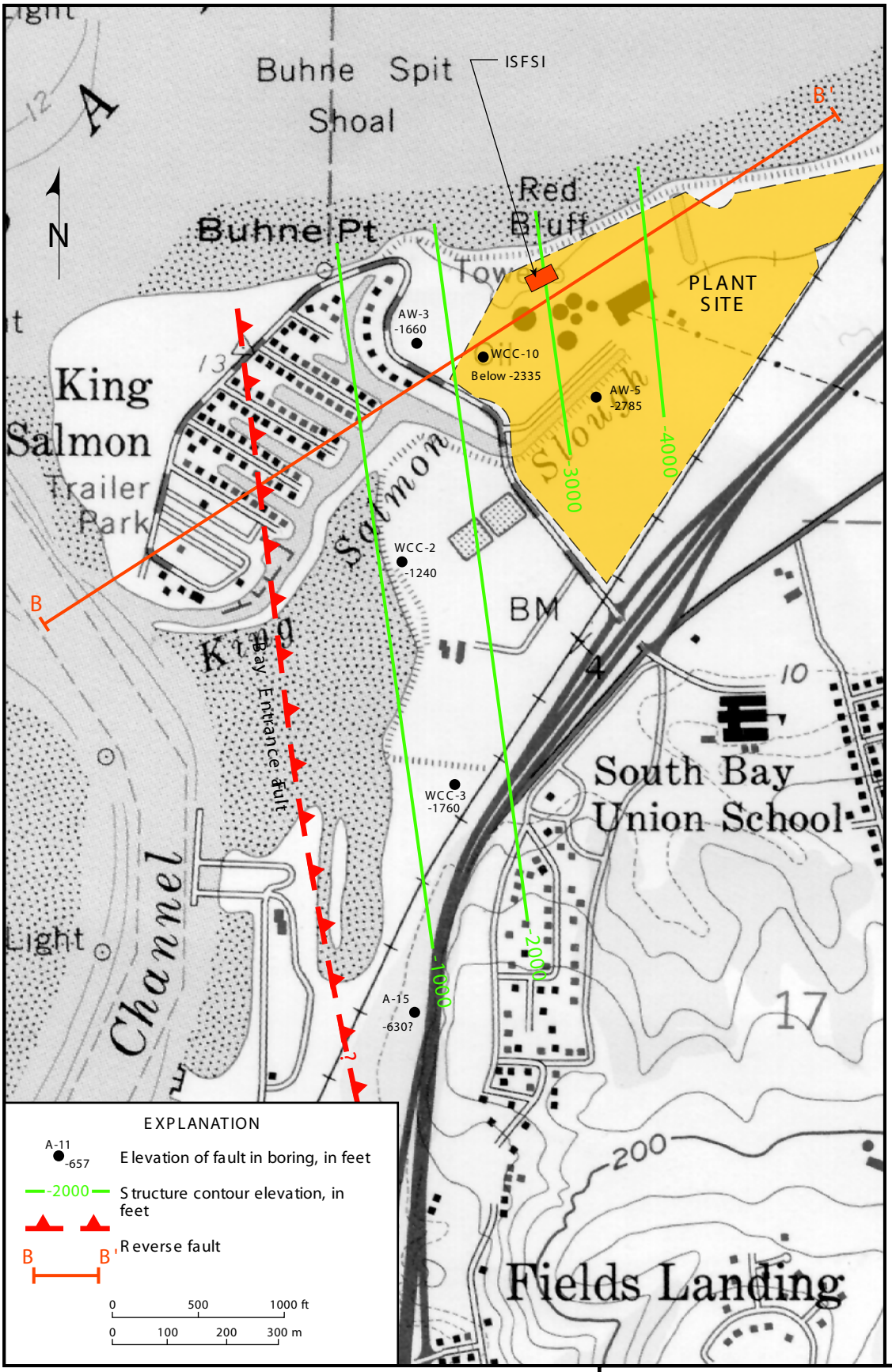
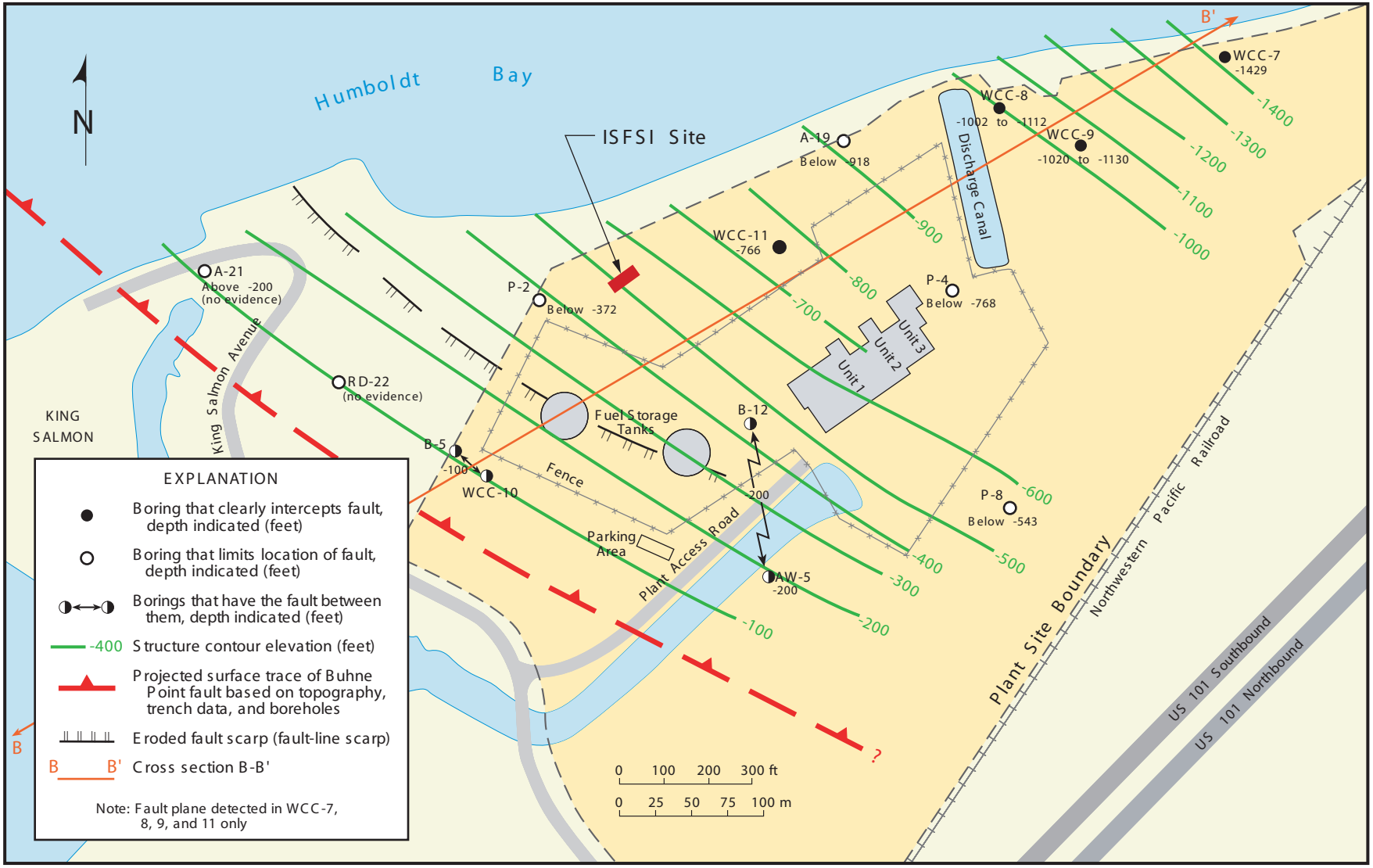


Cross section B-B' is shown on Figure 2.6-50. (modified from Woodward-Clyde Consultants, 1980, Figure C-18).

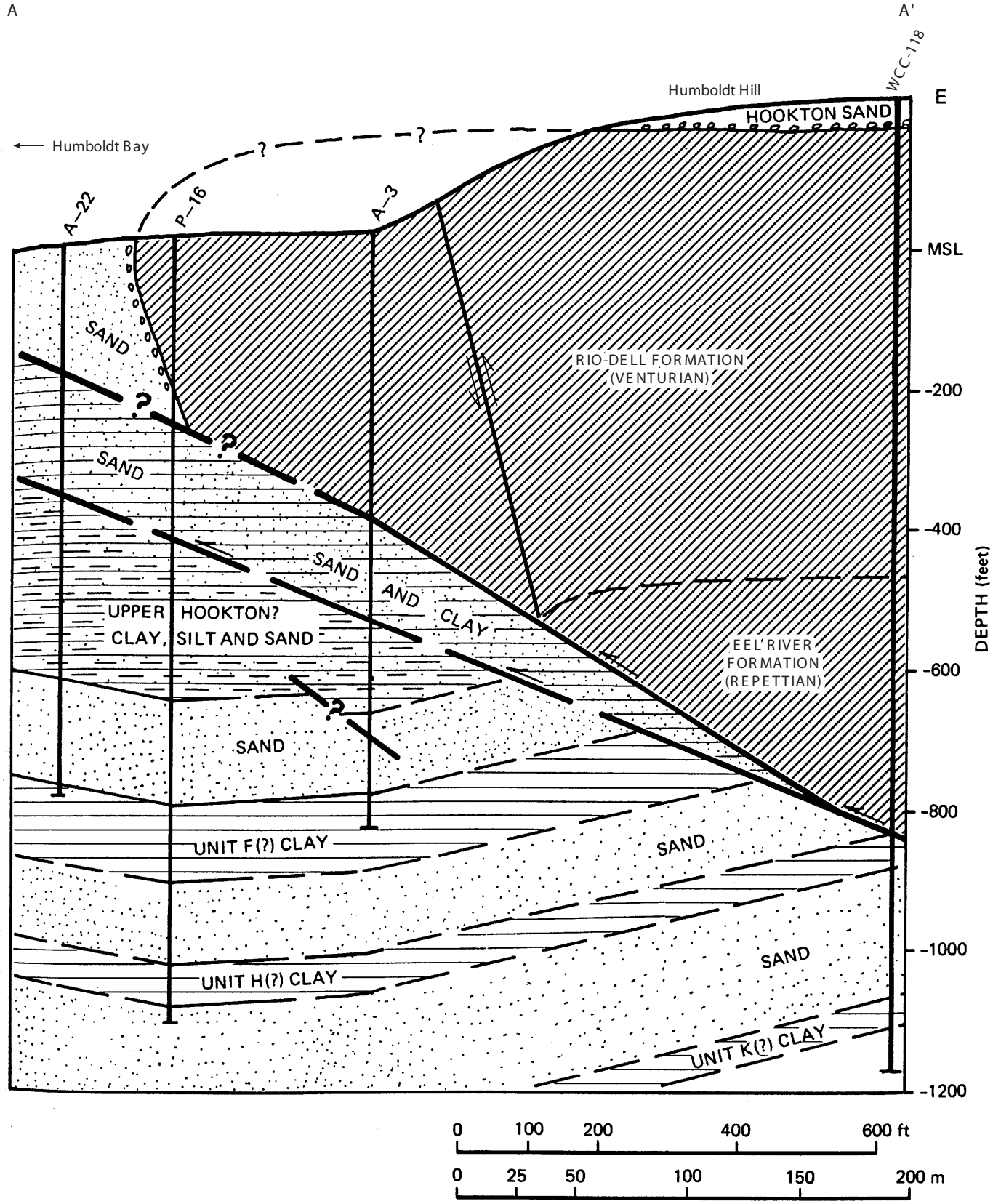
FSAR UPDATE

HUMBOLDT BAY ISFSI

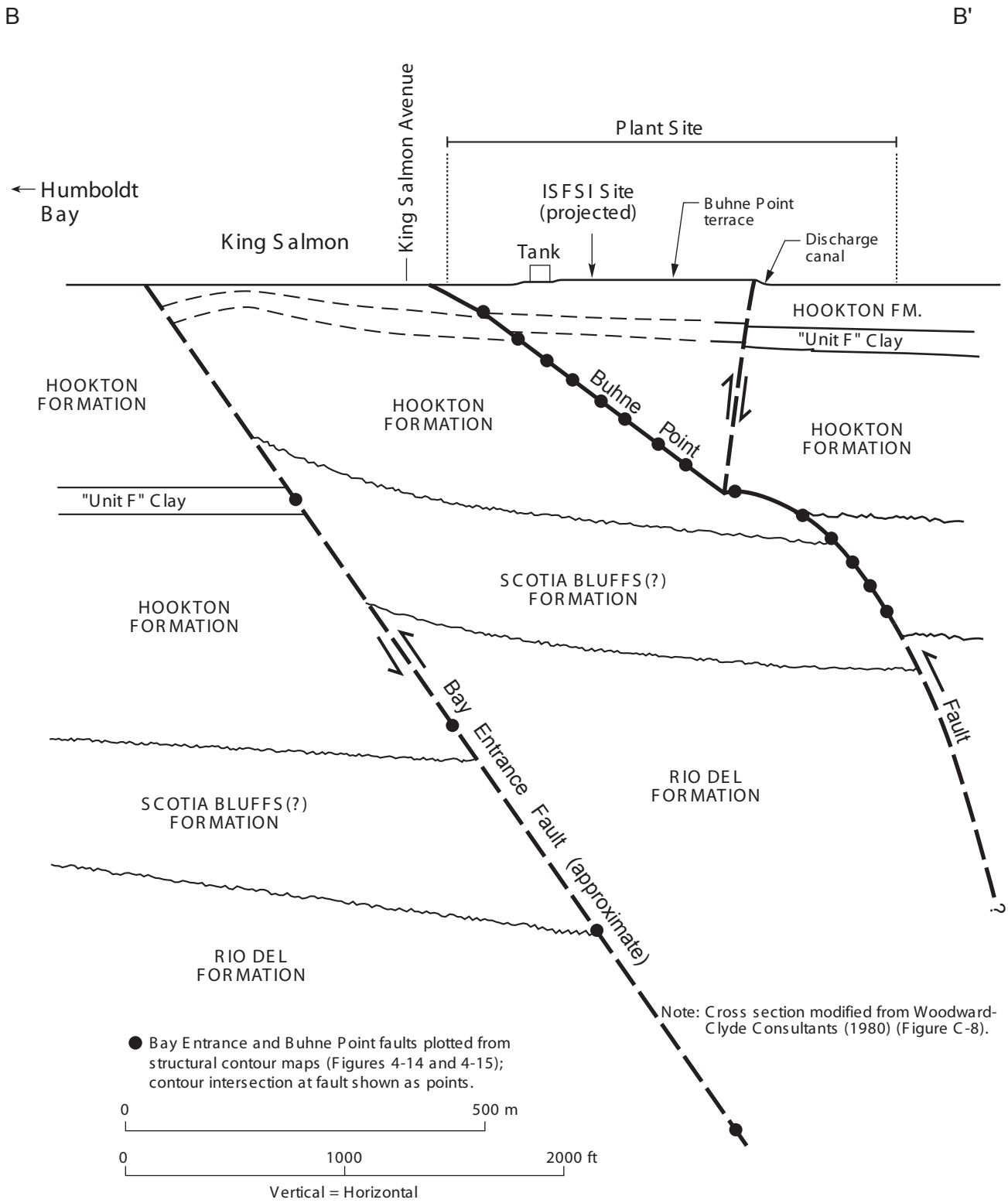
FIGURE 2.6-47
STRUCTURE CONTOUR MAP OF THE BAY ENTRANCE FAULT



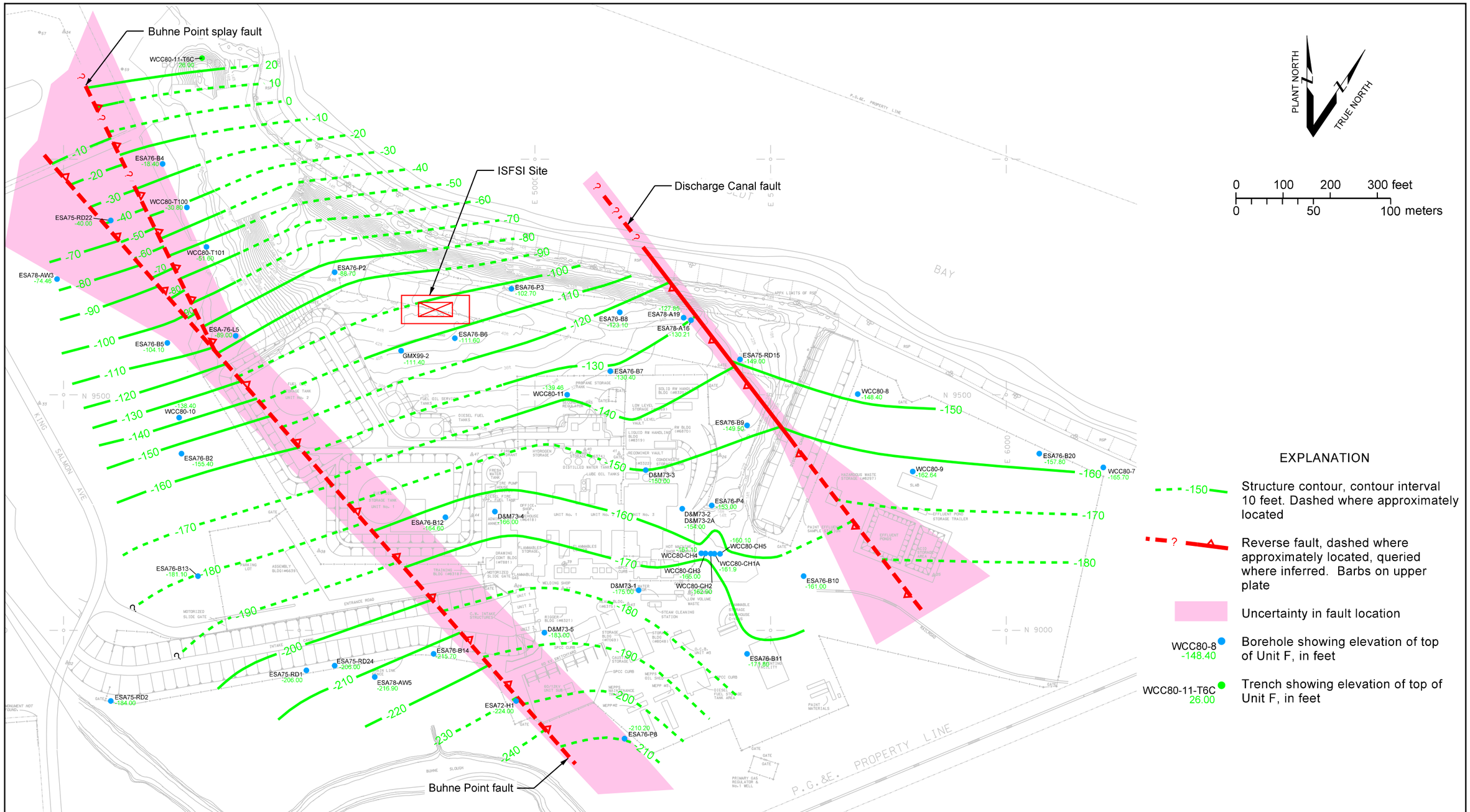
FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-48
Structure contour map of the Buhne Point fault (reinterpretation of data presented on Woodward-Clyde Consultants, 1980, Figure C-25). Cross section B-B' is shown on Figure 2.6-50.



FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-49
Cross section A-A' across the Little Salmon fault zone at Humboldt Hill (modified from Woodward-Clyde Consultants, 1980, Figure C-15). Location of cross section A-A' is shown on Figures 2.6-30 and 2.6-46.



FSAR UPDATE
HUMBOLDT BAY ISFSI'
FIGURE 2.6-50
Cross section B-B' across the Bay Entrance and Buhne Point faults. Location of cross section is shown on Figures 2.6-30 and 2.6-47.

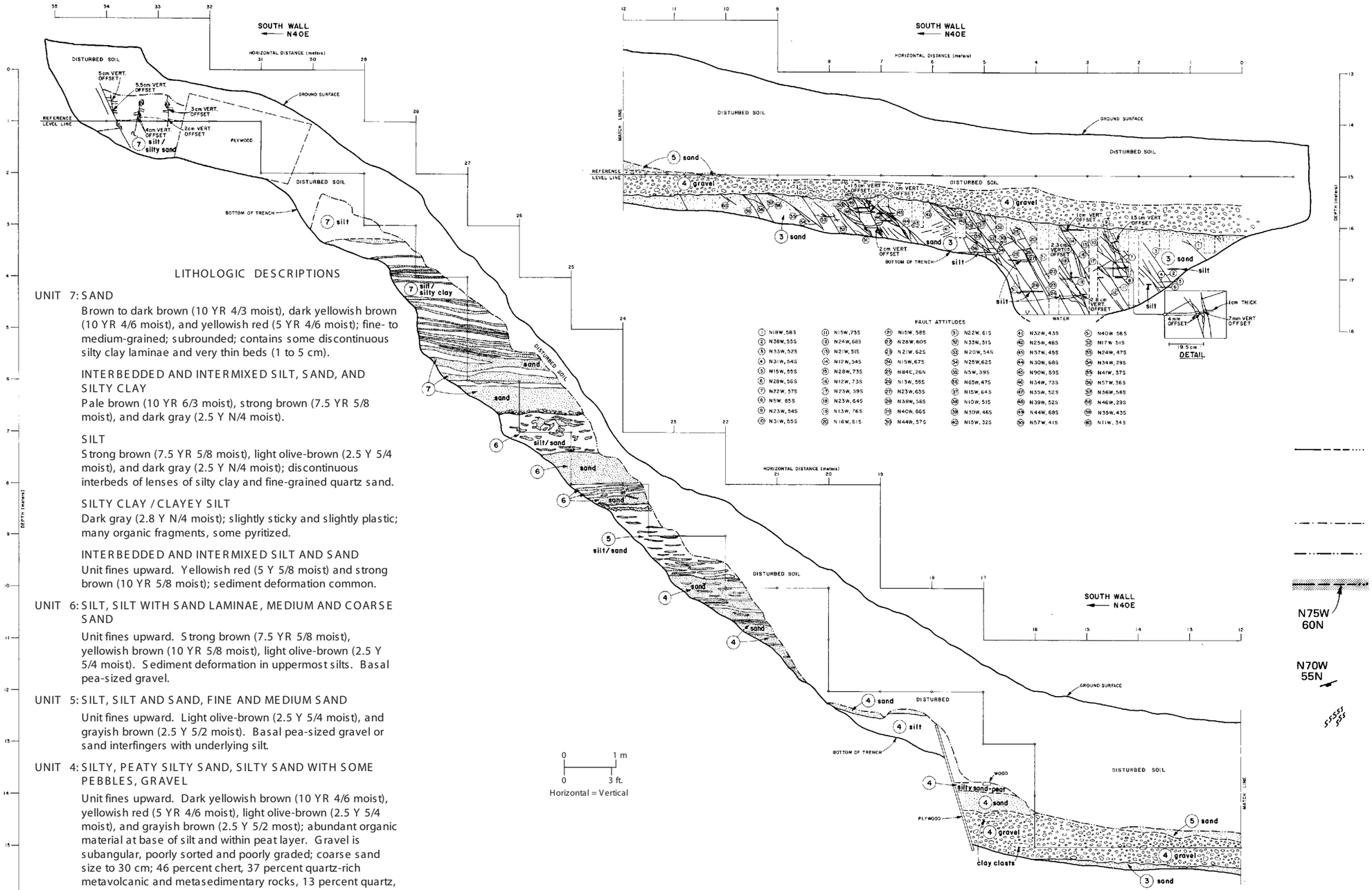


FSAR UPDATE

HUMBOLDT BAY ISFSI

FIGURE 2.6-51
STRUCTURE CONTOUR MAP OF TOP OF UNIT F

Revision 0 January 2006



LITHOLOGIC DESCRIPTIONS

UNIT 7: SAND

Brown to dark brown (10 YR 4/3 moist), dark yellowish brown (10 YR 4/6 moist), and yellowish red (5 YR 4/6 moist); fine- to medium-grained; subrounded; contains some discontinuous silty clay laminae and very thin beds (1 to 5 cm).

INTERBEDDED AND INTERMIXED SILT, SAND, AND SILTY CLAY

Pale brown (10 YR 6/3 moist), strong brown (7.5 YR 5/8 moist), and dark gray (2.5 Y N/4 moist).

SILT

Strong brown (7.5 YR 5/8 moist), light olive-brown (2.5 Y 5/4 moist), and dark gray (2.5 Y N/4 moist); discontinuous interbeds of lenses of silty clay and fine-grained quartz sand.

SILTY CLAY / CLAYEY SILT

Dark gray (2.8 Y N/4 moist); slightly sticky and slightly plastic; many organic fragments, some pyritized.

INTERBEDDED AND INTERMIXED SILT AND SAND

Unit fines upward. Yellowish red (5 Y 5/8 moist) and strong brown (10 YR 5/8 moist); sediment deformation common.

UNIT 6: SILT, SILT WITH SAND LAMINAE, MEDIUM AND COARSE SAND

Unit fines upward. Strong brown (7.5 YR 5/8 moist), yellowish brown (10 YR 5/8 moist), light olive-brown (2.5 Y 5/4 moist). Sediment deformation in uppermost silts. Basal pea-sized gravel.

UNIT 5: SILT, SILT AND SAND, FINE AND MEDIUM SAND

Unit fines upward. Light olive-brown (2.5 Y 5/4 moist), and grayish brown (2.5 Y 5/2 moist). Basal pea-sized gravel or sand interfingers with underlying silt.

UNIT 4: SILTY, PEATY SILTY SAND, SILTY SAND WITH SOME PEBBLES, GRAVEL

Unit fines upward. Dark yellowish brown (10 YR 4/6 moist), yellowish red (5 YR 4/6 moist), light olive-brown (2.5 Y 5/4 moist), and grayish brown (2.5 Y 5/2 most); abundant organic material at base of silt and within peat layer. Gravel is subangular, poorly sorted and poorly graded; coarse sand size to 30 cm; 46 percent chert, 37 percent quartz-rich metavolcanic and metasedimentary rocks, 13 percent quartz, 4 percent graywacke sandstone, 2 percent clay balls, rare sand lenses.

UNIT 3: SAND

Olive-brown (2.5 Y 4/4 moist); medium-grained; subrounded to subangular; contains discontinuous thin (2 mm to 4 cm) silt lenses.

EXPLANATION

Lithologic contact; solid line where resolution is less than 2 cm, dashed line where 2-5 cm, dotted line where 5-15 cm.

Soil contact

Disturbed soil contact

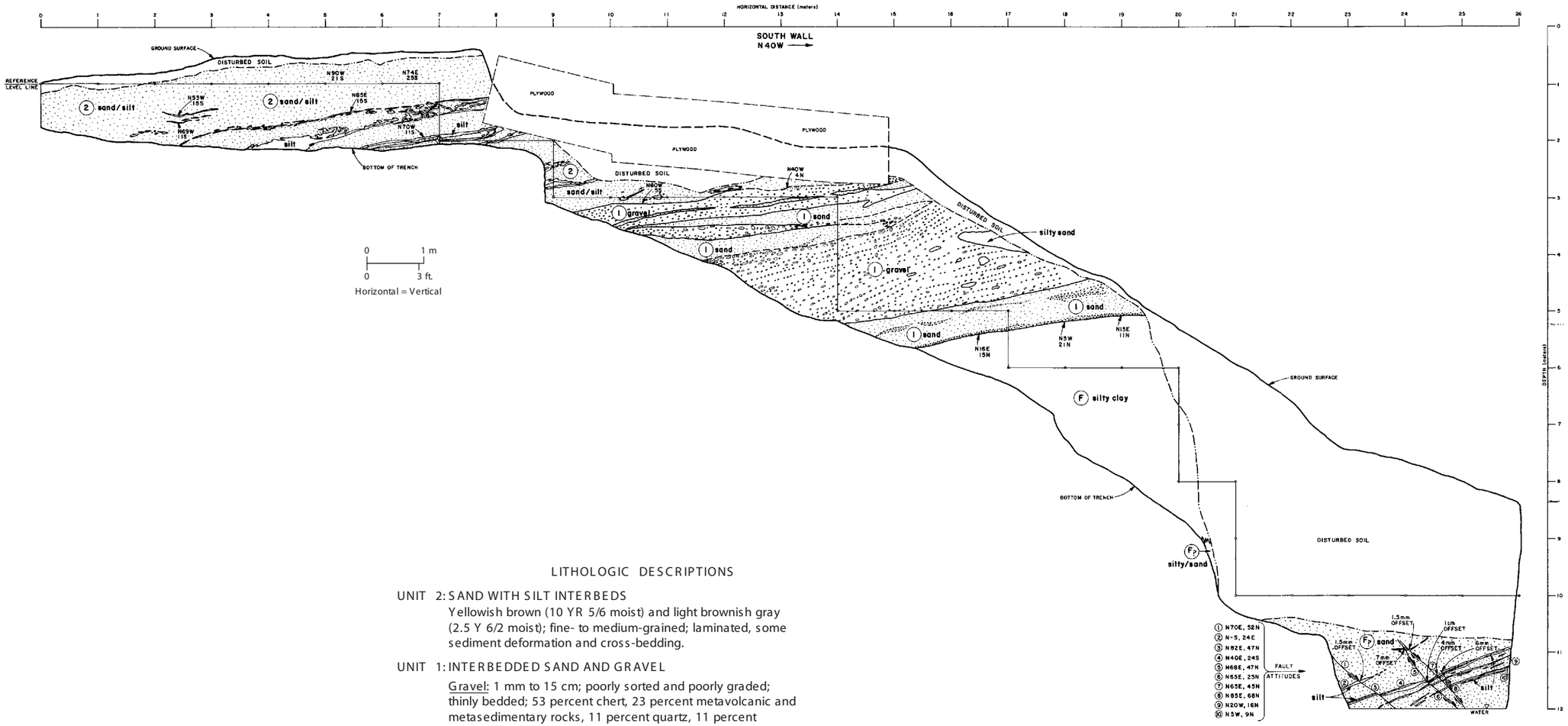
N75W 60N — Fault; solid line where resolution is less than 2 cm, dashed line where 2-5 cm, dotted line where 5-15 cm; strike and dip of fault plane indicated; arrows indicate sense of relative displacement.

N70W 55N — Strike and dip of jointing

Shears

FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-52

Log of trench 11-T6b showing small faults of the Buhne Point fault in the lower Hookton Formation (from Woodward-Clyde Consultants, 1980, Figure C-35). Location of trench is shown on Figure 2.6-31.



LITHOLOGIC DESCRIPTIONS

UNIT 2: SAND WITH SILT INTERBEDS

Yellowish brown (10 YR 5/6 moist) and light brownish gray (2.5 Y 6/2 moist); fine- to medium-grained; laminated, some sediment deformation and cross-bedding.

UNIT 1: INTERBEDDED SAND AND GRAVEL

Gravel: 1 mm to 15 cm; poorly sorted and poorly graded; thinly bedded; 53 percent chert, 23 percent metavolcanic and metasedimentary rocks, 11 percent quartz, 11 percent graywacke sandstone, 2 percent clay balls.

Sand: Strong brown (7.5 YR 4/6 moist); massive; medium-grained; subangular.

UNIT F: SILTY CLAY

Very dark gray (10 YR 3/1 moist); slightly sticky and slightly plastic silty clay; rare shattered sea shells. Grades to interbedded and intermixed silt and sand. Unit fines upward. Interbedded and intermixed silt and sand is dark brown (7.5 YR 3/4 moist) and dark grayish brown (10 YR 4/2 moist). Sand is olive-brown (2.5 Y 4/4 moist); medium-grained; subrounded to subangular; contains some discontinuous, thin (2 mm to 4 cm) silt lenses.

EXPLANATION

Lithologic contact; solid line where resolution is less than 2 cm, dashed line where 2-5 cm, dotted line where 5-15 cm.

Soil contact

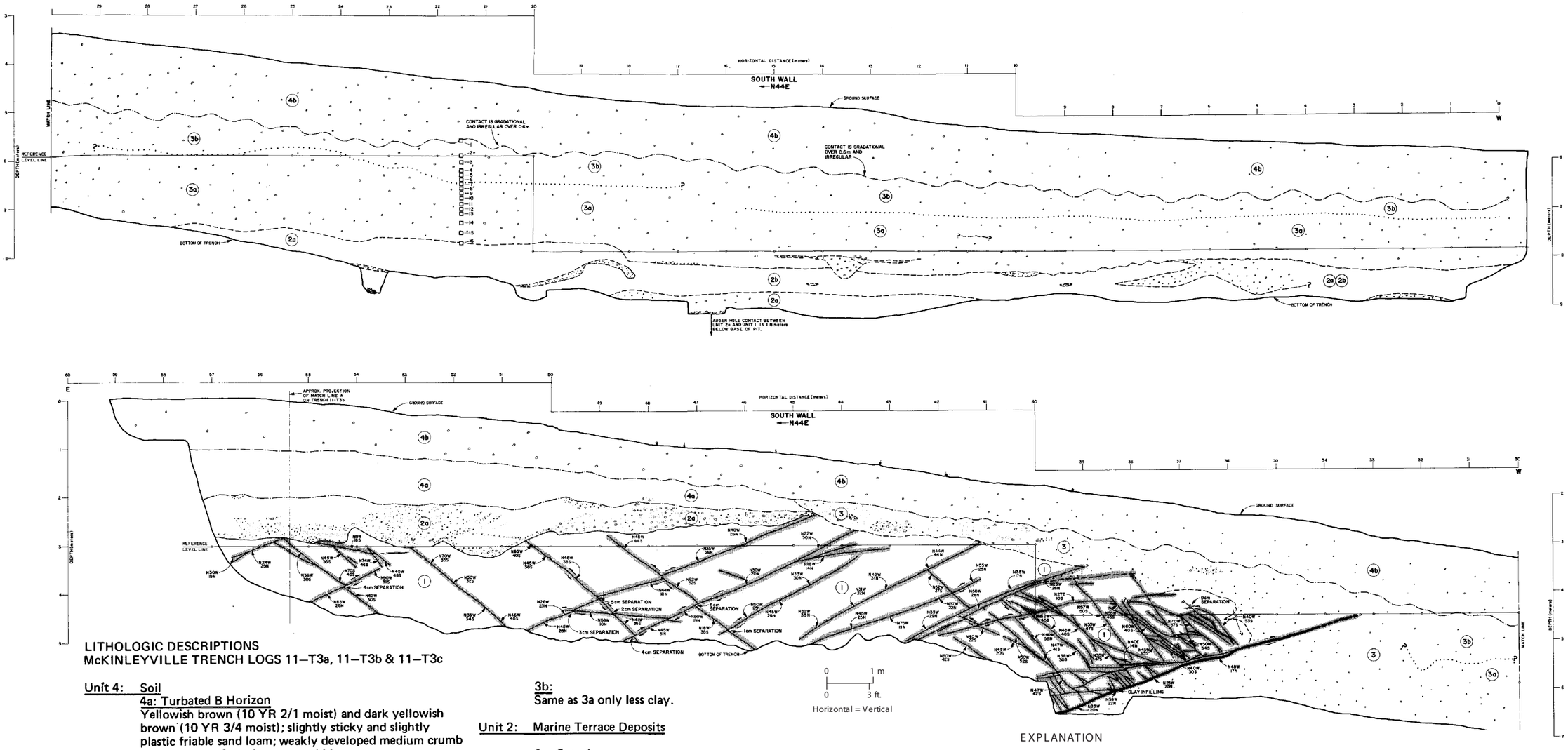
Disturbed soil contact

N75W 60N — Fault; solid line where resolution is less than 2 cm, dashed line where 2-5 cm, dotted line where 5-15 cm; strike and dip of fault plane indicated; arrows indicate sense of relative displacement.

