

Del Mar Bluffs Geotechnical Study

Part 2: Conceptual Repair Alternatives

prepared for



prepared by



Leighton and Associates, Inc.

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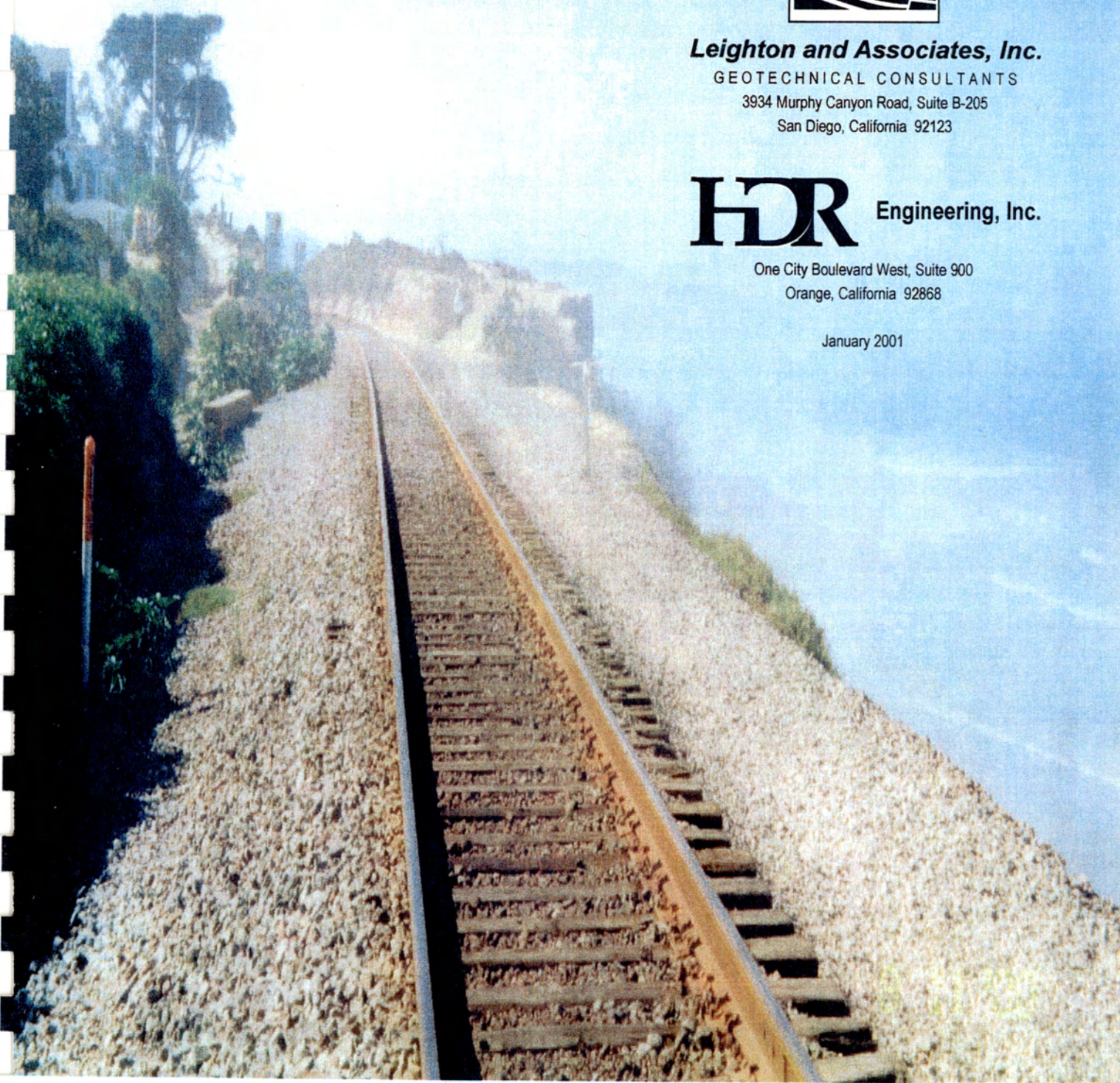
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January 2001





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DEL MAR BLUFFS, GEOTECHNICAL STUDY
DEL MAR, CALIFORNIA
PART II
CONCEPTUAL REPAIR ALTERNATIVES

Project No. 040151-001

January 31, 2001

Prepared For

NORTH COUNTY TRANSIT DISTRICT
810 MISSION AVENUE
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Project No. 040151-001

To: North County Transit District
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Attention: Ms. Leslie Blanda, Manager of Capital Development

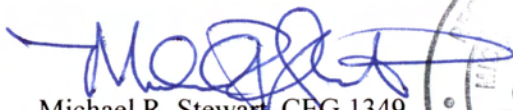
Subject: Del Mar Bluffs, Geotechnical Study, Del Mar, California
Part II - Conceptual Repair Alternatives

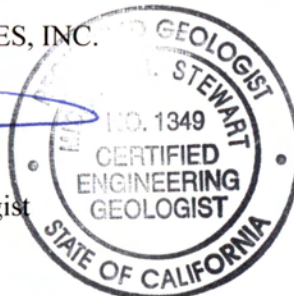
In accordance with your direction and in conjunction with HDR Engineering Incorporated (HDR), this report presents conceptual repair alternatives for consideration at the Del Mar Bluffs in Del Mar, California. In Part No. I of the Del Mar Bluff Study, Leighton and Associates and HDR performed a geotechnical evaluation of the bluffs. That report provides a geotechnical evaluation of the bluffs, includes a general discussion of the site geotechnical conditions, and prioritizes the bluff with respect to risk between Milepost 244.1 and Milepost 245.7. The conceptual alternatives presented herein are intended to provide mid-term maintenance and preservation initiatives (+/- 20 years) to mitigate risk associated with slope instability within the North County Transit District (NCTD) right-of-way along the Del Mar Bluffs.

If you have any questions regarding this report, please do not hesitate to contact this office. We appreciate this opportunity to be of service.

Respectfully submitted,

LEIGHTON AND ASSOCIATES, INC.


Michael R. Stewart, CEG 1349
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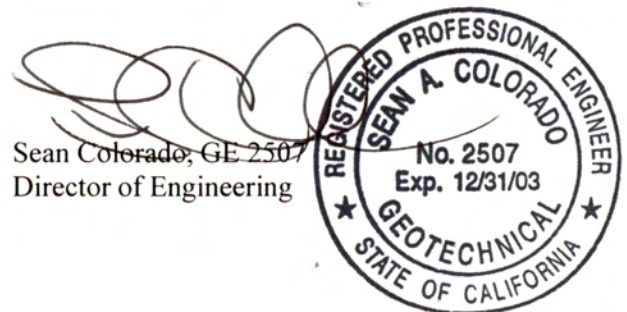


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1.0 EXECUTIVE SUMMARY

This report has been prepared as a supplemental document to the Del Mar Bluffs Geotechnical Study prepared by Leighton and Associates and referenced in Appendix A (Leighton, 2001). That report provides a geotechnical evaluation of the Del Mar Bluffs along the North County Transit District (NCTD) right-of-way between Milepost MP 244.1 and MP 245.7 in the City of Del Mar California. The approximate limits of the study area are indicated on Figure No. 1, Site Location Map (page 3). In addition to a geotechnical evaluation of the bluff, that report provided an evaluation of risk to the railroad and a prioritization of preservation initiatives to mitigate risk associated with loss of track-bed support within the next 20 years. In general, the areas can be divided into areas with needs for drainage improvements, bluff toe protection, and bluff embankment support. The following summarizes our risk prioritization. We have provided discussion that is more detailed beginning on page no. 6.

1. In terms of Drainage Improvements

<u>Priority</u>	<u>Location</u>
High	8 th Street and 11 th Street to Coast Boulevard
Medium	10 th to 11 th Street, 5 th to 7 th Street
Low	Southern Section

2. In terms of Bluff Toe Protection

<u>Priority</u>	<u>Location</u>
High	7 th to 8 th Street and 11 th Street to MP 244.2
Medium	MP 245.16 to MP 245.37
Low	Center Section, High Cliffs

3. In terms of Bluff Stability Improvement (static conditions)

<u>Priority</u>	<u>Location</u>
High	7 th to 8 th Street and 11 th Street to MP 244.2
Medium	5 th to 6 th Street
Low	High Cliffs and South Section

4. In terms of Bluff Stability Improvement (seismic and hydrostatic conditions)

<u>Priority</u>	<u>Location</u>
High	All areas



The purpose of this report is to provide alternatives for selection of mid-term measures to mitigate risk associated with slope instability that could compromise the rail alignment. For the purpose of this report, mid-term is considered to be approximately 20 years.

To aid in the selection process, a summary of all the alternatives and a ranking based on a variety of conditions is included as Appendix C. We anticipate that the actual selection of an alternative will be based on a variety of issues that include factors other than solely geotechnical considerations. These include environmental considerations, the ease of permitting, cost, and whether the work can be performed within the NCTD right-of-way. The selected alternatives will likely include a combination of repair methods. In summary, the alternatives generally focus on controlling erosion and improving the stability of the bluffs. Measures discussed to control erosion include retaining structures, revetments, surface and subsurface drainage, and beach nourishment. Stability of the bluffs can be improved by the construction of retaining structures or buttress-type embankments reducing ground water flows, controlling seepage, reducing loads on the slope, and a general flattening or stabilization of the slope face.

The alternatives presented in this report are conceptual in nature and not considered site specific. Additional site investigation and design development will be required to implement the selected alternatives.



2.0 DISCUSSION

In accordance with the direction of HDR and NCTD, this report presents conceptual measures that may be considered for mitigation of the geologic factors that contribute to bluff instability and retreat. Our previous geotechnical evaluation (Part I) was performed to assess the risk posed to the railway as a result of existing site conditions. The factors included in the risk prioritization included such factors as the height of the bluff, the proximity of the track to the top of bluff, groundwater seepage, the various geologic units, rates of bluff retreat, the presence of existing failures and also the presence of existing stabilization devices and drainage improvements. While not directly incorporated in the risk matrix, the calculated factor of safety to resist deep-seated instability was compared to the risks determined for the year 2000 matrix. For convenience, a copy of the present (year 2000) and the year 2020, risk matrices and maps from our previous report are included within this report as Appendix B. The focus of this report is to provide conceptual repair and maintenance alternatives for consideration.

In order to prepare a matrix of the various repair alternatives, it is important to understand some of the various factors that influence the stability of the bluffs supporting the rail alignment. Concerning bluff retreat, we have determined that there is a relatively low rate of annual bluff retreat. This was based on both historical data and geologic conditions along the base of the bluff that help to minimize the effects of marine erosion. Bluff retreat is partially controlled by both localized and episodic events. For example, an area could experience negligible bluff retreat in a 40-year period, followed by loss of several feet as a result of one severe storm with a large swell and surf that occurs at a high tide. While the erosion that can occur in a single storm may be significant, the annualized rate of erosion would be very low for the example presented. Although we recognize episodic failure will cause retreat rates to vary significantly from year to year, we have performed our analysis based on annualized rates.

In the northern portion of the bluff, approximately 625 feet of the bluff has shoreline protection installed at the base of the bluff. This protection includes both wooden and concrete sea walls with some riprap in areas. Where these improvements exist, review of the location of the bluff toe and track-bed support line indicates that in most of these areas track-bed lateral support is already at a minimum. Therefore, any additional erosion in this area could impact the rail support. In addition, most of these protective structures are old, are typically under-designed, and will require ongoing maintenance or improvements to function effectively. For these reasons, these structures have been considered to be ineffective for the protection. The following illustrates the existing structures and their construction dates:



Table 1 Bluff Structures and Construction Dates			
Mile Post	Street	Type of structure	Year built
244.32	13th Street	Timber R. Wall at toe	1966
244.33	13 th Street	Soldier Piles	1978
244.44	12th Street	Concrete R. Wall at top	1910
244.47	11.5 Street	Concrete R. Wall at top	1910
244.47	11.5 Street	Timber R. Wall at toe	1964
244.75	7.5 Street	Concrete R. Wall at top	1906
244.8	7.5 Street	Timber R. Wall at toe	1977
244.8	7th Street	Soldier Piles	1978
245.16	Stratford Court	Concrete R. Wall at toe	1910 & 41
245.4	And. Canyon	Concrete R. Wall at toe	1910 & 41

Water is one of the major factors that contributes to the overall weakening of the bluff and the abundance of observable failures. This includes both surface and subsurface water. Many drainage improvements have been previously made such as the installation of subdrains, storm drains and lined drainage ditches, and improved surface drainage; however, water both surface and subsurface contributes to the deterioration of the bluff. Therefore, the control of water is a major consideration in the selection of repair and maintenance measures.

Localized erosional areas, the result of storm drain discharge and pedestrian traffic exist along the alignment. If allowed to increase in severity, these areas could locally impact the rail operation if not mitigated. Major erosional features are located at MP 244.1, MP 244.47, MP 244.7, MP 244.76, and MP 244.9.

While the overall inclination (steepness) from the tracks to the base of the bluff is a good indication of the overall stability, other factors such as over-steepened areas may be indicative of an area that is more prone to instability. The approximate location of the major over-steepened areas are summarized on the risk matrices (Appendix B). The most significant over-steepened area is located at MP 244.46. In addition, while the bluff retreat rates are relatively low, the typical method of failure for the upper portions of the bluff is a localized block fall that may include several feet of retreat in one event. Therefore, the presence of over-steepened areas, especially when combined with other adverse conditions, is a condition worthy of close scrutiny.



3.0 SUMMARY OF RISK ASSESSMENT

This section presents a summary of risk as presented in Part I of the Del Mar Bluffs Geotechnical Evaluation (Leighton, 2001). Our risk assessment matrices from that report are reproduced in Appendix B as Table 10 for the year 2000 and as Table 11 for the year 2020. In order to prepare the matrix, we selected 28 locations along the alignment and ranked each site on the factors described above. In addition, we reviewed the areas where slope stability analyses were performed and compared the calculated factor of safety to the assigned risk. Factor of safety was not a criteria utilized in our risk matrix because slope stability analyses were performed on only selected cross-sections which may not be representative of an entire section of bluff. In our opinion the slope height, setback from rail, and the projection from the track to toe (track-bed support line) incorporate aspects of the slope stability concerns into the matrix.

The 28 "risk matrix sites" we utilized are shown on Plate No's. 1 through 5, Site Plan and Geologic Maps. For each identified condition, we have ranked the sites on a 1 to 5 basis, with 5 having the highest risk. We have then totaled the scores for all of the sites with the highest scores indicating the areas of highest risk. Finally, based on our knowledge of the site conditions we have defined the limits of the areas that are representative of each risk and included those limits on the geotechnical maps. The areas with the highest risk are therefore the sites most likely to be impacted within the 20-year time frame considered in this study.

A summary of the entire alignment is presented below with the lateral limits shown on the Site Plans and Geotechnical Maps. For convenience a reduced copy of the maps is included as Appendix B.

3.1 Year 2000 Area-by-Area Review

Area from MP 244.10 to 244.19

Risk Priority	Low
Risk Matrix Sites Included:	1
Cross-Sections Included:	None
Slope Stability Analyses Included:	None

This area is generally low risk priority due to the wide distance from the track to the bluff top. In addition, the area provides adequate track bed support. Seepage is minor and foot traffic on the bluff face does not occur. Localized areas of ponding and poor surface drainage are present. A storm drain outlet at the north end is causing some accelerated erosion.



Area from MP 244.19 to 244.43

Risk Priority	High
Risk Matrix Sites Included:	2, 3, 4, 5, 6 and 7
Cross-Sections Included:	J-J', K-K', I-I', Q-Q', T-T', R-R' and S-S'
Slope Stability Analyses Included:	J-J', K-K', