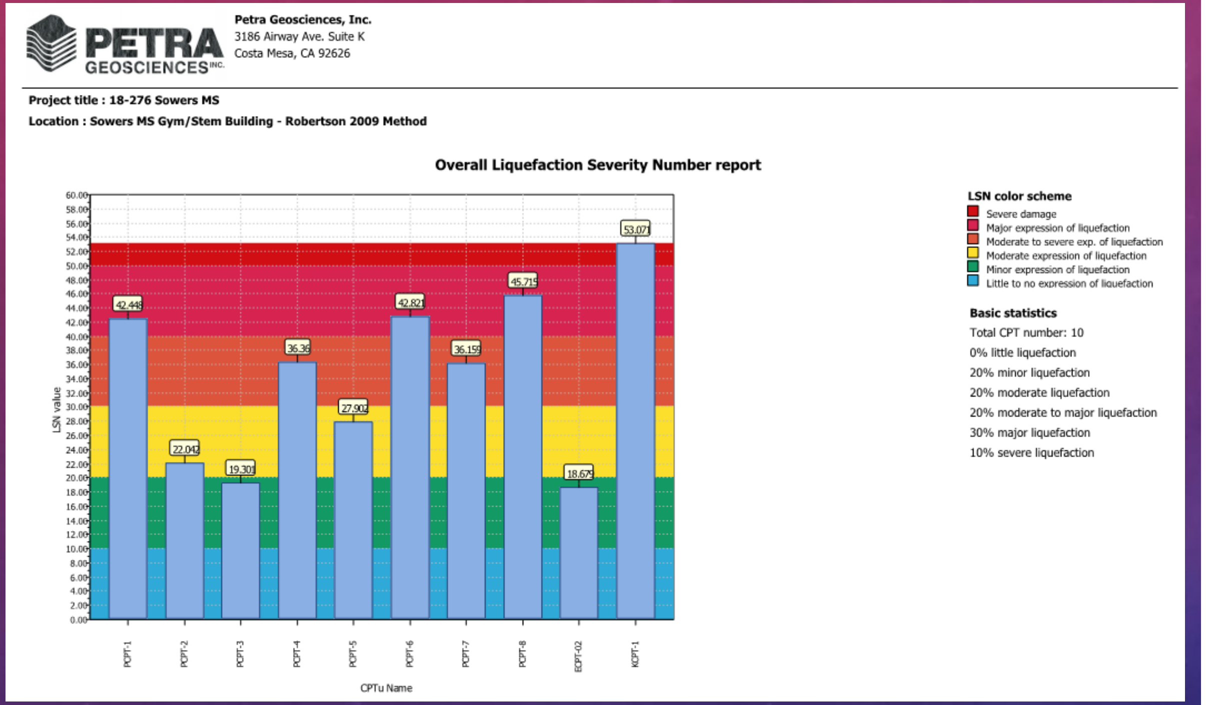
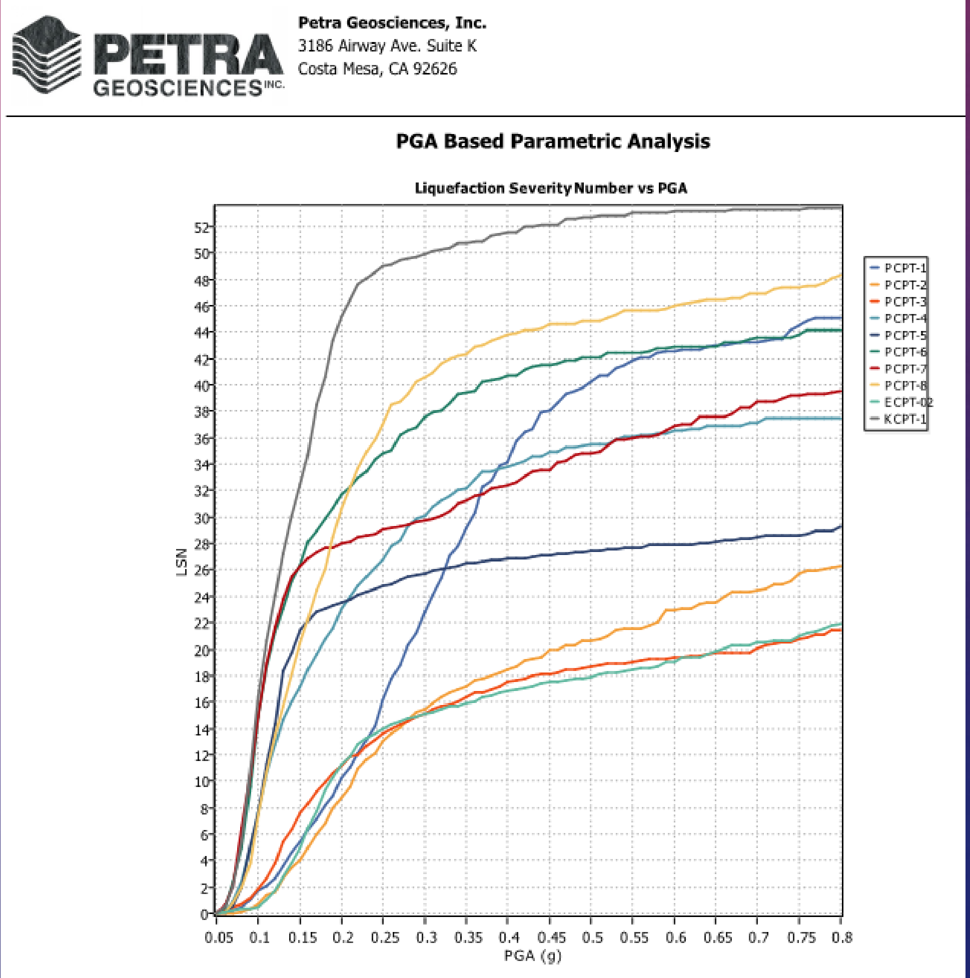
LIQUEFACTION SEVERITY IN RELATION TO SHAKING POTENTIAL