N70W 55N — Strike and dip of jointing

Shears

FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-53
Log of trench 11-T6c showing small faults of the Buhne Point fault in the lower Hookton Formation (from Woodward-Clyde Consultants, 1980, Figure C-35). Location of trench is shown on Figure 2.6-31.



LITHOLOGIC DESCRIPTIONS
McKINLEYVILLE TRENCH LOGS 11–T3a, 11–T3b & 11–T3c

Unit 4: Soil

4a: Turbated B Horizon
Yellowish brown (10 YR 2/1 moist) and dark yellowish brown (10 YR 3/4 moist); slightly sticky and slightly plastic friable sand loam; weakly developed medium crumb ped structure. Contains some pebbles.

4B: A Horizon
Black (10 YR 2/1 moist), slightly sticky and slightly plastic, friable to loose sand loam. Ped structures weakly developed. Contains burrows and roots.

Unit 3: Colluvium

3a:
Olive-yellow (2.5 YR 6/6 moist), fine-to medium-grained subangular, moderately sorted, friable to slightly indurated sand; randomly oriented pebbles and cobbles.

3b:
Same as 3a only less clay.

Unit 2: Marine Terrace Deposits

2a: Gravel
Pebbles and cobbles in a light olive-brown (2.5 Y 5/4 moist), fine- to medium-grained sand matrix (approximately 15 percent of unit); moderately sorted.

2b: Terrace Sand
Pale olive (5 YR 6/4 moist); fine-grained; subangular; moderately to well sorted; friable; cross-bedded.

Unit 1: Crannell Brown Sand
Yellowish brown (10 YR 5/6 moist); fine-grained; sub–angular, 70 to 80 percent quartz and 20 to 30 percent lithic fragments; moderately to well sorted; friable to slightly indurated.

EXPLANATION

Lithologic contract; solid where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm.

Soil contact

Disturbed soil contact

Fault; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm; strike and dip of fault plane indicated; arrows indicate sense of relative displacement.

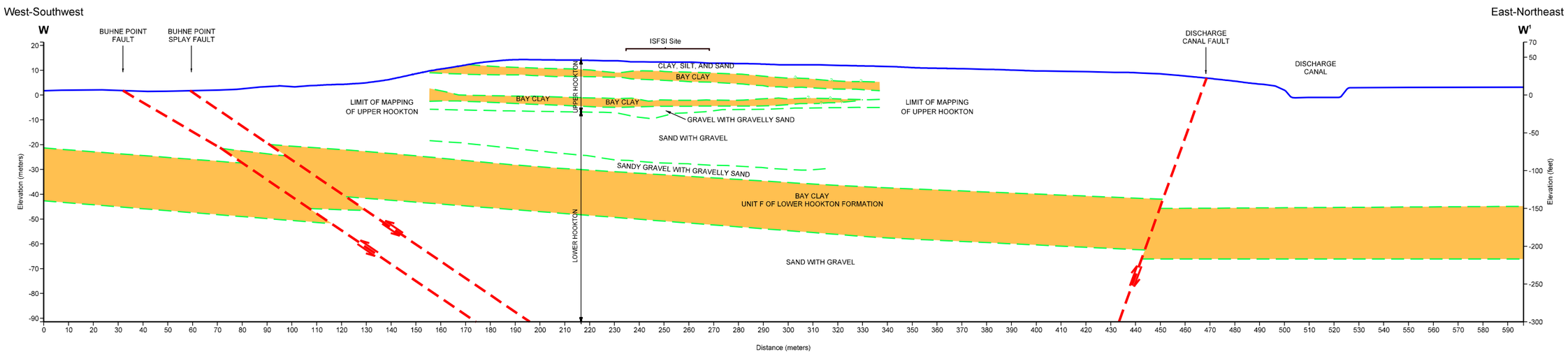
55N Strike and dip of jointing

Shears

FSAR UPDATE

HUMBOLDT BAY ISFSI

FIGURE 2.6-54
McKINLEYVILLE TRENCH (FROM WOODWARD-CLYDE CONSULTANTS, 1980, FIGURE B-19a). LOCATION OF TRENCH SHOWN ON FIGURE 2.6-13.



Fault, dashed where inferred, arrows show sense of displacement.

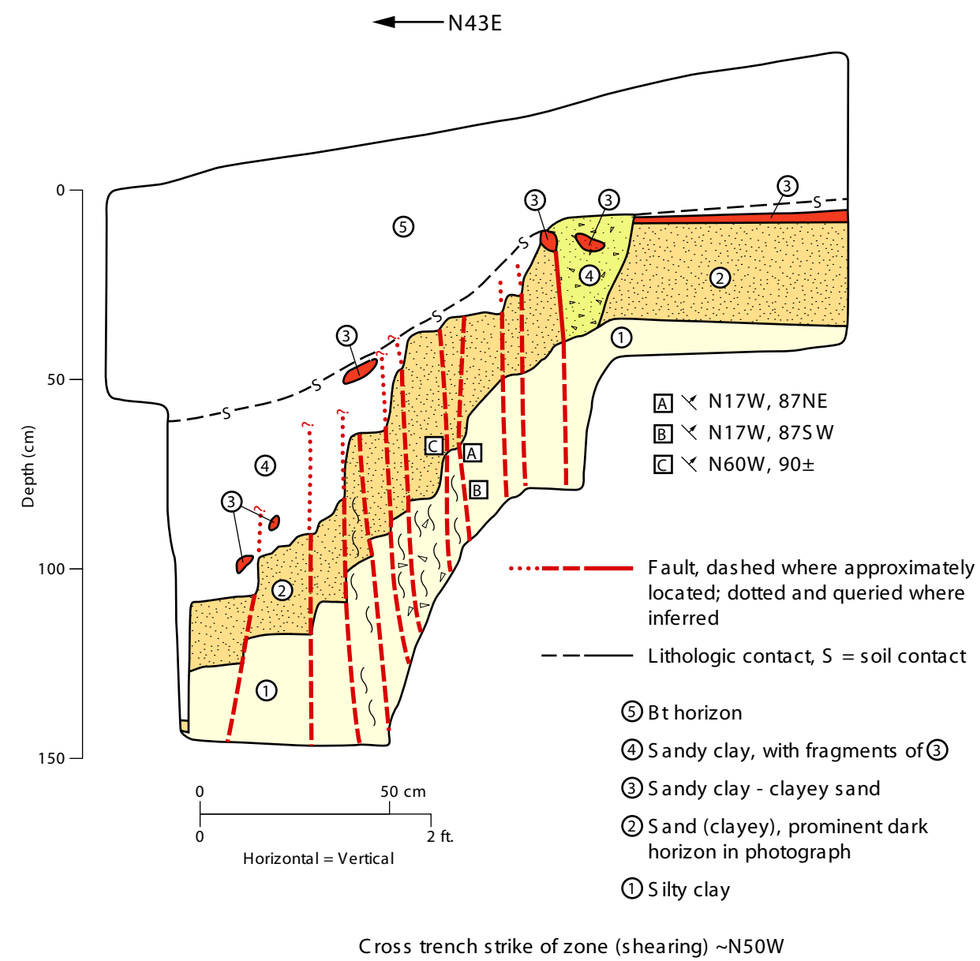
Lithologic contact, dashed where approximate, queried where inferred.

Note: Location of cross section is shown on Figure 2.6-31. Unit F location based on structure contour map (Figure 2.6-51). Stratigraphy above Unit F based on correlation of boreholes (ESA76-P2, GMX99-2, ESA76-6 through –8) and trenches. See Figure 2.6-31 for locations of boreholes.

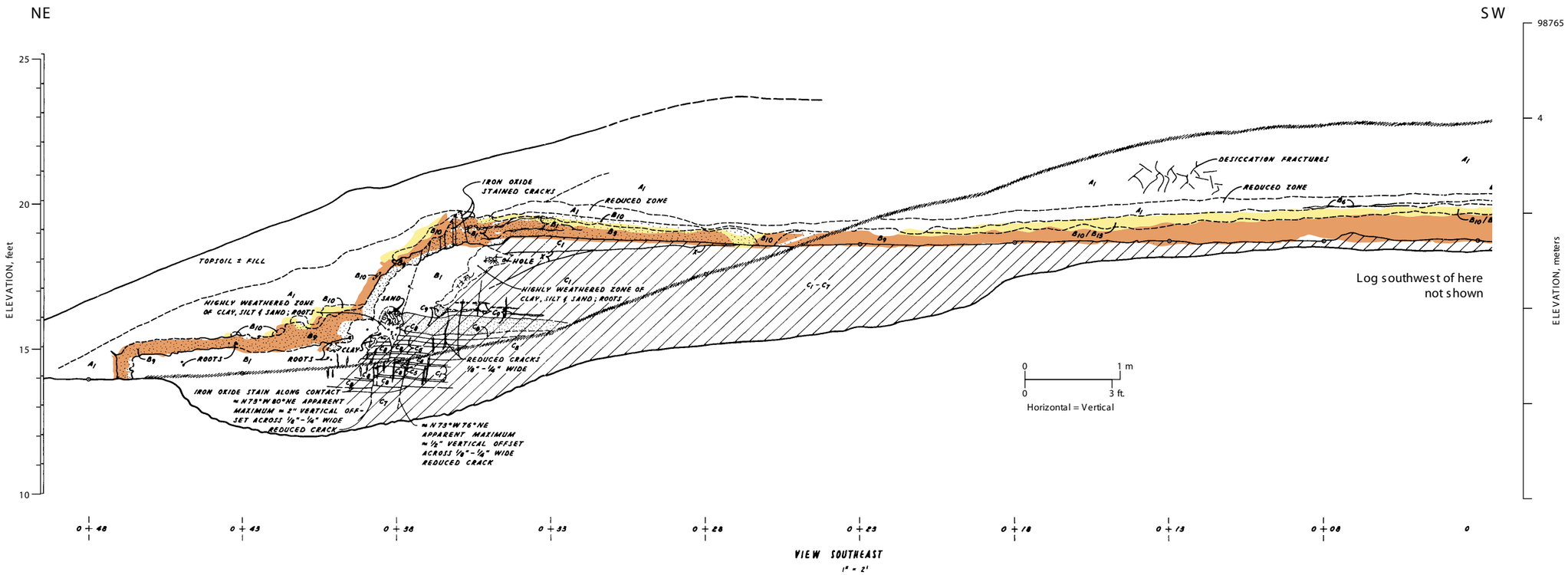
FSAR UPDATE

HUMBOLDT BAY ISFSI

FIGURE 2.6-55
GEOLOGIC
CROSS SECTION W-W[1]



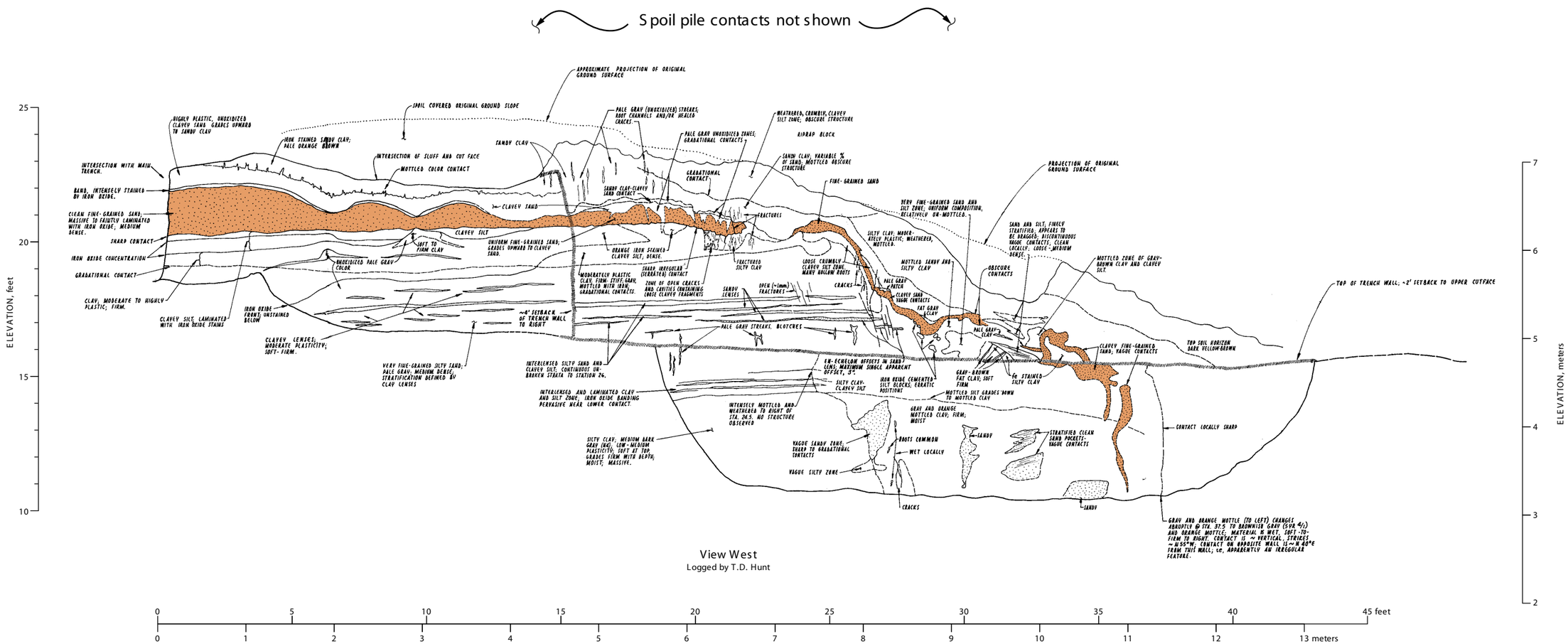
FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-56
Exposure of Discharge Canal fault in sea cliff west of Discharge Canal. The vertical string line in the middle of the photograph is 100 cm long. (Photographs JW-3-23 and 24; taken on March 21, 2000). Location of exposure is shown as outcrop JW-7 on Figure 2.6-31.



Log of northeastern part of trench BP-2 (from Earth Sciences Associates, 1977, Figure C37 [colors added for emphasis]). Station numbers are in feet. Location of trench is shown on Figure 2.6-31.

FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-57 LOG OF ESA (1977) TRENCH BP-2

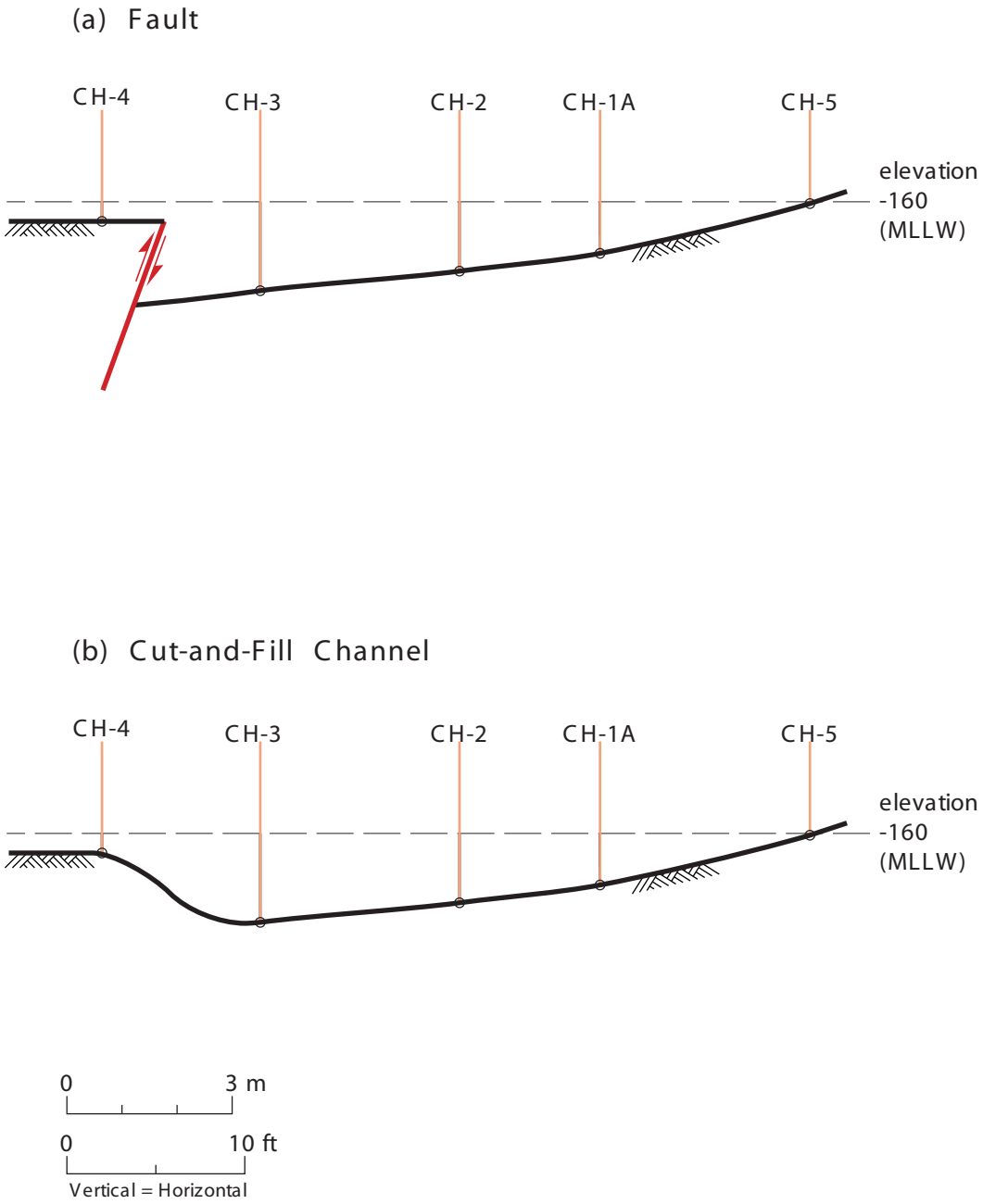
Revision 0 January 2006



Log of trench BP-3 (from Earth Sciences Associates, 1977, Figure C37 [colors added for emphasis]). Station numbers are in feet. Location of trench is shown on Figure 2.6-31.

FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-58 LOG OF ESA (1977) TRENCH BP-3

Revision 0 January 2006



FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-59
Alternative interpretations of the irregularities in the top of the Unit F clay between boreholes WCC80-CH4 and WCC80-CH5. Locations of boreholes shown on Figure 2.6-31.

FSAR UPDATE
HUMBOLDT BY ISFSI
FIGURE 2.6-60
Trench GMX-T1, view east-southeast. View along trench with Humboldt Bay Power Plant in the background. Part of trench GMX-T2 is in the foreground. (Photograph FHS-00/8-1 #29 taken August 1, 2000.)

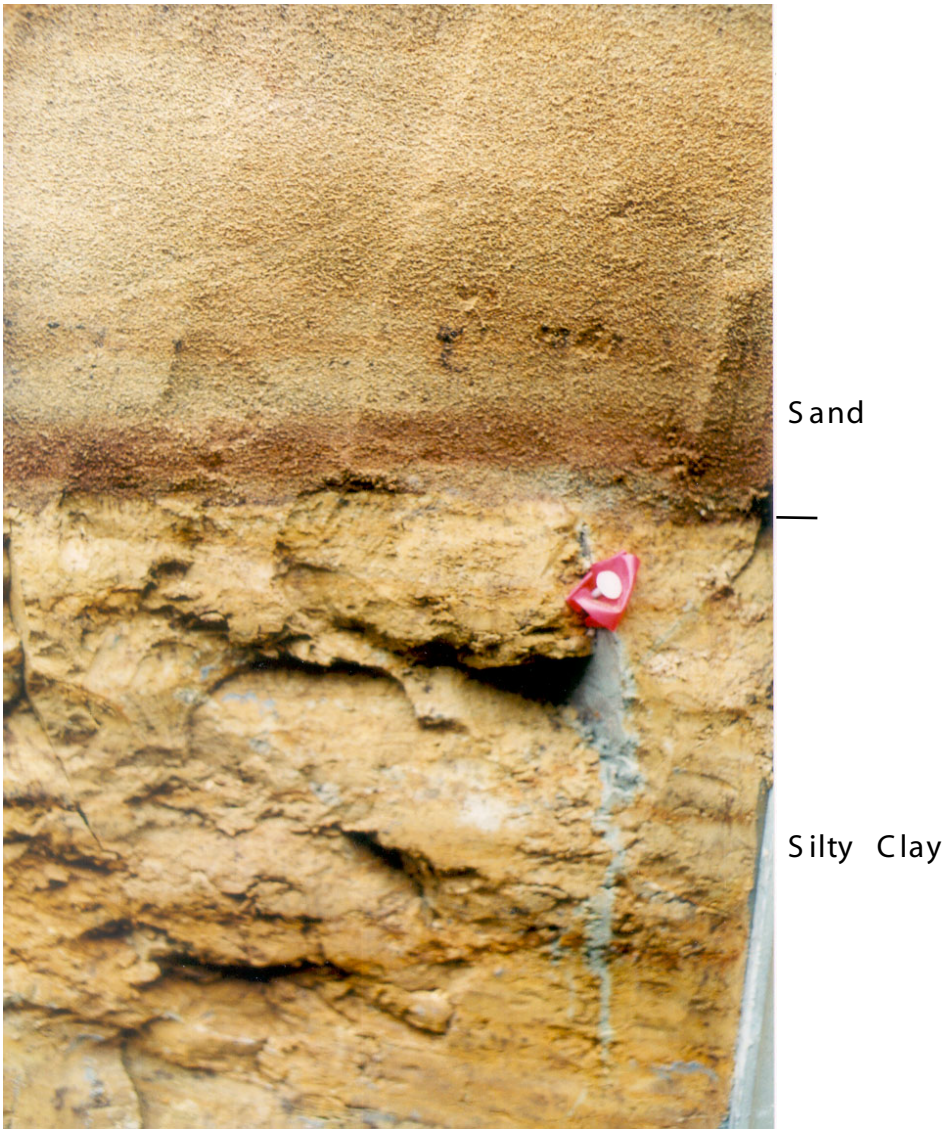
FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-61 SURVEYING GEOLOGIC CONTACTS IN TRENCH GMX-T2. VIEW IS TOWARD THE SOUTH. (PHOTOGRAPH FHS-00/7-4 #9 TAKEN AUGUST 1, 2000.)

Fill

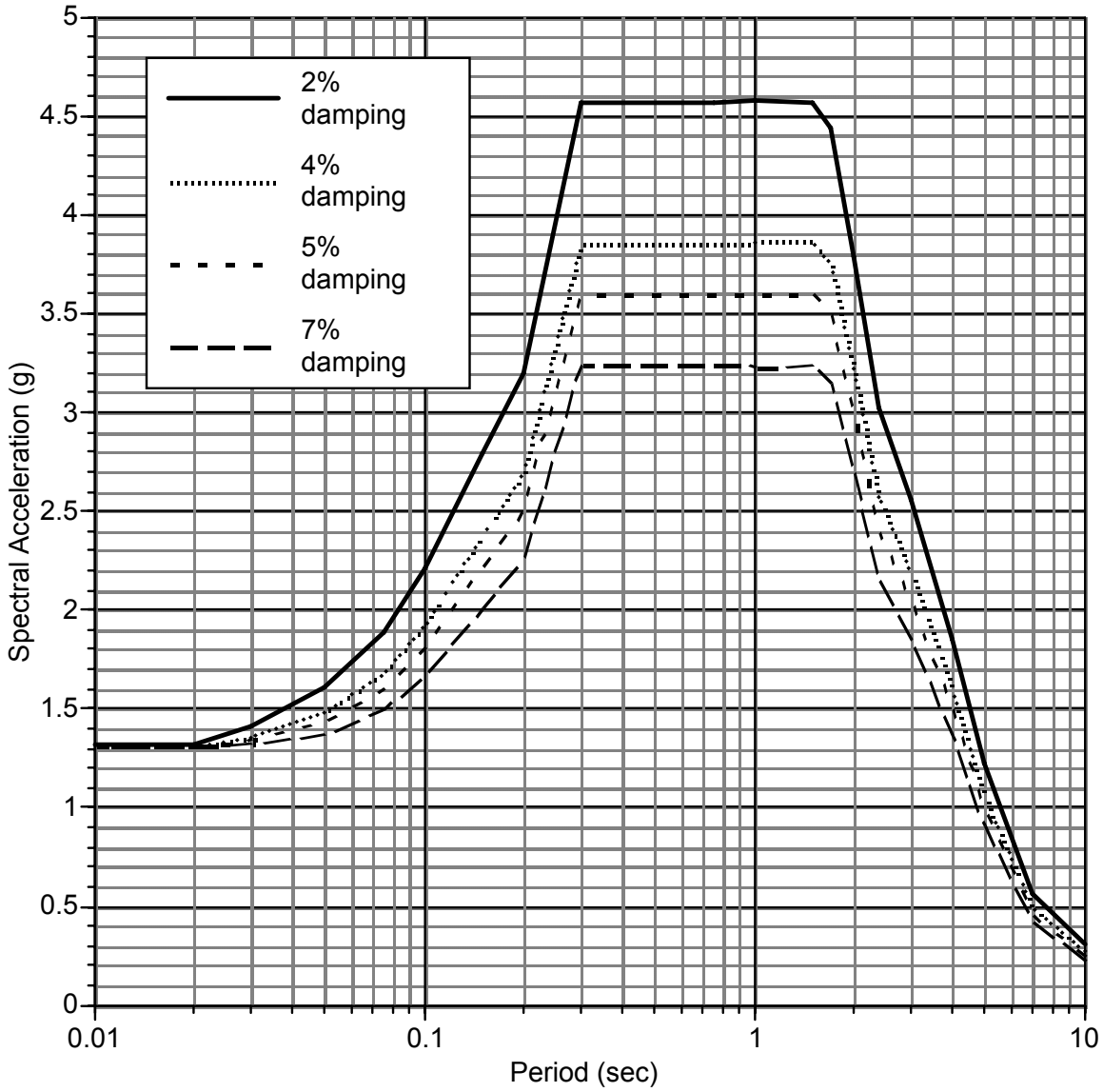
SAFETY ANALYSIS REPORT
HUMBOLDT BAY ISFSI
FIGURE 2.6-62
Artificial fill overlying sand and silt layers of the upper Hookton Formation in northwest wall of trench GMX-T2 between station 36 ft. and station 44 ft. (Photograph FHS-00/7-4 #19 taken August 1, 2000.)

FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-63
Clay fractures in upper Hookton Formation in trench GMX-T2. Fractures are at station ~25 ft., depth ~5 ft. Note continuous bedding across fractures below where they have been bleached in the weathered silty clay. (Photograph FHS-00/8-3 #32 taken August 3, 2000.)

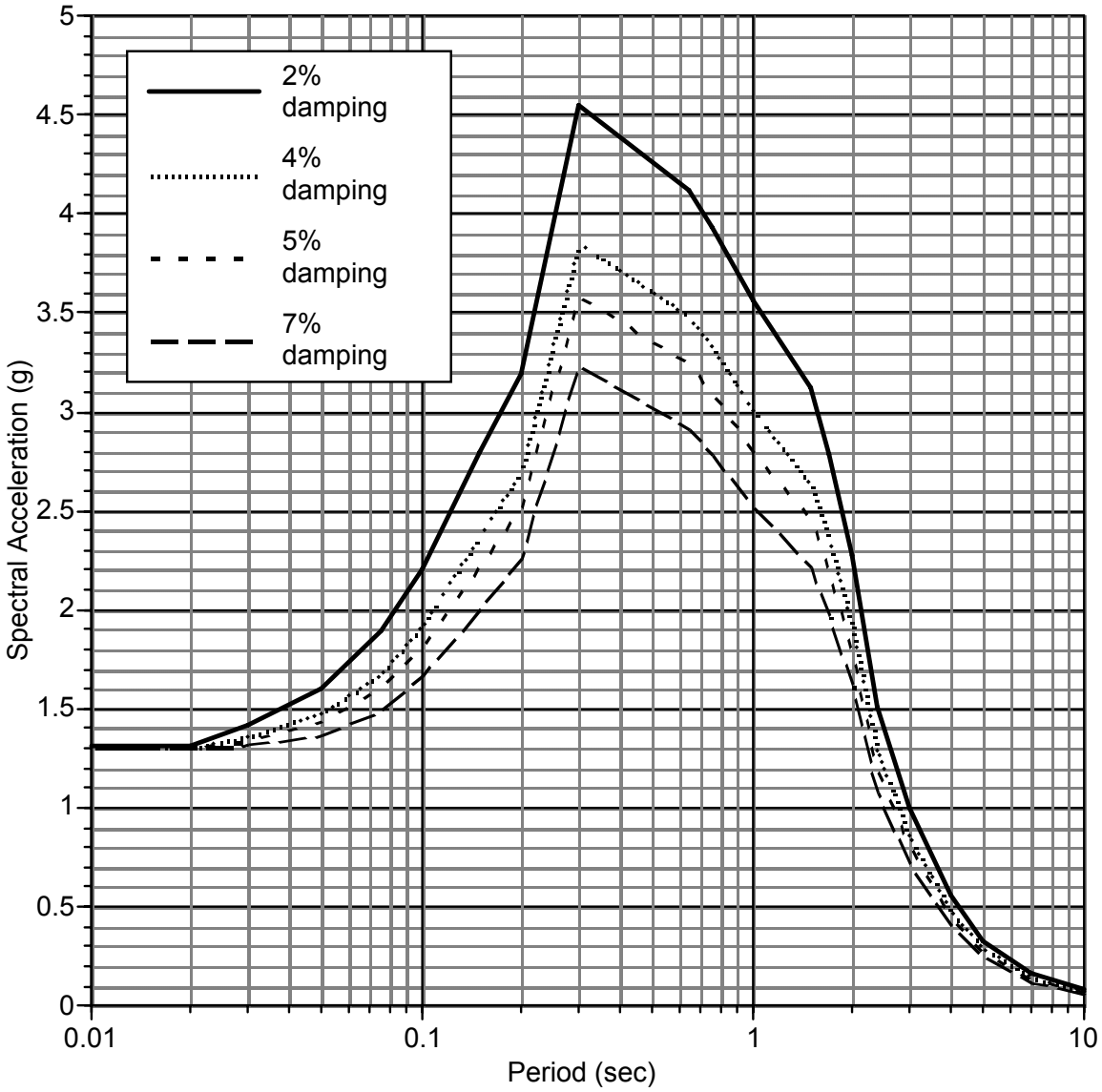
FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-64
Fracture lined with black compressed rootlets in clayey-silt bed in trench GMX-T2. Fracture is at station 40 ft., depth ~11 ft. (Photograph FHS-00/7-3 #21 taken August 3, 2000.)



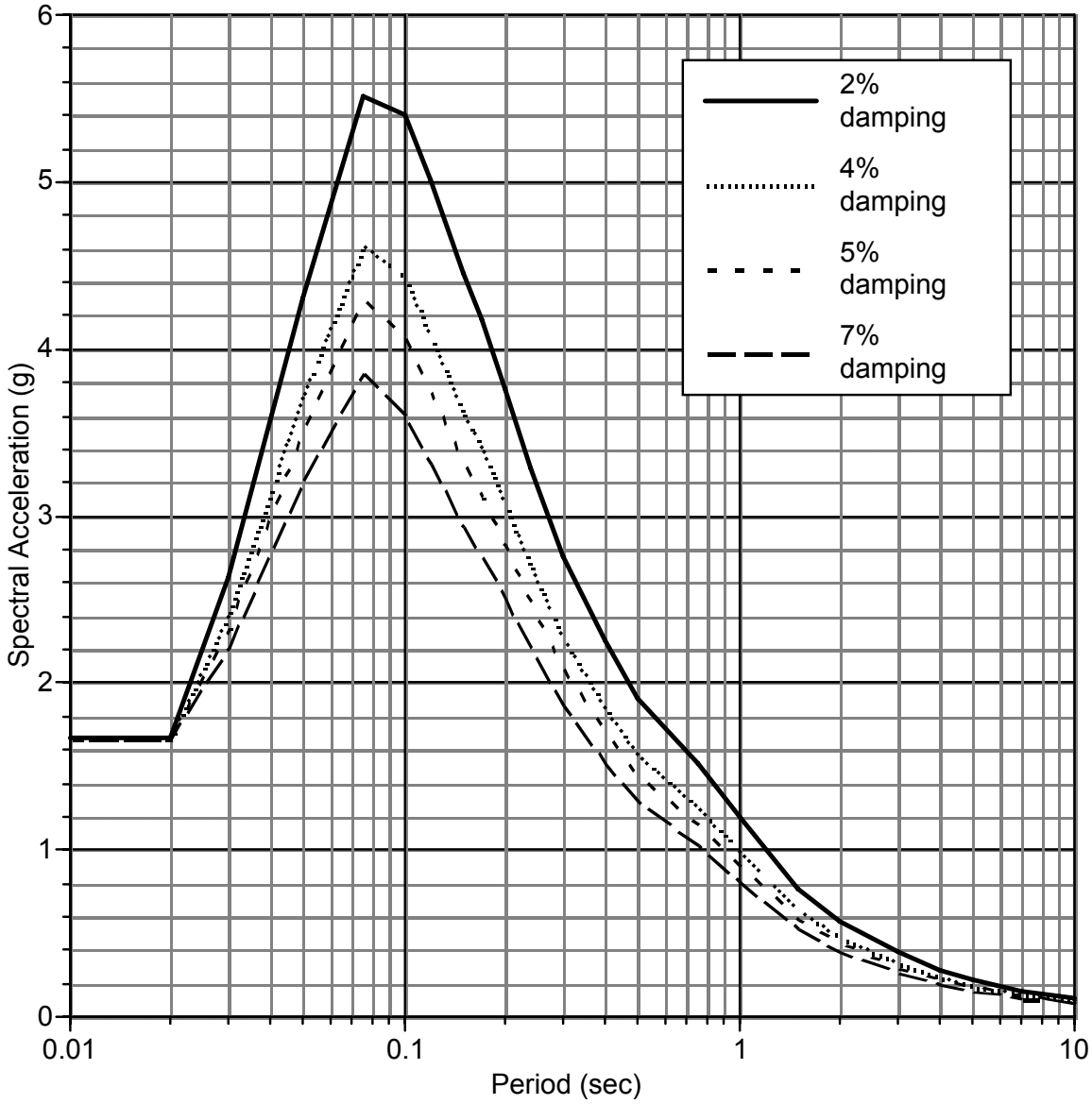
FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-65
Continuous bedding across bleached fracture in silty clay in trench GMX-T2. Fractures are at station 30 ft., depth ~4 ft. (Photograph FHS-00/8-3 #26 taken August 3, 2000.)



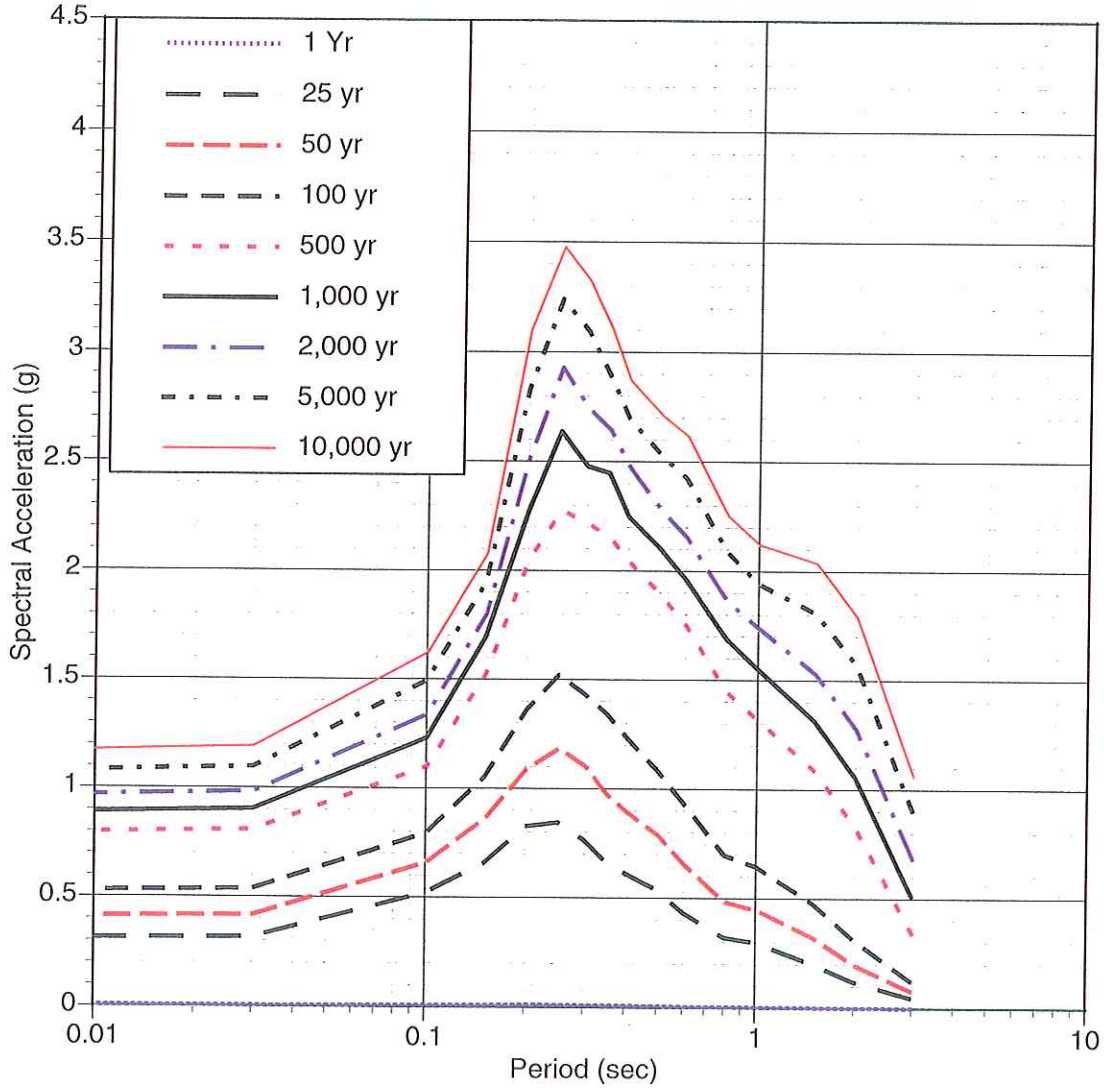
FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-66 FAULT NORMAL DESIGN SPECTRUM FOR DAMPING VALUES OF 2%, 4%, 5%, AND 7%



FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-67 FAULT PARALLEL DESIGN SPECTRUM FOR DAMPING VALUES OF 2%, 4%, 5%, AND 7%

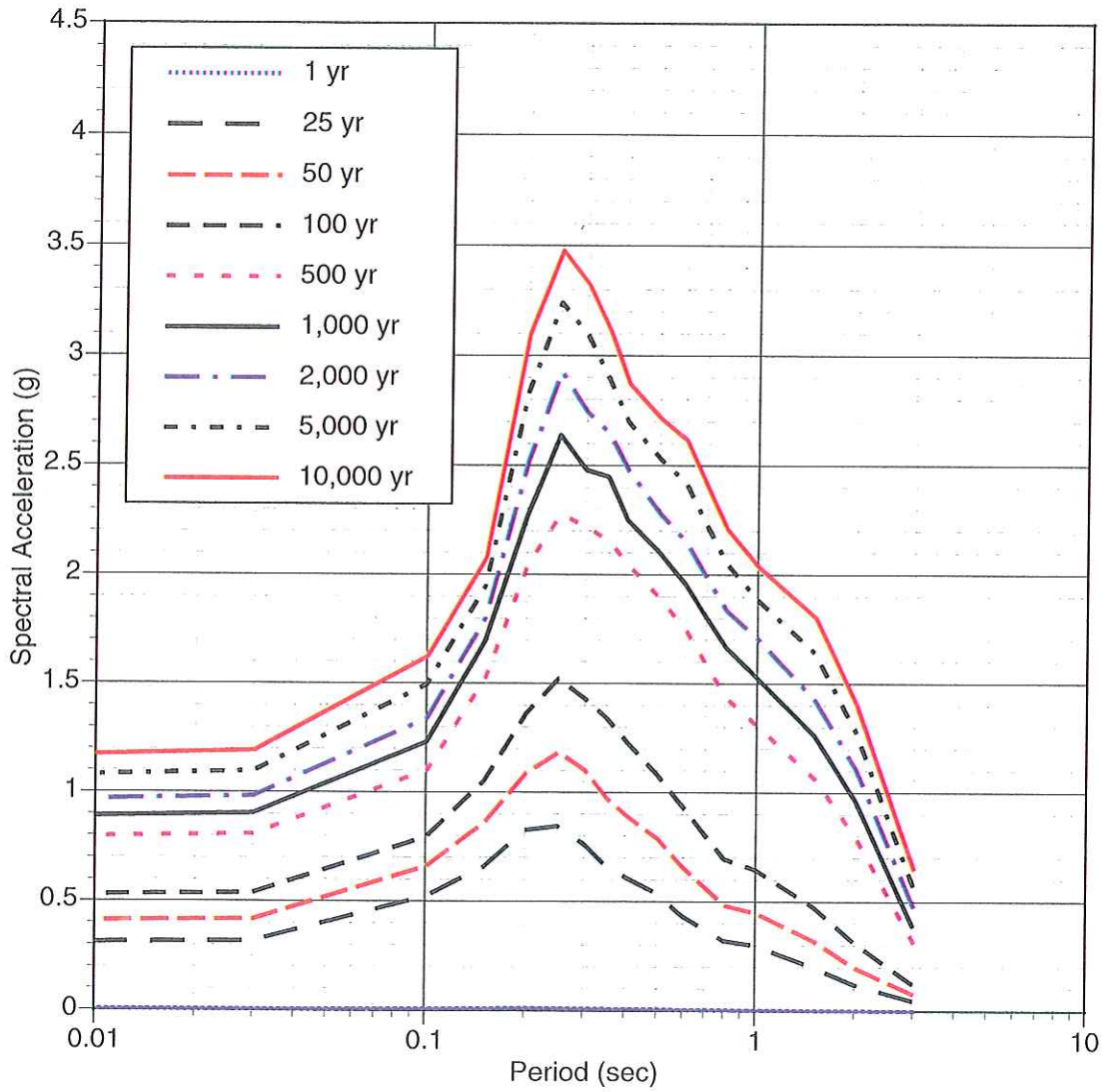


FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-68 VERTICAL SPECTRUM FOR DAMPING VALUES OF 2%, 4%, 5%, AND 7%



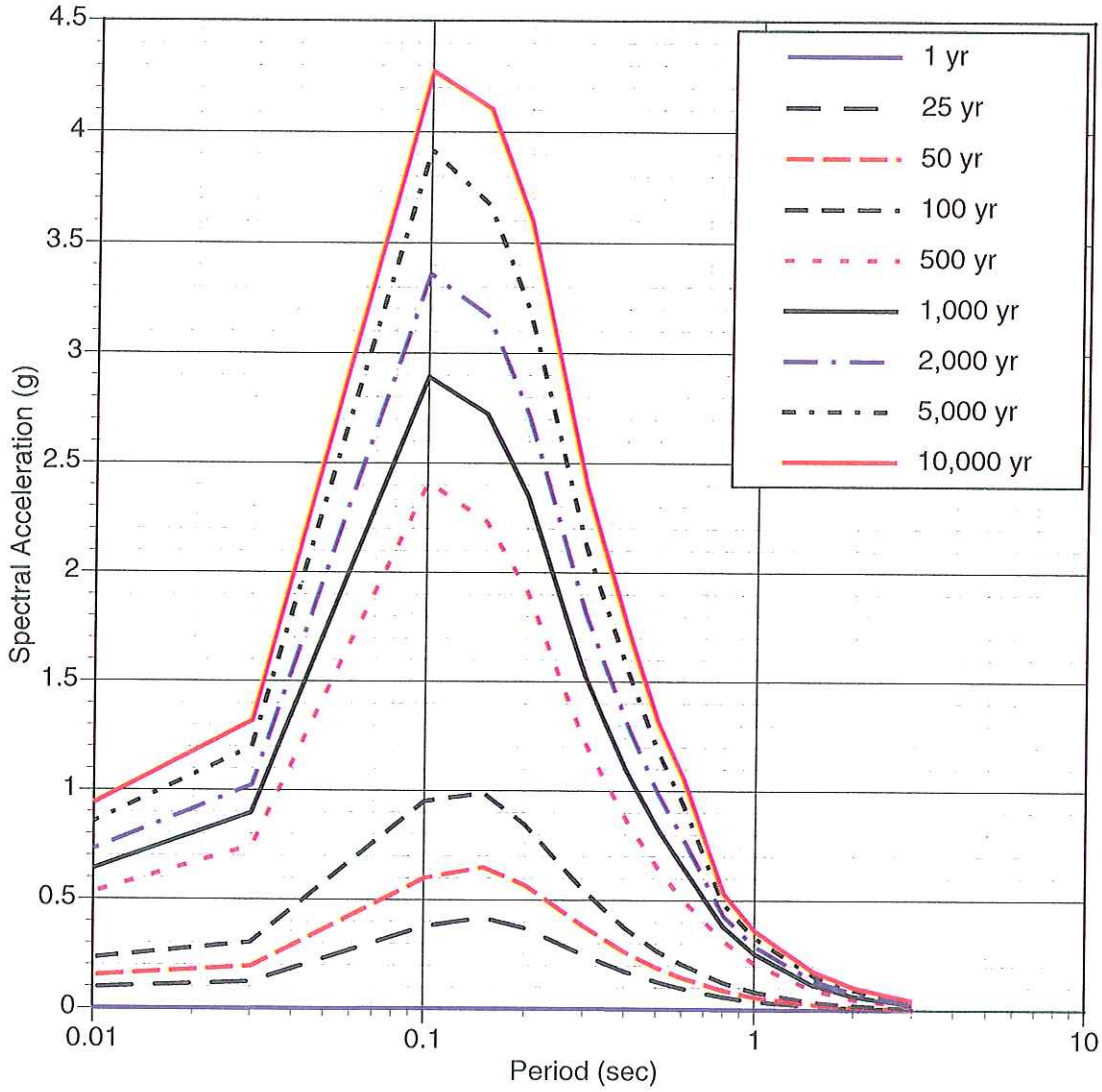
FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-69 EQUAL HAZARD SPECTRA FOR THE FN COMPONENT, SOIL SITE CONDITIONS

Revision 0 Jamuary 2006



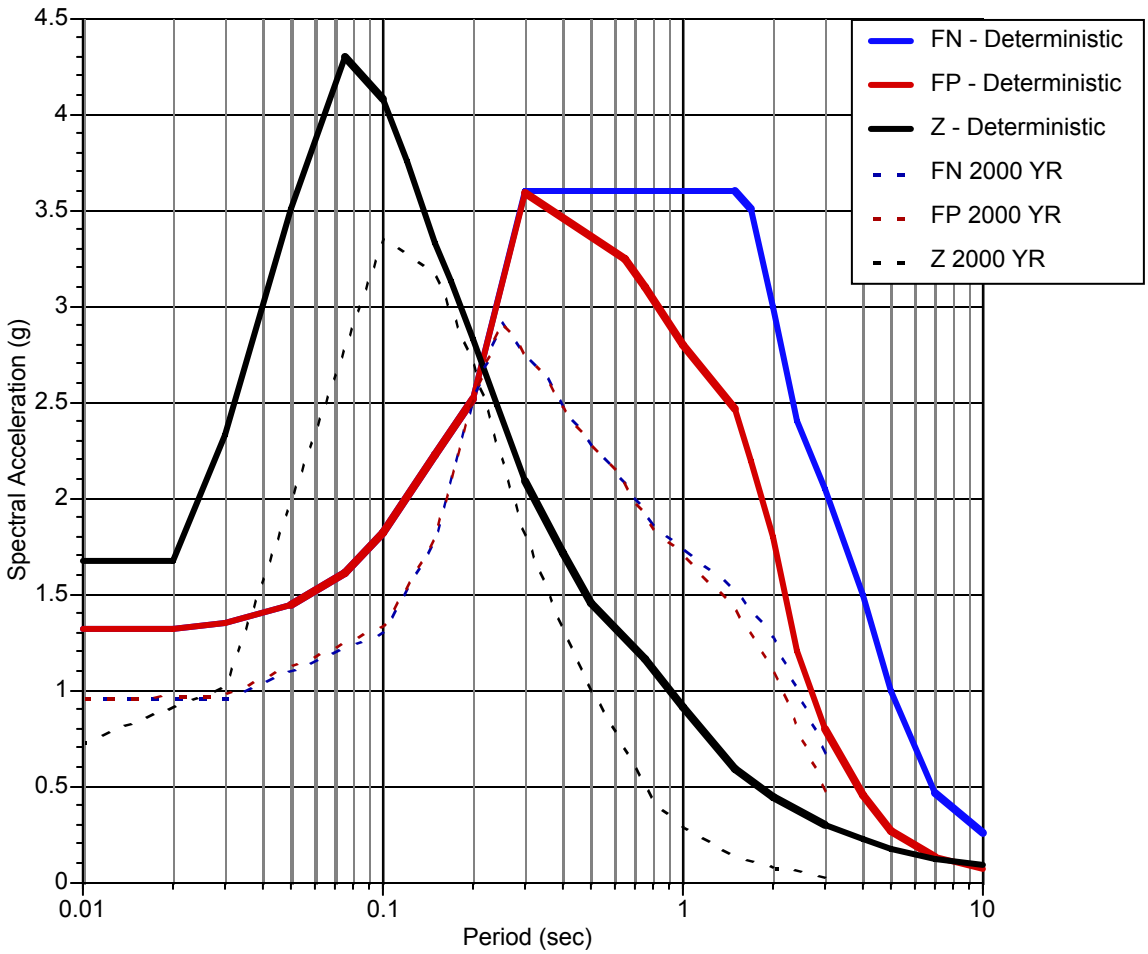
FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-70 EQUAL HAZARD SPECTRA FOR THE FP COMPONENT, SOIL SITE CONDITIONS

Revision 0 January 2006



FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-71 EQUAL HAZARD SPECTRA FOR THE VERTICAL COMPONENTS FOR SOIL

Revision 0 January 2006

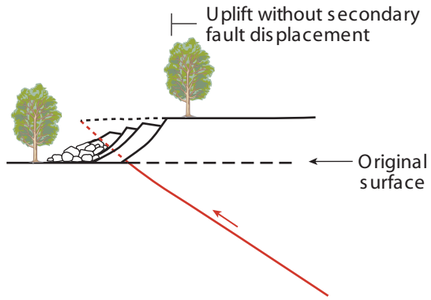


FSAR UPDATE

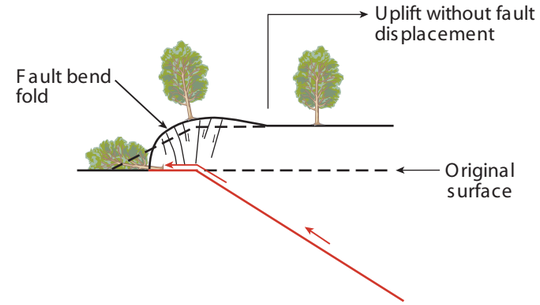
HUMBOLDT BAY ISFSI

FIGURE 2.6-72
COMPARISON OF DETERMINISTIC SPECTRA WITH 2000-YEAR PROBABILISTIC SPECTRA

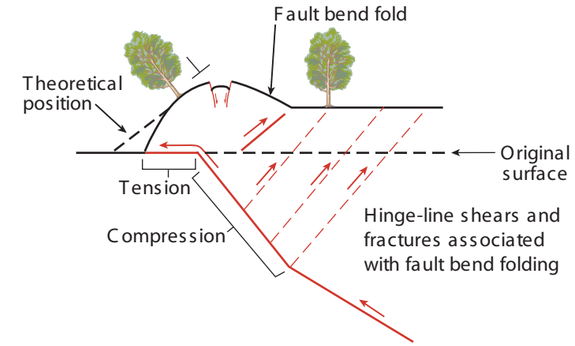
Revision 0 January 2006



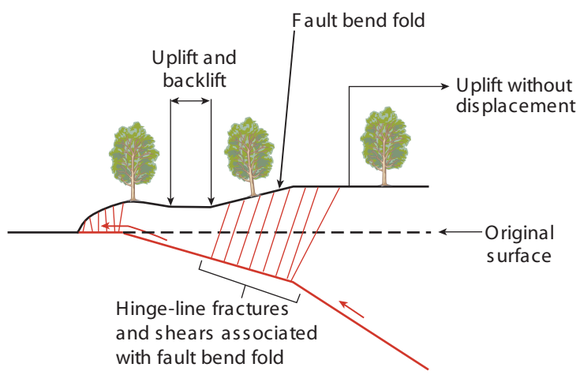
a) Collapsed fault scarp from reverse fault having constant dip.



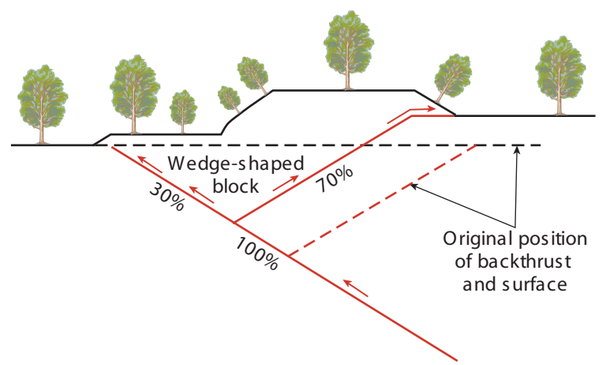
b) Uplift, folding and bulldozing at fault scarp from reverse fault having constant dip.



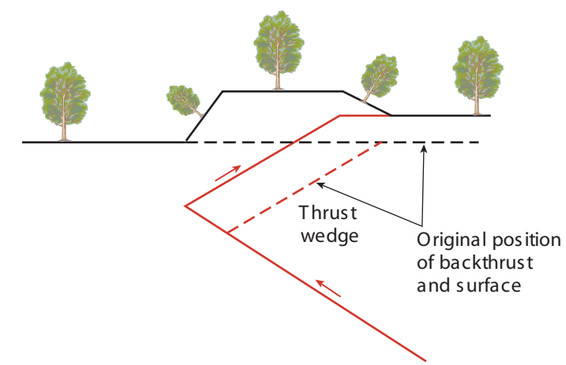
c) Uplift, compact folding at fault scarp from reverse fault that steepens dip as it approaches the surface.



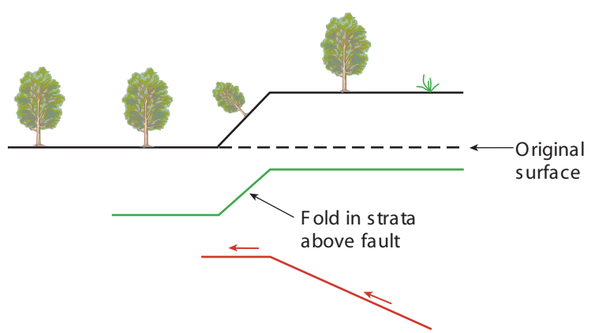
d) Uplift, folding, bulldozing, and tilting from reverse fault that shallows in dip as it approaches the surface.



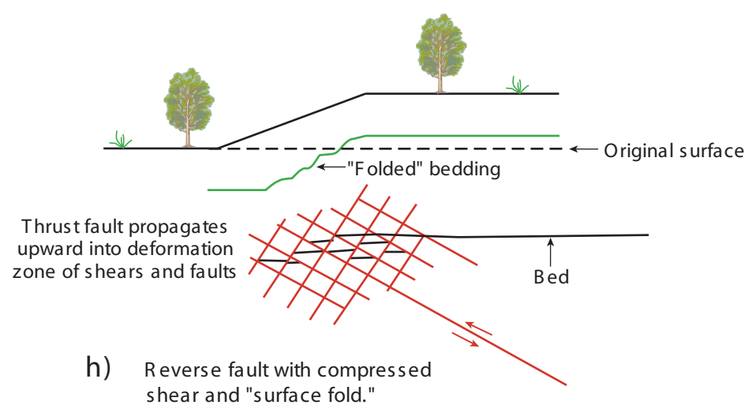
e) Reverse fault with forethrust (30% of slip), backthrust (70% of slip), and wedge-shaped block.



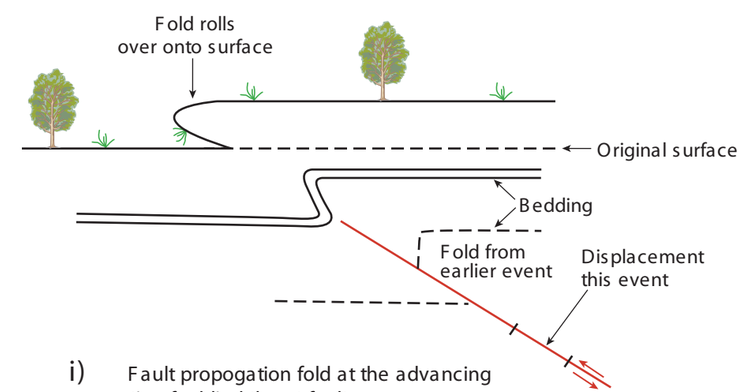
f) Reverse fault with blind forethrust and simple backthrust produced by a thrust wedge.



g) Simple blind thrust with fault bend fold developed above a fault ramp.



h) Reverse fault with compressed shear and "surface fold."



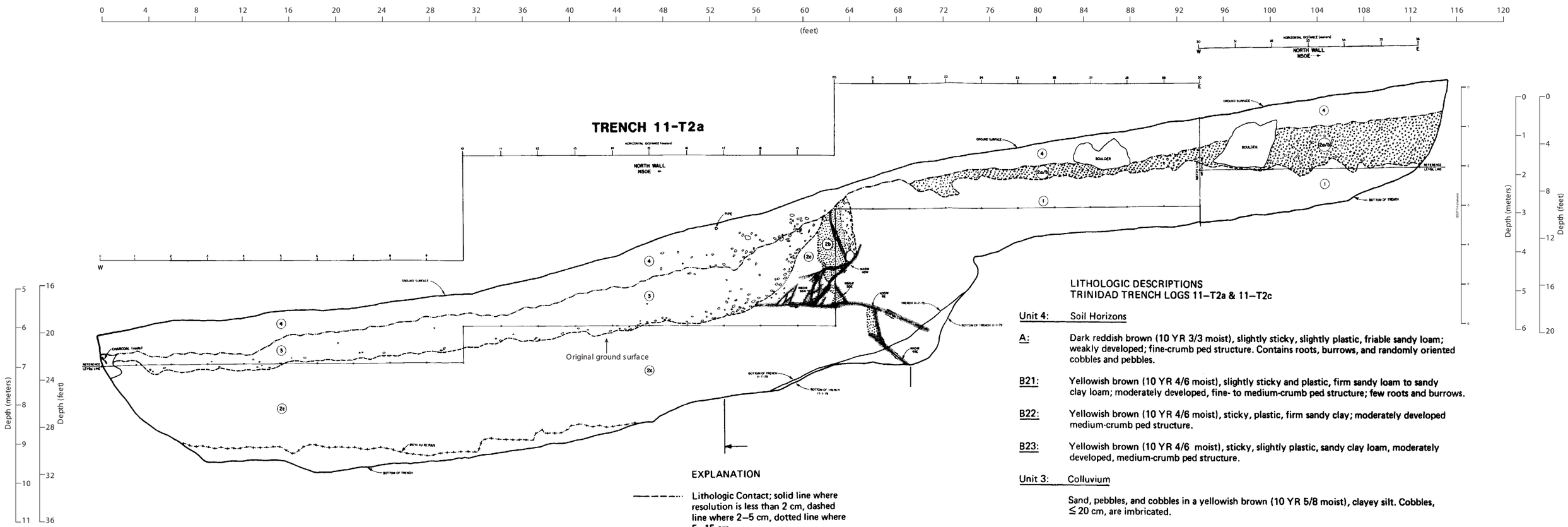
i) Fault propogation fold at the advancing tip of a blind thrust fault.

FSAR UPDATE

HUMBOLDT BAY ISFSI

FIGURE 2.6-73
TYPICAL TYPES OF SURFACE DEFORMATION ASSOCIATED WITH THRUST FAULTING

FSAR UPDATE
HUMBOLDT BAY ISFSI
FIGURE 2.6-74
Collapsed fault scarp in alluvium on the Hanning Bay fault, Montague Island, Alaska. The fault dips to the left into the scarp that formed during the 1964 Alaska earthquake (from Plafker and others, 1969).



LITHOLOGIC DESCRIPTIONS
TRINIDAD TRENCH LOGS 11–T2a & 11–T2c

Unit 4: Soil Horizons

A: Dark reddish brown (10 YR 3/3 moist), slightly sticky, slightly plastic, friable sandy loam; weakly developed; fine-crumb ped structure. Contains roots, burrows, and randomly oriented cobbles and pebbles.

B21: Yellowish brown (10 YR 4/6 moist), slightly sticky and plastic, firm sandy loam to sandy clay loam; moderately developed, fine- to medium-crumb ped structure; few roots and burrows.

B22: Yellowish brown (10 YR 4/6 moist), sticky, plastic, firm sandy clay; moderately developed medium-crumb ped structure.

B23: Yellowish brown (10 YR 4/6 moist), sticky, slightly plastic, sandy clay loam, moderately developed, medium-crumb ped structure.

Unit 3: Colluvium

Sand, pebbles, and cobbles in a yellowish brown (10 YR 5/8 moist), clayey silt. Cobbles, ≤ 20 cm, are imbricated.

Unit 2: Marine Terrace Deposits

2a: Boulder and cobble lag
Subrounded boulders and cobbles, ≤ 1.0 m, primarily of Franciscan lithology; pea-sized gravel and minor sand matrix.

2b: Interbedded sand and gravel
Brownish yellow (10 YR 5/8 moist) coarse-grained sand and subrounded to rounded, poorly sorted pebbles in beds 2 cm to 15 cm thick; interbedded with medium-grained, moderately sorted sand in beds 2 cm to 10 cm thick.

2c: Sand
Grayish brown to light olive-brown (2.5 YR 5/3 moist) massive sands in a clayey silt matrix; occasional pebbles; clayey silt decreases below a yellowish red (5 YR 4/8 moist) semi-permeable, 1 to 4 cm thick iron-rich hardpan.

Unit 1: Franciscan Formation Argillite

Dark gray (2.5 YR 4/0 moist); pervasively sheared argillite; 10 cm to 1 m random, well rounded blocks.

EXPLANATION

- Lithologic Contact; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm.
- Soil Contact
- Disturbed Soil Contact
- N75W 60N — Fault; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm; strike and dip of fault plane indicated; arrows indicate sense of relative movement.
- N70W 55N — Strike and Dip of jointing
- Shears

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HUMBOLDT BAY ISFSI
FIGURE 2.6-75

This trench exposure near Trinidad, approximately 36 kilometers north of the ISFSI site, is an example of surface deformation produced by a displacement on a low-angle thrust fault (from Woodward-Clyde Consultants, 1980, Figure B-14). The style of deformation corresponds to Type b on Figure 2.6-73

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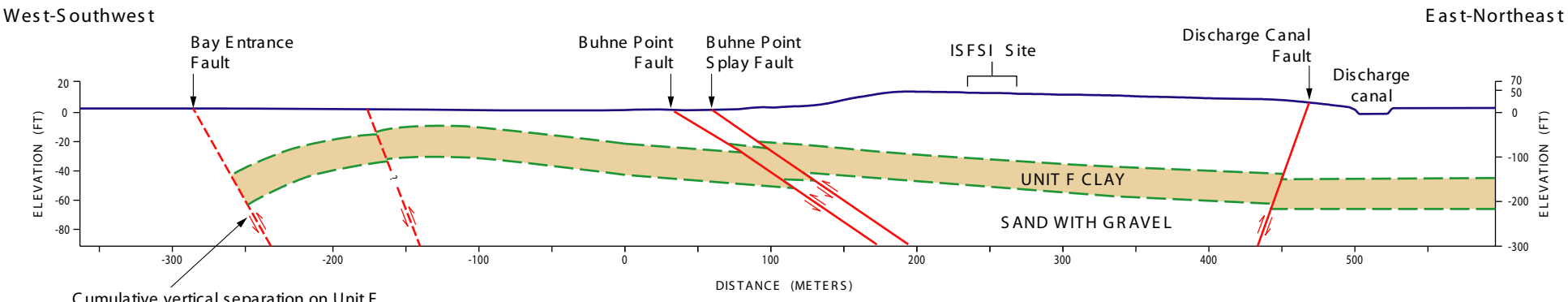
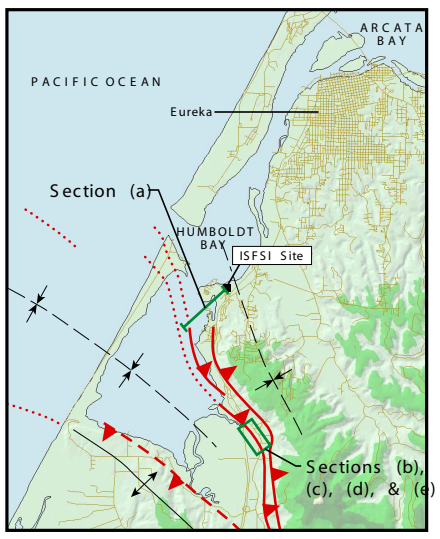
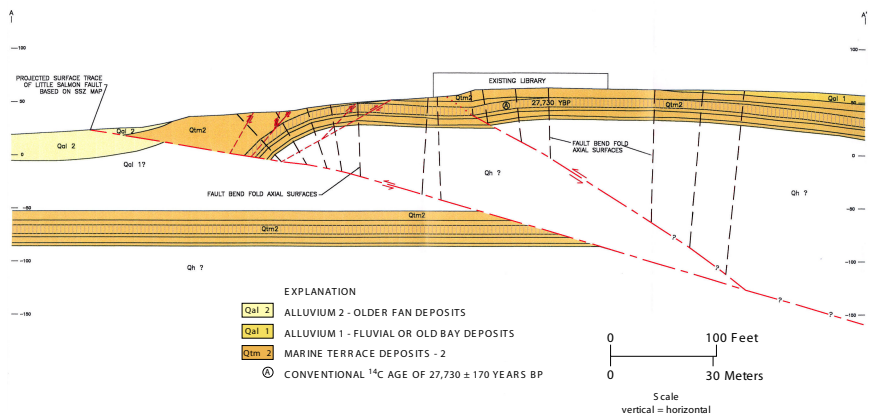
FIGURE 2.6-76
Fault scarp on the Chelungpu fault at the Kuang Fu Middle School, Taiwan. The scarp, formed during the 1999 Chi-Chi earthquake, illustrates the type of faulting in which the fault tip follows the ground surface.

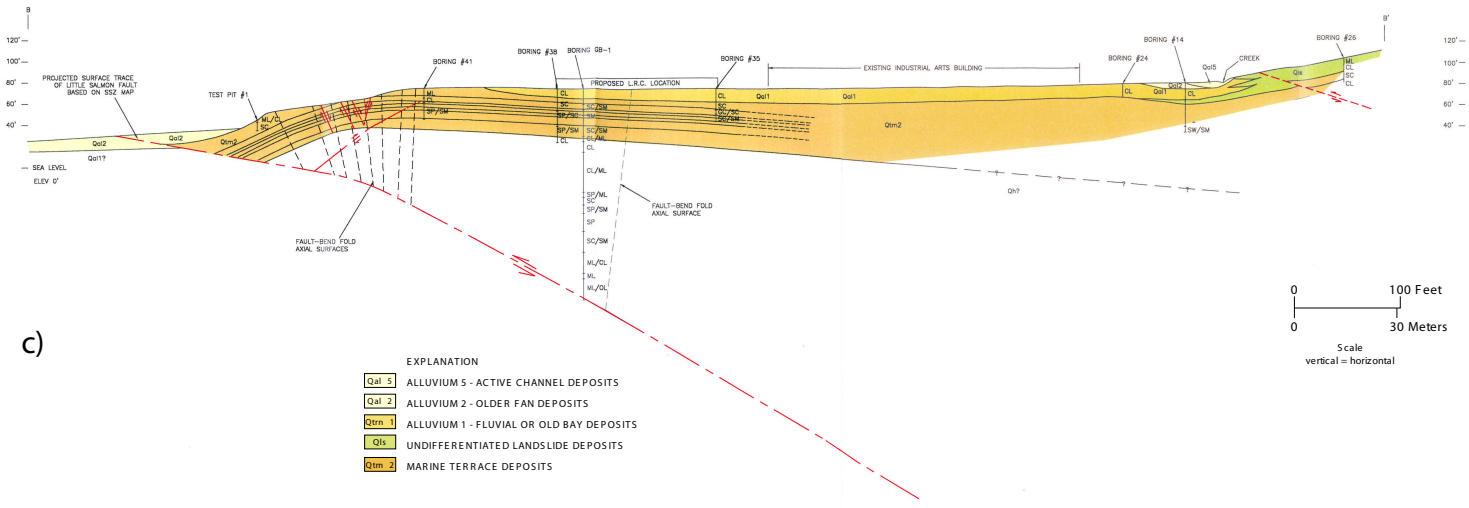


a)

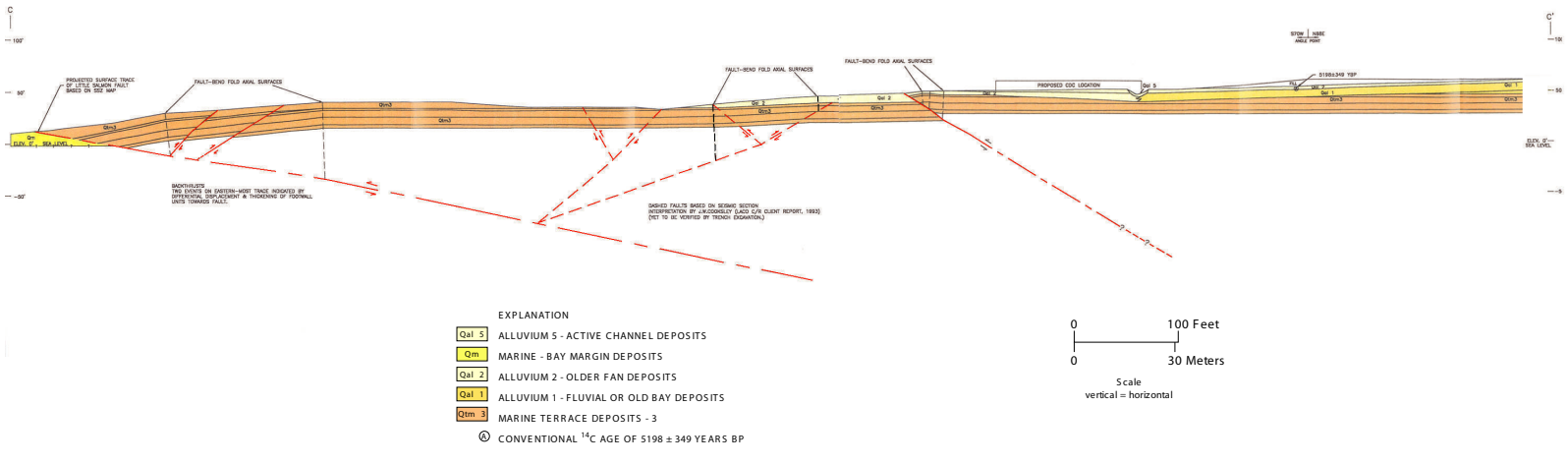




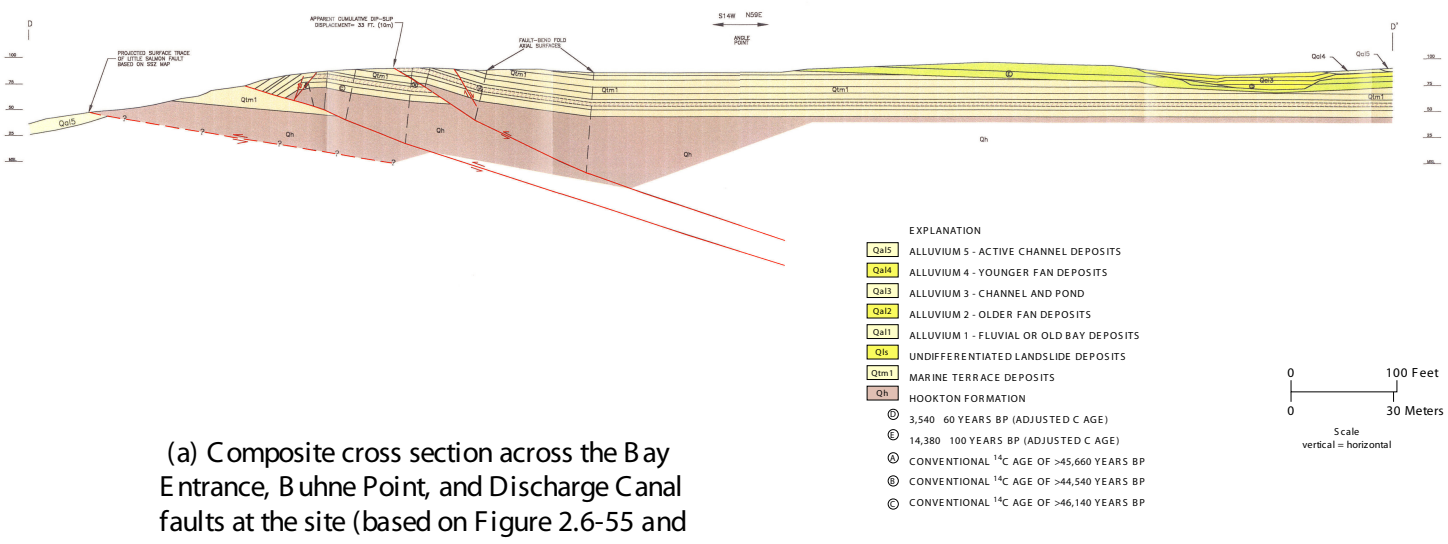
b)



c)



d)



e)

(a) Composite cross section across the Bay Entrance, Buhne Point, and Discharge Canal faults at the site (based on Figure 2.6-55 and Woodward-Clyde Consultants, 1980, Figure C-8).

(b through e) Geologic cross sections across a trace of the Little Salmon fault zone at College of the Redwoods (from LACO Associates, 1999b, Figures 5 through 8, respectively).

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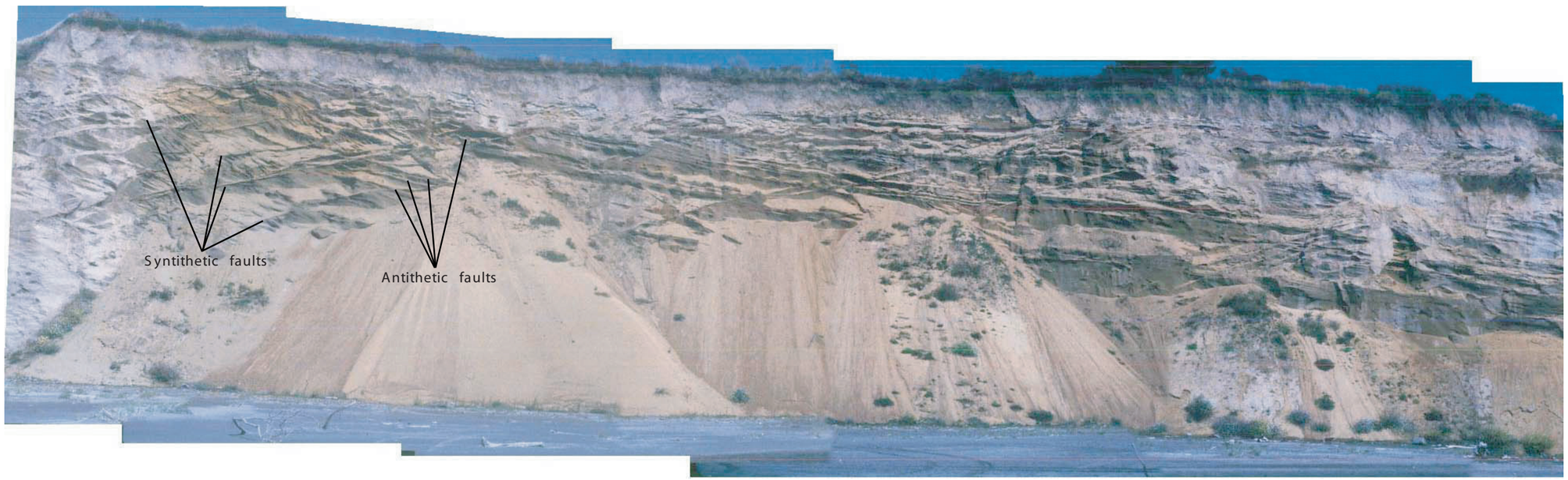
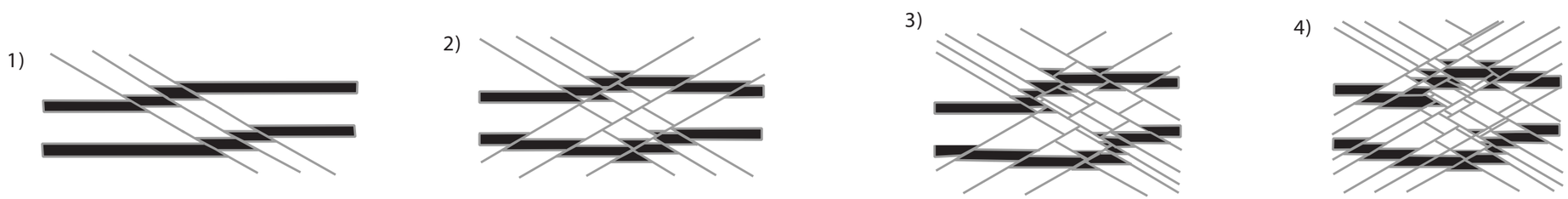
HUMBOLDT BAY ISFSI
FIGURE 2.6-77
Comparison of faulting near the Humboldt Bay ISFSI site with deformation mapped in the hanging wall of the Little Salmon fault zone at College of the Redwoods, about 5 kilometers south of the site.



(a) Complex zones of deformation in the hanging wall of the McKinleyville fault (Mad River fault zone) exposed in the sea cliff at Clam Beach, north of Arcata (photograph by Thomas Dunklin, Arcata, California, 1999). The displacement is up to the northeast. The cliff is about 35 m high, and the photo shows a section about 150 m long.



(b) The evolution of complex zones of deformation is shown sequentially with (1) initiation of faulting and development of synthetic shears and (2) continued deformation and development of antithetic shears. Repeating the process during continued movement (during either the same earthquake or subsequent earthquakes) produces a complex rhombohedral pattern of closely spaced shears (3) and (4) that individually have small displacements, but collectively can accommodate a large amount of crustal shortening.

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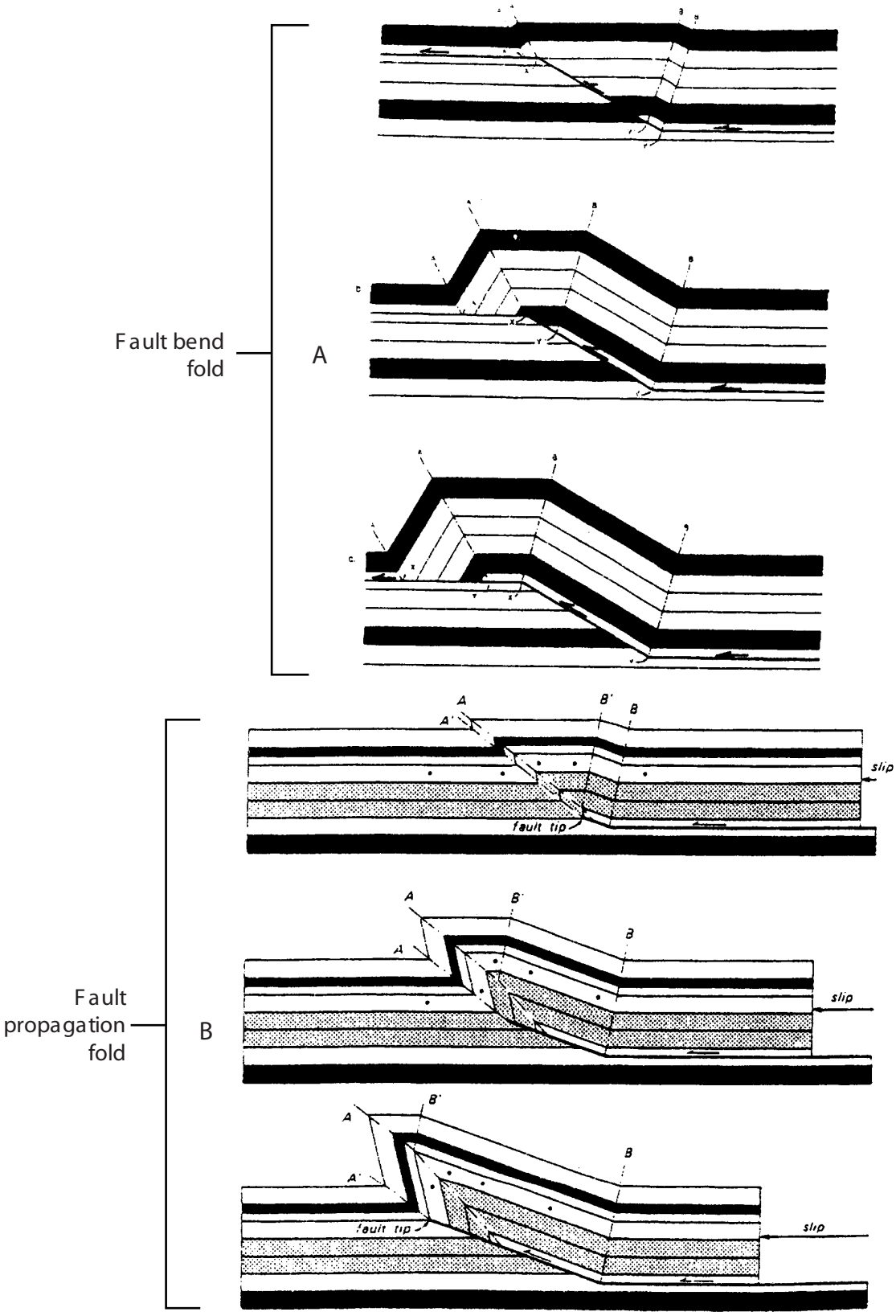
FIGURE 2.6-78 COMPLEX ZONES OF DEFORMATION WHERE CRUSTAL SHORTENING IS ACCOMMODATED BY NUMEROUS SMALL-DISPLACEMENT CONJUGATE FAULTS



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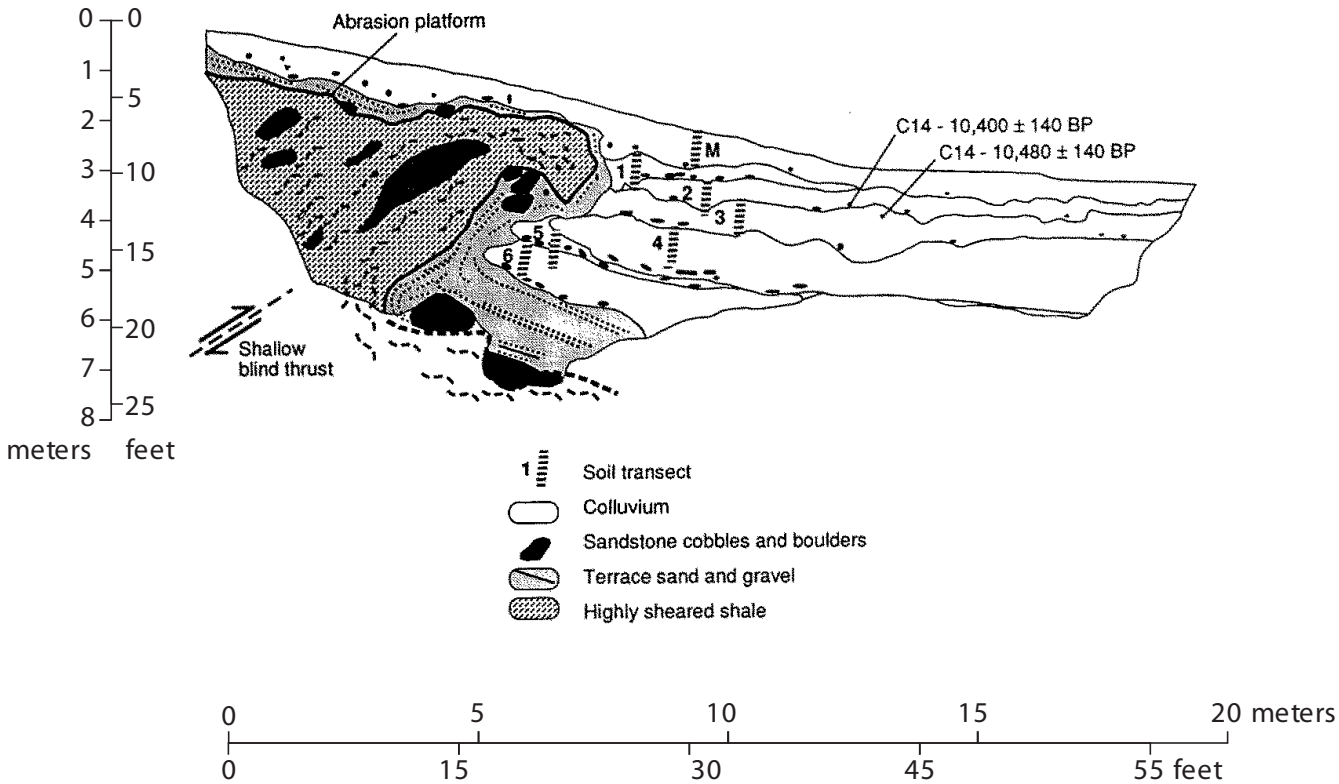
HUMBOLDT BAY ISFSI
FIGURE 2.6-79
Schematic progressive development of fault bend and fault propagation folds (from Suppe, 1983). Folds develop as thrust sheet rides over a step in decollement.



The fault displaces a late Pleistocene marine terrace near Humbolt Bay (from Carver and McCalpin, 1996, Figure 5.13). The terrace deposits are underlain by very ductile, intensely sheared shaley melange. The thrust fault is blind, and displacement occurs at the surface as a sharp, overturned fault-propagation fold. The marine terrace platform (heavy line) and overlying terrace sand and gravel are overturned in the forelimb of the fold. The sequence of colluvial deposits, labeled 1 through 6 (from youngest to oldest), is interpreted to have formed on the scarp face between slip events, indicating there have been repeated surface displacements along this fault trace. The style of deformation corresponds to Type i on Figure 8-1.

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FIGURE 2.6-80 LOG OF TRENCH ACROSS A TRACE OF THE MAD RIVER FAULT ZONE

A) Fault bend fold appears as flexure on the floor of a building destroyed by surface faulting during the 1999 Chi-Chi earthquake.

B) Shears and fractures in wall over the fault bend fold shown above.

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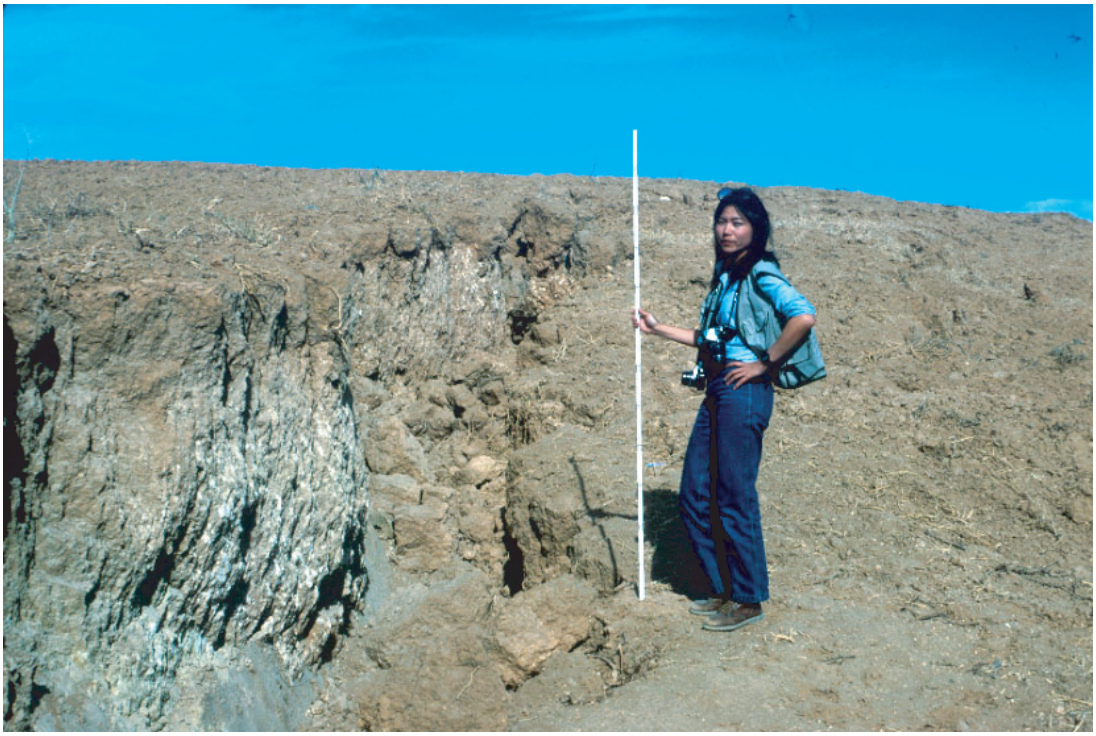
FIGURE 2.6-81 FAULT BEND FOLD AND ASSOCAITED SHEARS AND FRACTURES ON THE CHELUNGPU FAULT, FENGYUAN, TAIWAN

A) Tensional cracks and normal faults that formed in the 1980 El Asnam earthquake along a secondary fault that is about 7 kilometers from the main fault trace (photograph by F. H. Swan).



B) Normal fault scarp in the hanging wall near the same location as above.

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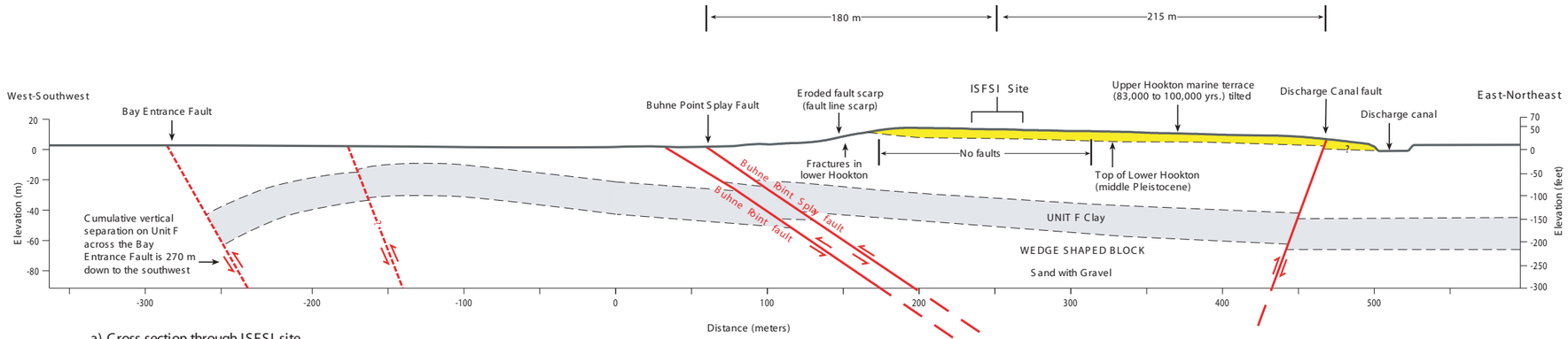
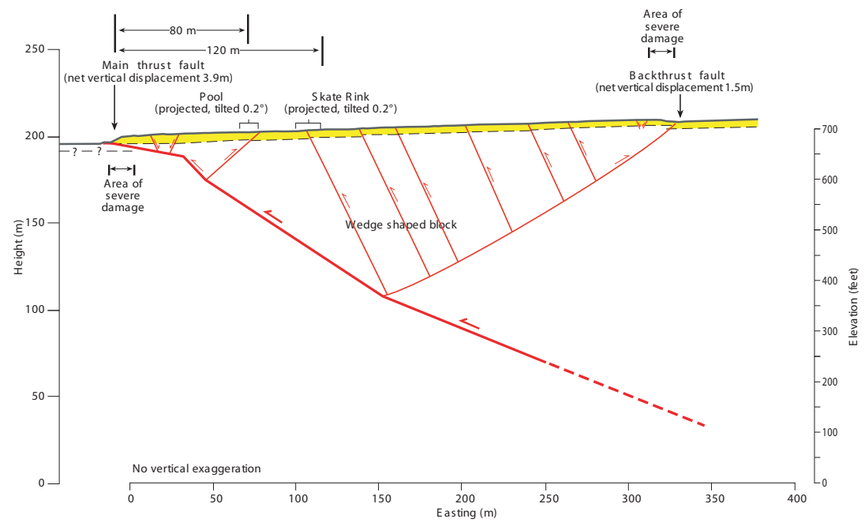
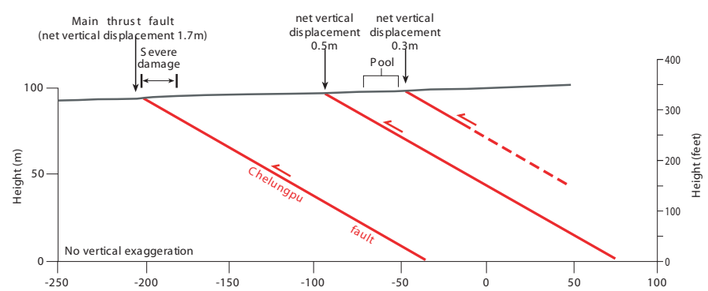
FIGURE 2.6-82 FRACTURES AND FAULTS IN THE HANGING WALL OF THE OUED FODDA FAULT, ALGERIA



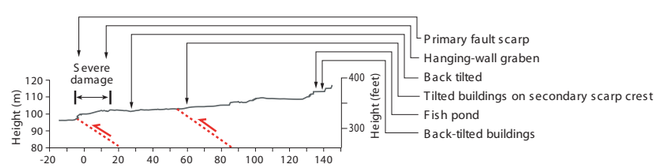
a) Cross section through ISFSI site.



b) Schematic geologic cross section through Chung Chen Park, Taichung, Taiwan showing inferred subsurface configuration of faults based on surface observations. Swimming pool and skate rink projected onto cross section along local structural trends.



c) Topographic profile C-C' across the Chelungpu fault, along the paved road directly north of Kuang Fu Middle School.



d) Topographic profile at Taiwan Studio City, showing locations of tilted fish pond, and other structures.

EXPLANATION

Fault, dashed where inferred; arrows show relative sense of displacement

Lithologic contact, dashed where approximate

0 100 meters

0 500 feet 1000 feet

Vertical = Horizontal

(a) Composite cross section across the Bay Entrance, Buhne Point, and Discharge Canal faults at the site (based on Figure 2.6-55 and Woodward-Clyde Consultants, 1980, Figure C-8).

(b through d) Geologic cross sections across the 1999 Chelungpu fault rupture (from Kelson and others, 2001).

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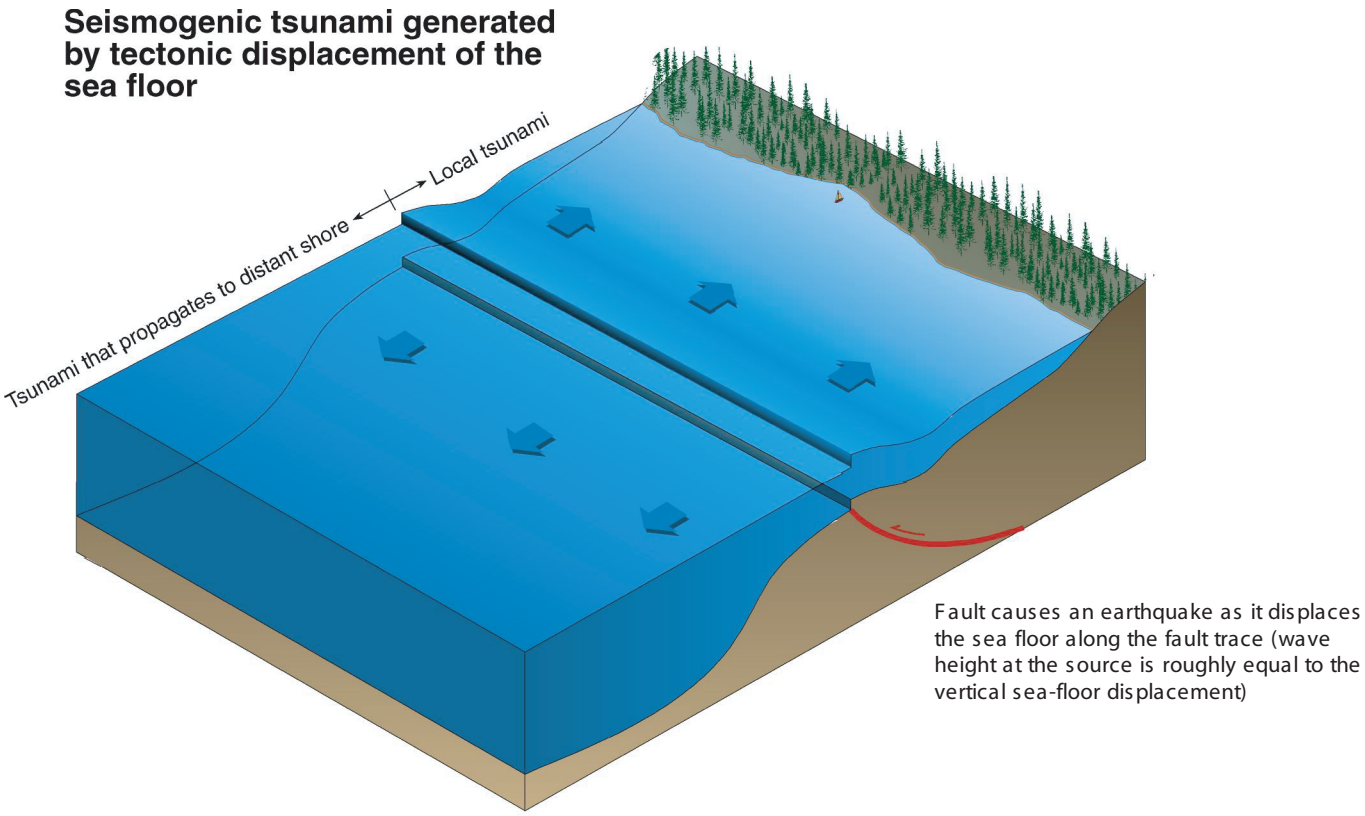
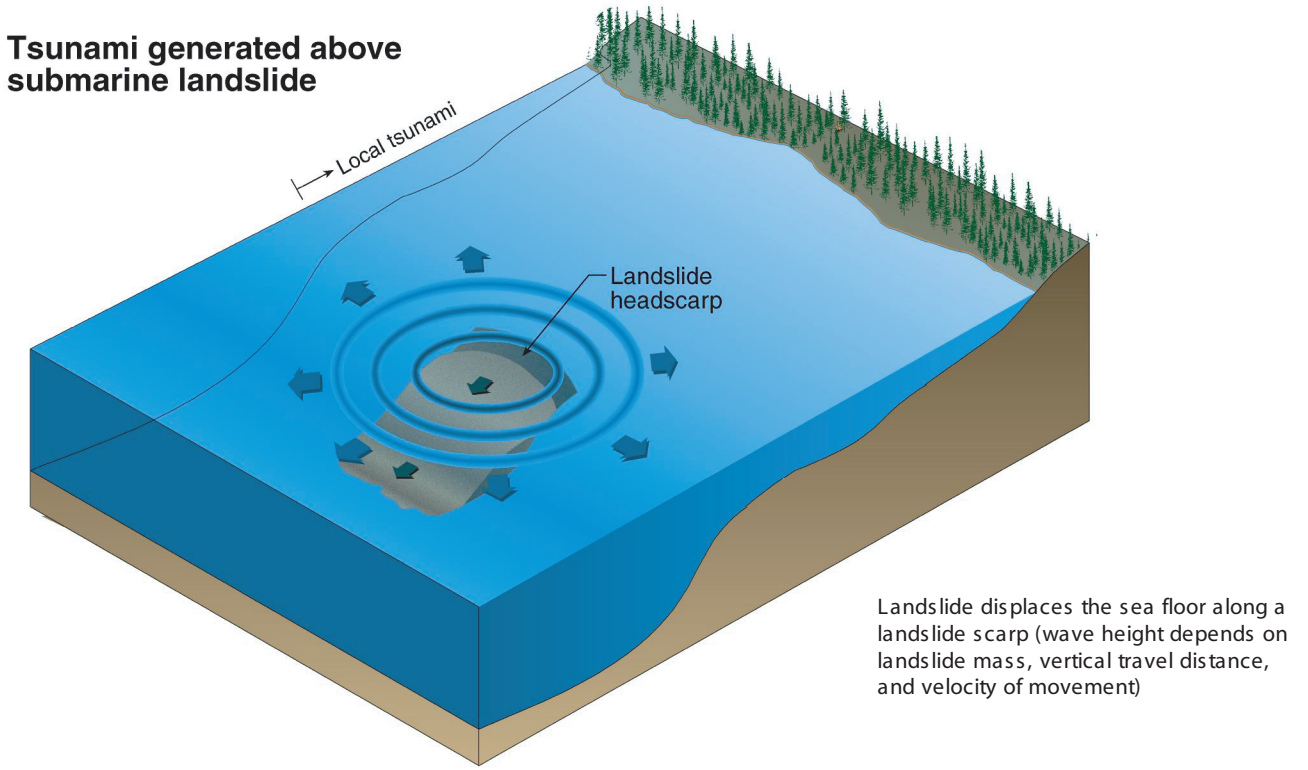
FIGURE 2.6-83
Comparison of faulting near the Humboldt Bay ISFSI site with 1999 surface rupture along the Chelungpu fault, Taiwan.





Vertical scale is greatly exaggerated

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FIGURE 2.6-84 SCHEMATIC DIAGRAMS OF MAJOR TSUNAMI SOURCES

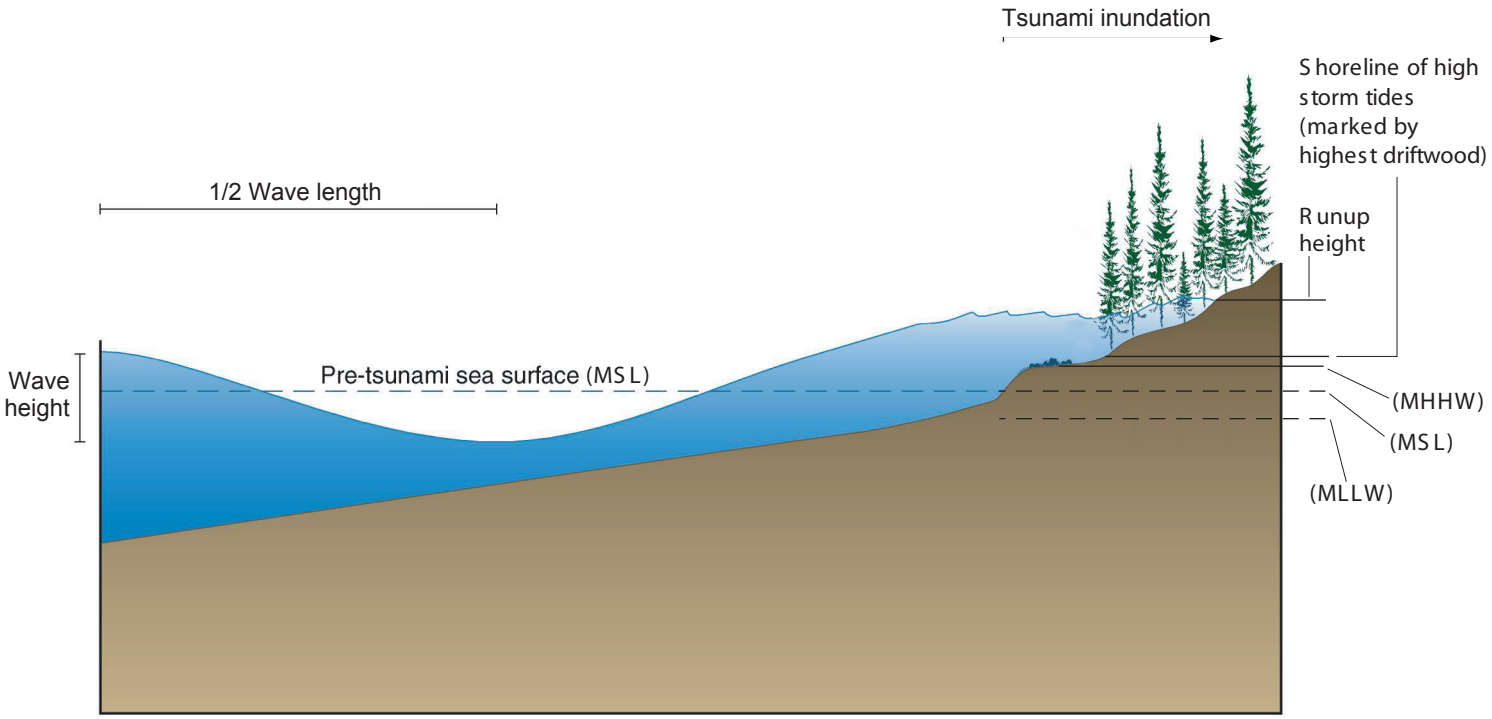

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FIGURE 2.6-85 ILLUSTRATION OF TSUNAMI TERMS

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