Wide range of predicted liquefaction severity even in the smaller area of the Gym/ Stem building indicates the site may be more prone to differential settlement issues.



Parametric analysis from Gym/ Stem building indicates even smaller earthquake may trigger most of the liquefaction hazard.



LATERAL SPREADING

Sheet pile lined canal likely inhibits lateral spreading at the site.

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AS-BUILT PLANS

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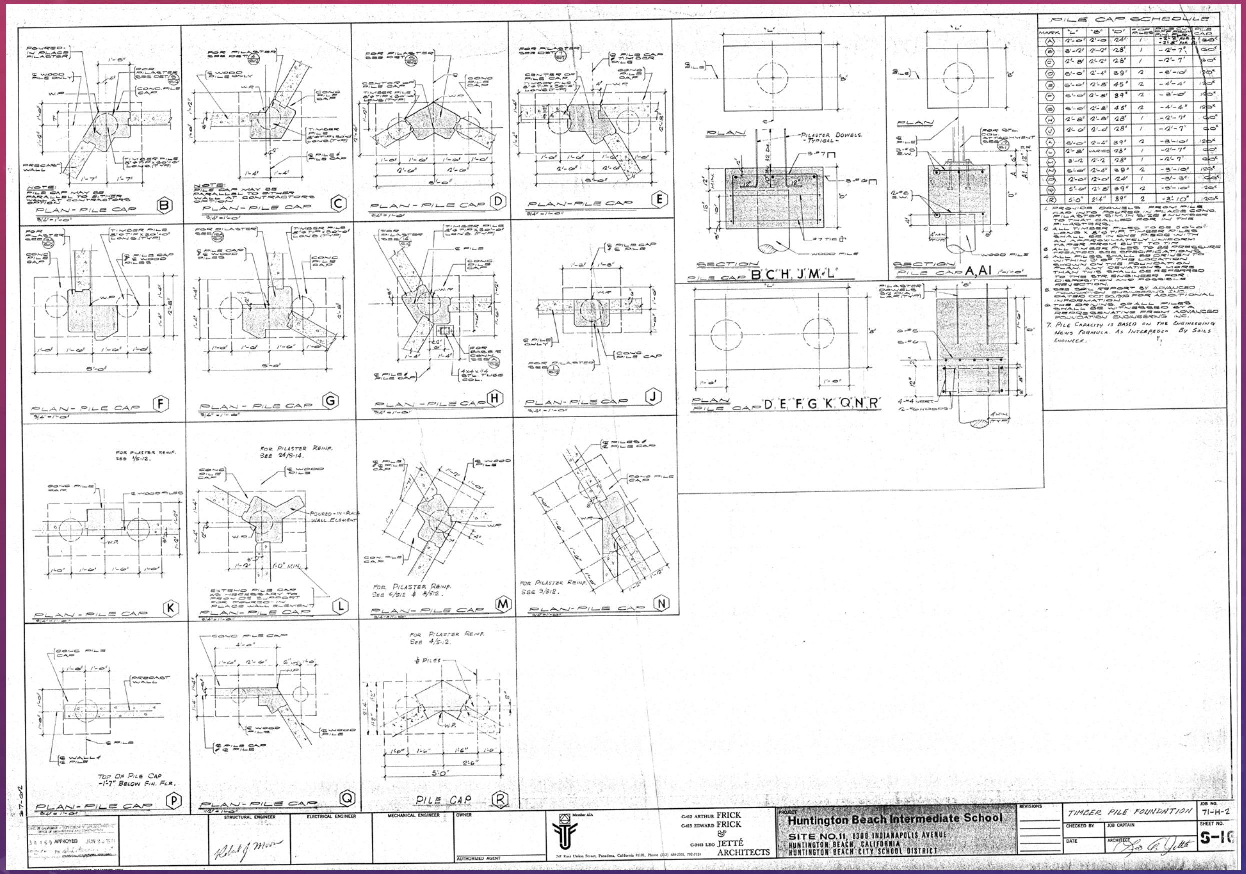
EXISTING BUILDING IS REPORTEDLY ON WOODEN PILE FOUNDATIONS



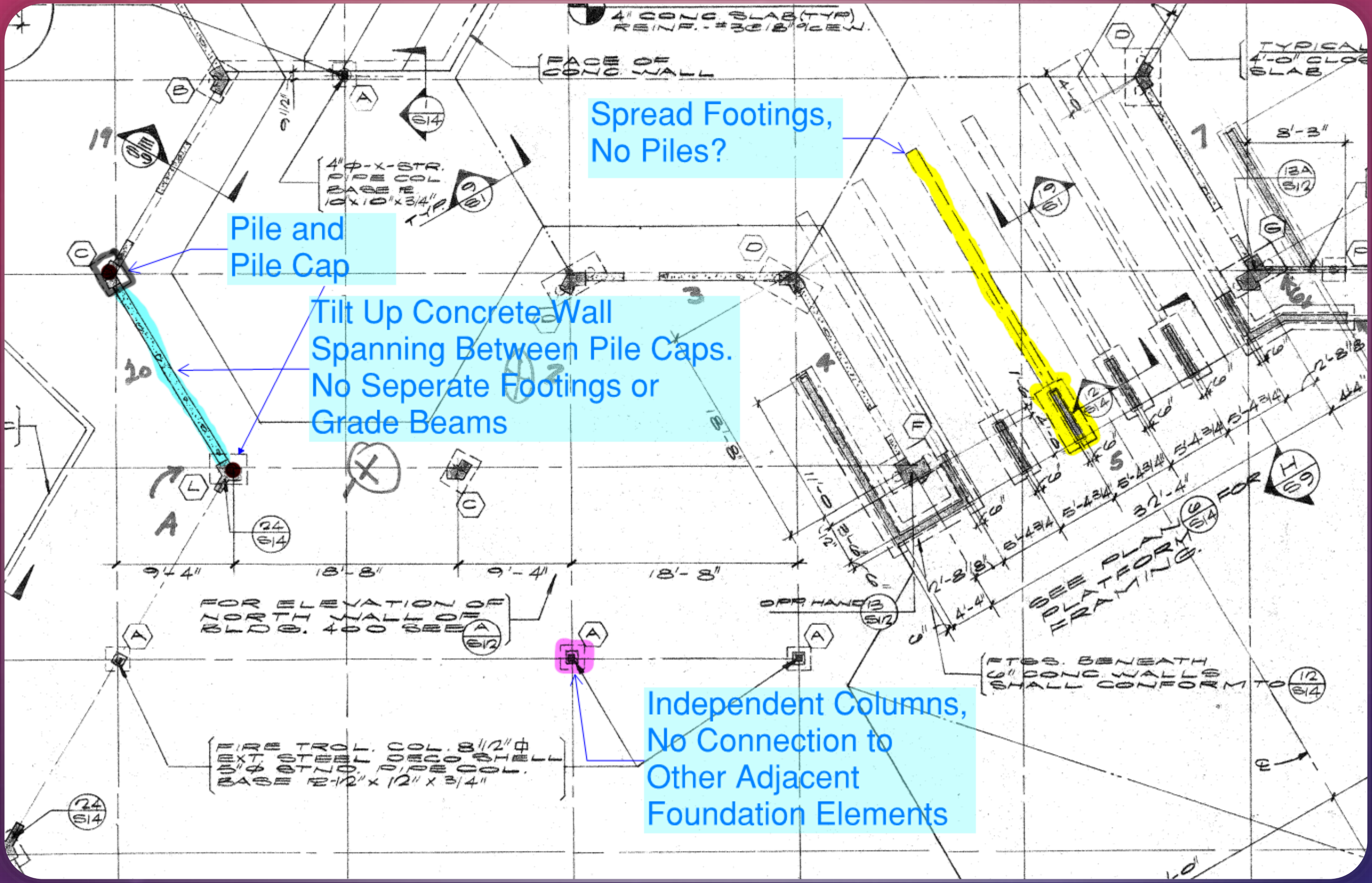
PILE CAP SCHEDULE

MARK	"L"	"B"	"D"	# OF PILES	PILES CUT OFF FROM FIN. FLR.	PILE CAP
A	2'-0"	2'-0	24"	1	-2'-2" FOR A; -2'-8" FOR A1	60K
B	3'-2"	2'-2"	28"	1	-2'-7"	60K
C	2'-8"	2'-2"	28"	1	-2'-7"	60K
D	5'-0"	2'-4"	39"	2	-3'-10"	120K
E	5'-0'	2'-8"	45"	2	-4'-4"	120K
F	5'-0"	2'-8"	39"	2	-3'-10"	120K
G	5'-0"	2'-8"	45"	2	-4'-4"	120K
H	2'-8"	2'-8"	28"	1	-2'-7"	60K
J	2'-6"	2'-0"	28"	1	-2'-7"	60K
K	5'-0"	2'-4"	39"	2	-3'-10'	120K
L	2'-8"	VARIES	28"	1	-2'-7"	60K
M	3'-2	2'-2	28"	1	-2'-7"	60K
N	5'-0"	2'-4"	39"	2	-3'-10"	120K
P	2'-0"	2'-0"	24"	1	-3'-3"	60K
Q	5'-6"	2'-8"	39"	2	-3'-10"	120K
R	5'-0"	2'-4"	39"	2	-3'-10"	120K

1. PROVIDE DOWELS FROM PILE CAP INTO POURED IN PLACE CONC. PILASTER SIM. IN SIZE & NUMBER TO THAT CALLED FOR IN THE PILASTERS.
2. ALL TIMBER PILES TO BE 50'-0" LONG x 8" ϕ TIP. TIMBER PILES SHALL BE IN ONE PIECE WITH AN APPROXIMATELY UNIFORM TAPER FROM BUTT TO TIP.
3. ALL TIMBER PILES TO BE PRESSURE TREATED. SEE SPECIFICATIONS.
4. ALL PILES SHALL BE DRIVEN TO WITHIN 3" OF THE LOCATION SHOWN ON THE FOUNDATION PLAN. ANY DEVIATIONS MORE THAN THIS SHALL BE REFERRED TO THE STR. ENGINEER FOR DISPOSITION AND POSSIBLE REJECTION.
5. SEE SOIL REPORT BY ADVANCED FOUNDATION ENGINEERING INC. DATED OCT. 30, 1970 FOR ADDITIONAL INFORMATION.
6. THE DRIVING OF ALL PILES SHALL BE WITNESSED BY A REPRESENATIVE FROM ADVANCED FOUNDATION ENGINEERING INC.
7. PILE CAPACITY IS BASED ON THE ENGINEERING NEWS FORMULA. AS INTERPRETED BY SOILS ENGINEER.

50' Long Piles may be too short to resist the liquefaction fully.

TYPICAL FOUNDATION LAYOUT



- Building Primarily Supported on Piles.
- A few isolated cases of spread footings without piles.
- No apparent grade beams.
- Tilt up wall connected to cast-in-place pilasters sitting on pile caps.
- Closure pour of concrete only connection of wall to slab.
- Independent interior columns apparently supported on single pile cap and pile. No connection to other foundations.

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EXAMPLES OF GROUND IMPROVEMENT PROJECTS

MITIGATION CONSIDERATIONS FOR SEVERAL EXISTING SCHOOL SEISMIC UPGRADE PROJECTS

- Construction had to occur in low-headroom conditions.
- Construction had to occur without substantial disturbance to school operation.
- Mitigation measures must demonstrate a post-earthquake total settlement of about 100 to 150 mm (4 to 6 in) or less, according to CGS Special Publication 117A requirements.

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MICROPILE INSTALLATION AT WARNER MS – WESTMINSTER SD

- Micropiles were installed at Warner MS to underpin an existing building to mitigate liquefaction hazards.
- Upgrade was part of AB 300 program.
- The micropiles were 244 mm (9-5/8 inch) diameter.
- Installed through predominately silty and clayey strata with intermittent sand lenses and drilled to a gravel layer approximately 21.3 m (70 ft) below the ground surface.
- The regulatory agency (DSA) required that verification tests be conducted under combined lateral and axial loading.

TWO SCHOOLS WITH EXISTING PILE FOUNDATIONS

- Both schools built in the 1950's. Both sites have existing foundations that were built utilizing Raymond Piles. Seismic upgrades as part of AB 300 program.

- <u>School No. 1 – Johnson MS - Westminster</u>
- Piles up to 380 mm (15 in) in diameter, depths ranging from 2.44 m (8 ft) to 8.23 m (27 ft) below the surface.

- <u>School No. 2 – Hill MS – Long Beach</u>
- Mixed shallow and deep foundations. Pile diameters range from 457 to 610 mm (18 to 24 in), pile depths range from 4.88 to 6.10 m (16 to 20 ft).

MITIGATIONS CHOSEN

- The buildings had too high of a risk of collapse to be used and had to be either strengthened or torn down and replaced.
  - Johnson MS – Liquefaction and related settlement primary concern
  - Hill MS – Liquefaction and Lateral Spreading (building was very close to canal)

- For one school (Johnson MS) it was feasible to mitigate the adverse impacts of liquefaction by encasing the existing piles within a jet grouted zone.
- For the second school (Hill MS), it was more cost effective to replace the building. A new building was constructed at a significant distance from canal.

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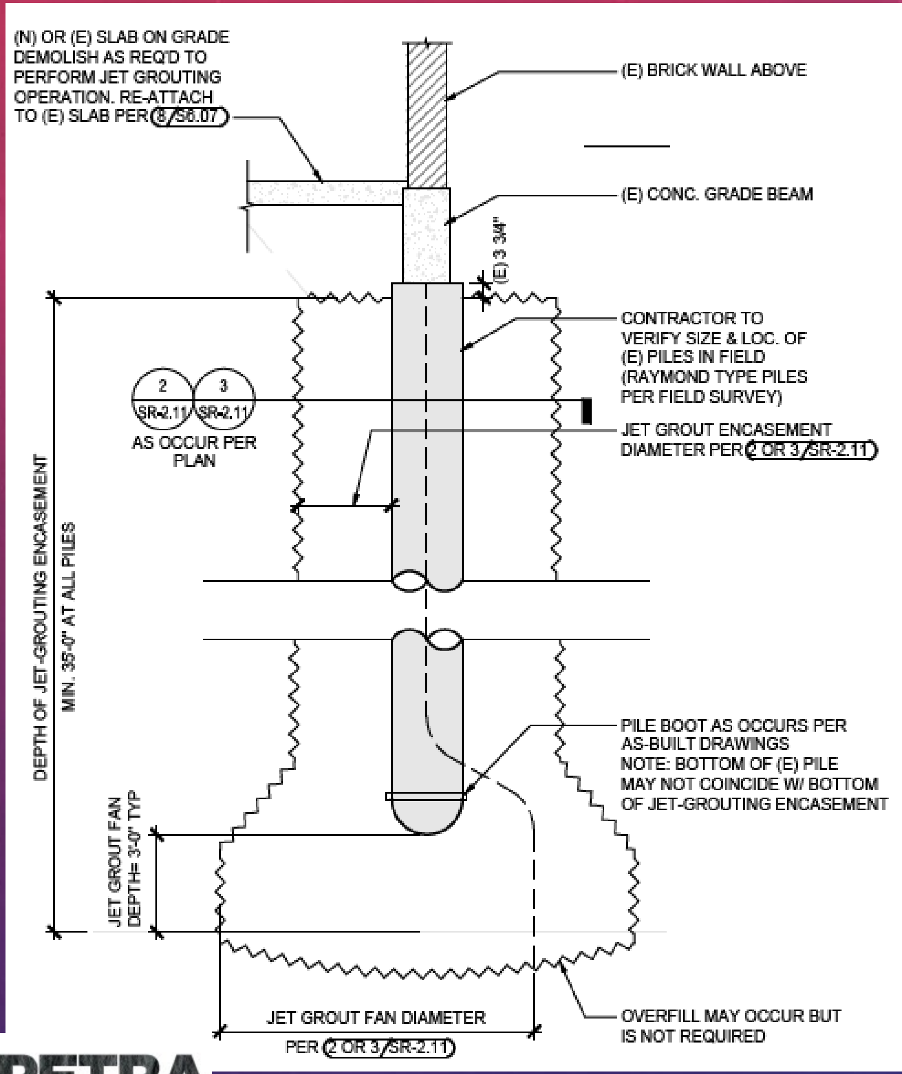
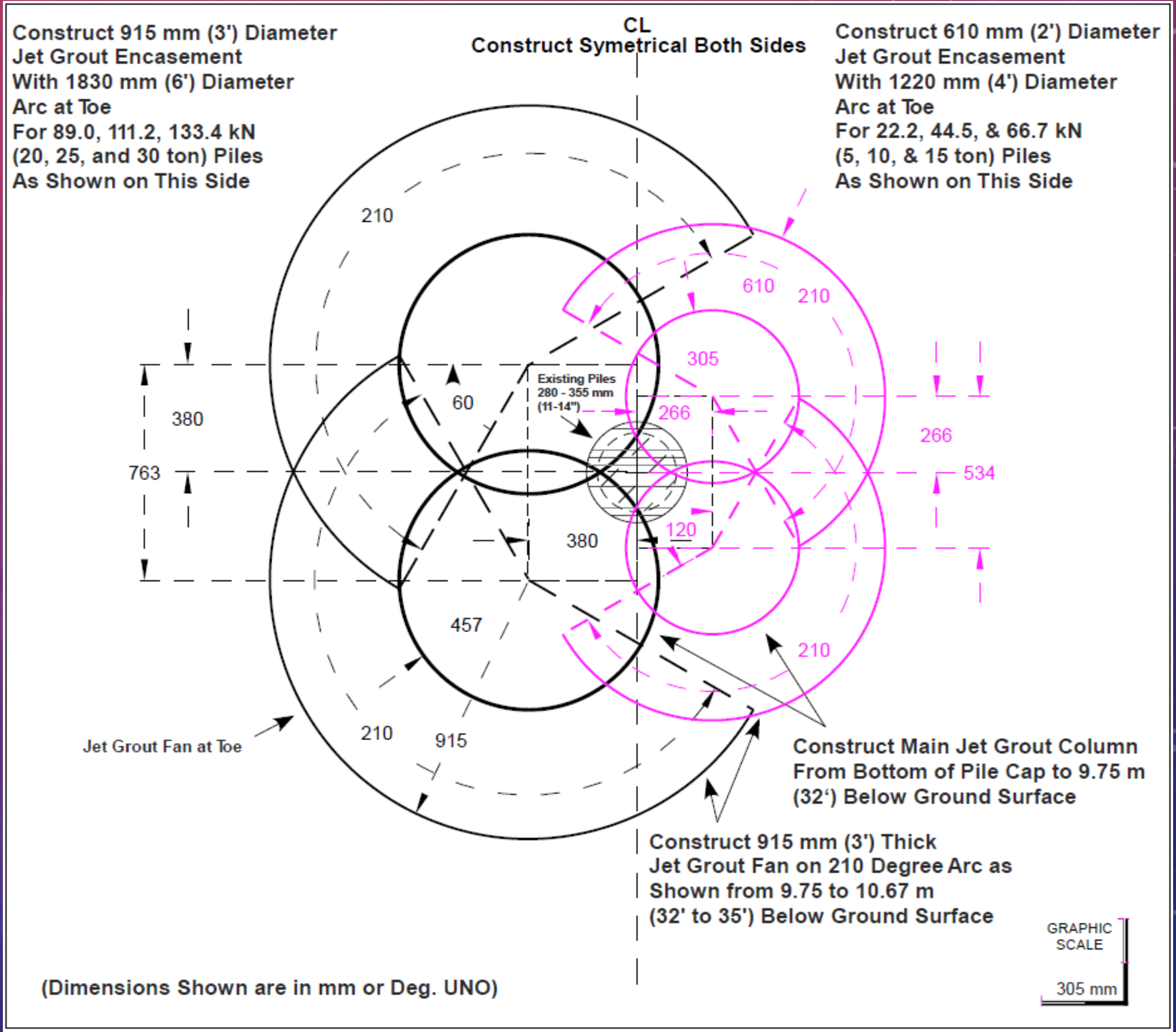
JET GROUTING LAYOUT – JOHNSON MS - WESTMINSTER





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JET GROUT CONSTRUCTION

CONSTRUCTION OF JET GROUT ENCASEMENT WITH LIMITED ACCESS RIG.

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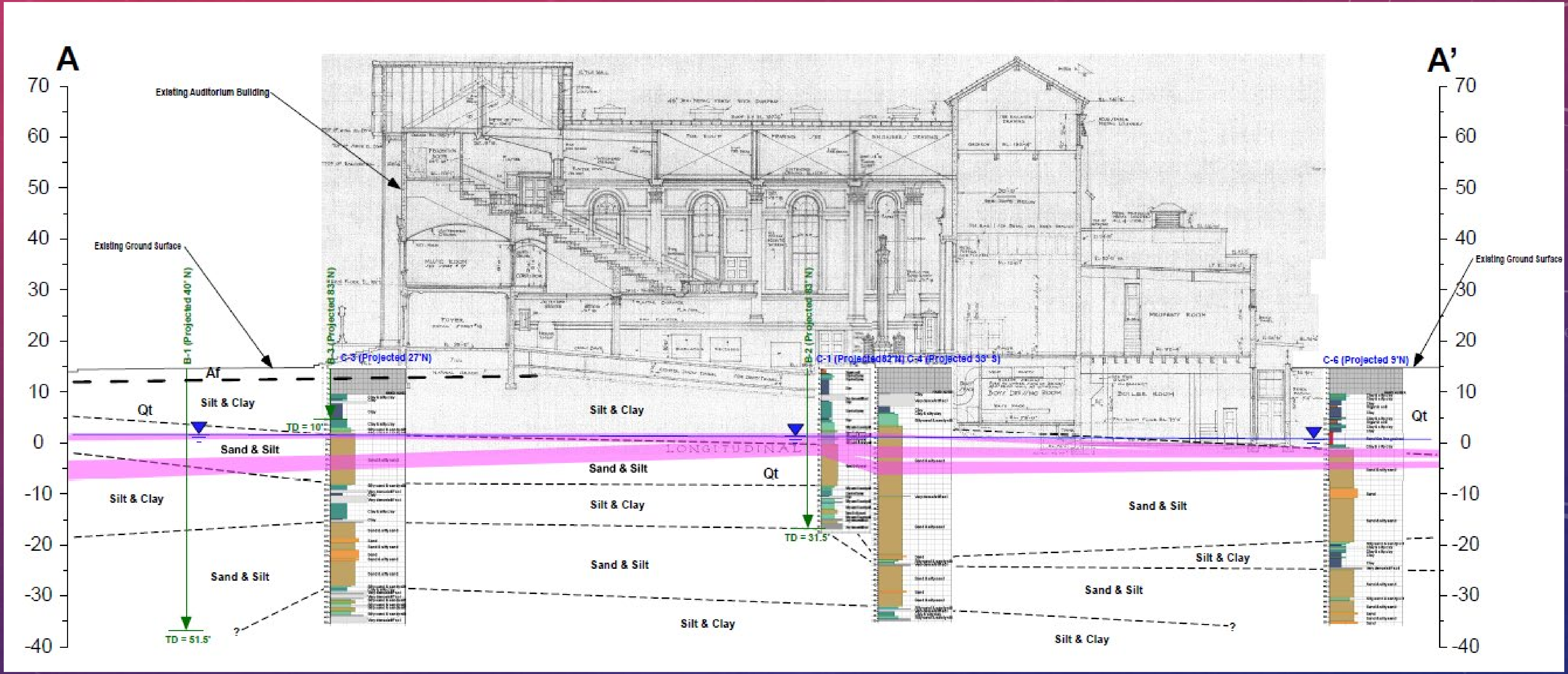
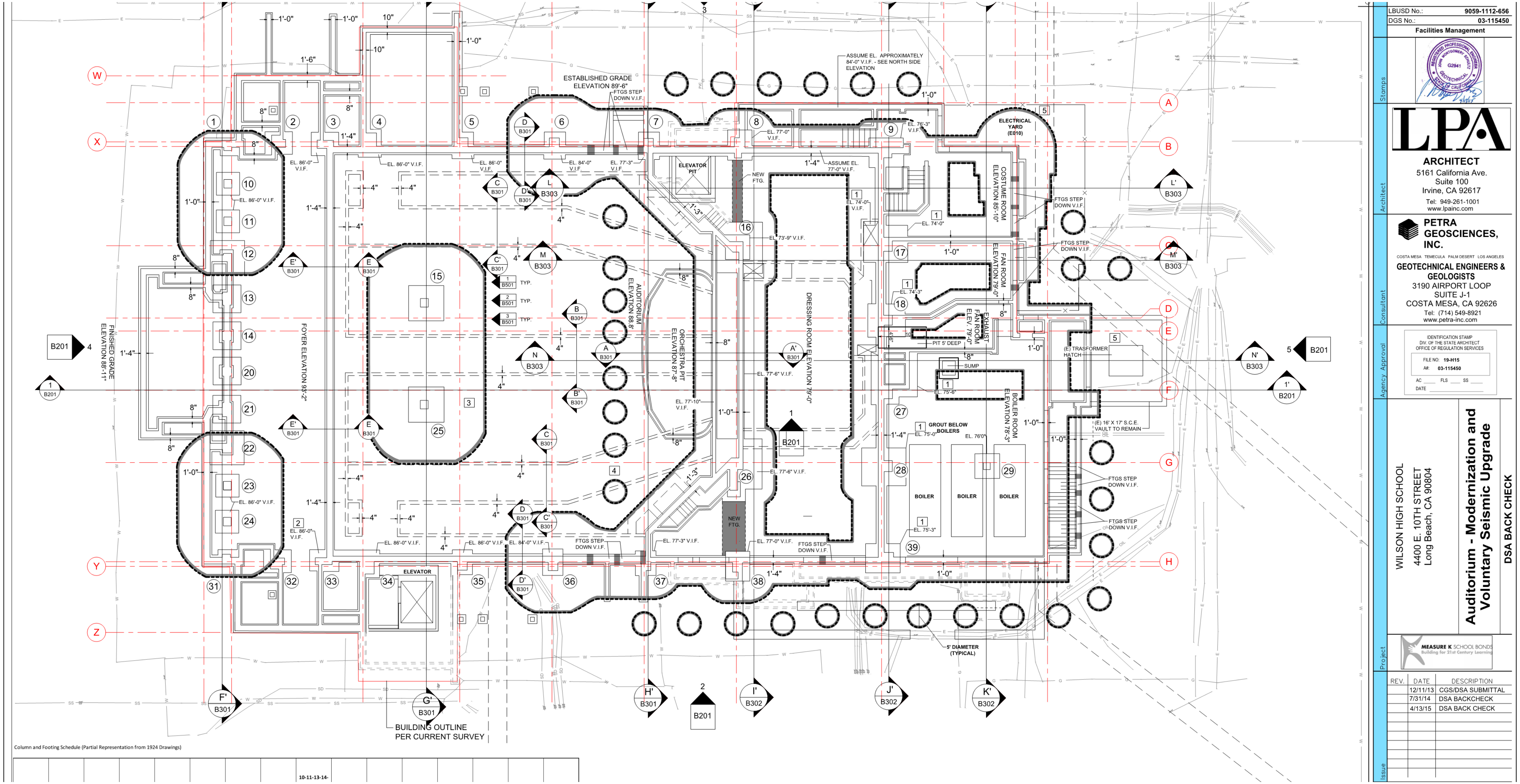
WILSON HS AUDITORIUM BUILDING – LONG BEACH





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HORIZONTAL DRILLING TO INSTALL PERMEATION GROUTING LIQUEFACTION MITIGATION

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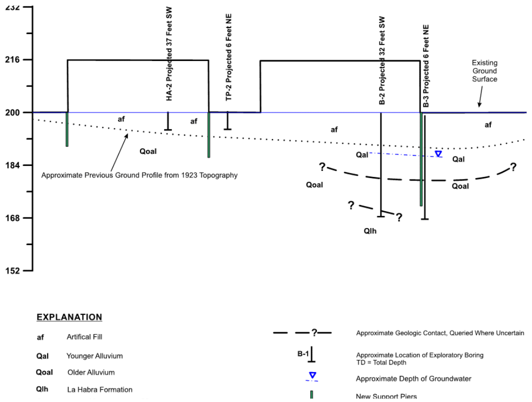
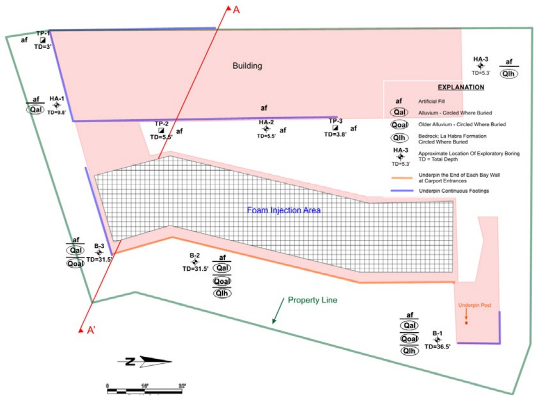
DISTRESSED APARTMENT COMPLEX PROJECT IN WHITTIER

- Distress caused by fill settlement, expansive soils, and liquefaction during the 1987 Whittier Narrows Earthquake.
- Rehabilitated with Jacked Push Piers and Foam Injection





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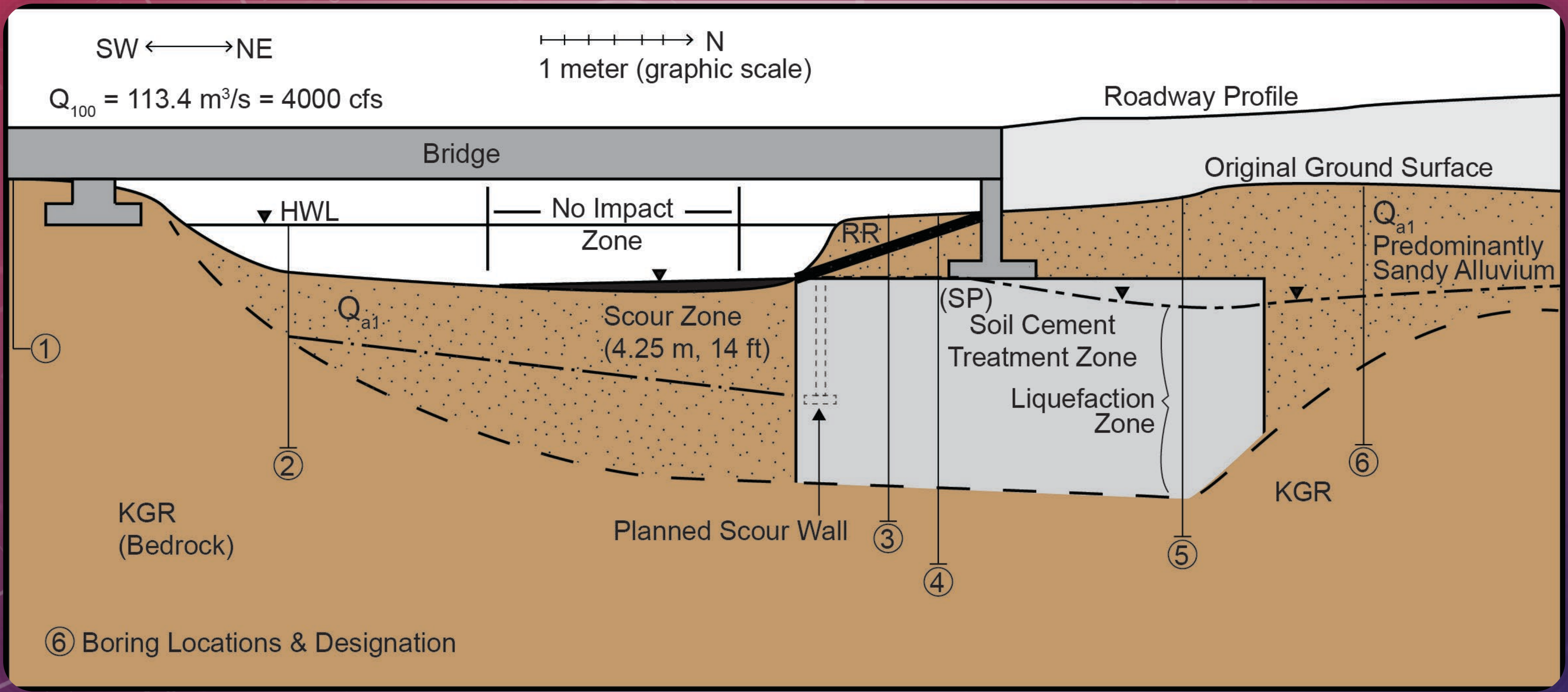
Foam Injection is a less intrusive process only requiring 5/8-inch diameter holes drilled through existing slabs.



GROUND IMPROVEMENT PROGRAM FOR BRIDGE PROJECT IN RIVERSIDE

LIQUEFACTION AND SCOUR MITIGATION OF NORTH ABUTMENT DOWN TO 50 FEET, SUBSTANTIAL IMPROVEMENT IN BEARING CAPACITY

DEEP SOIL MIXING FOR BRIDGE ABUTMENT

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LIQUEFACTION MITIGATION STRATEGIES

- There are different strategies to provide support to foundations to mitigate against damage from liquefaction. They can be summarized as follows:
    - Bypass the hazard by going deep with piles.
    - Densify the ground so it does not liquefy.
    - Contain the soil so shaking is reduced and the soil and water can not move through the matrix.
    - Strengthen the soil by injecting rigid elements or solidifying the soil in-place.
    - Float the structure over the liquefied soil.
    - Bridge the structure over the liquefied soil.

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NEW CONSTRUCTION VS EXISTING STRUCTURE REHABILITATION

CODE REQUIREMENTS

- New Construction
  - 2019 CBC
    - ASCE 7-16

- Existing Construction / Updates
  - 2019 Existing Building Code
    - ASCE 31 / ASCE 41

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SITE-SPECIFIC CONSIDERATIONS

- Silty soils that are prone to liquefaction.
- Substantial liquefaction triggering for smaller earthquakes.
- Conditions of existing piles?
- Downdrag
- Soil strength loss
- Lateral load requirements from shaking, and tsunami hazard.
- Is there a substantial bearing layer at depth (80 to 90’) below the site?
- What are failure mechanisms of existing structure?

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POTENTIAL GROUND IMPROVEMENT OR STRUCTURAL SUPPORT METHODS TO BE EXPLORED FOR SOWERS MS

Methods That Could be Used for New Construction

- Deep Soil Mixing
- Driven Piles
- Foam Injection
- Compaction Grouting
- Cellular Cofferdams
- Jet Grouting
- Compensated Foundation
- Auger Cast Piles
- Caissons
- Vibro-Replacement Methods (Stone Columns)

Methods to Consider for Existing Building Rehabilitation

- Jet Grouting
- Jacked Down Piles
- Micro-Piles
- Foam Injection
- Horizontal Drilling & Grouting

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DECISIONS / GUIDANCE NEEDED FROM SCHOOL BOARD

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GUIDANCE NEEDED

- What performance requirement does the school board desire for smaller earthquakes than the Maximum Considered Earthquake Level required by Code?

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RECOMMENDATIONS FOR FUTURE STUDIES

Do	Do some additional exploration and excavate existing piles and determine their current conditions.
Undertake	Undertake a site-specific tsunami hazard analysis. (Will be useful for either new construction or existing structure rehabilitation).
Have	Have structural engineer assess the existing building per ASCE 31/41 to understand likely failure mechanisms.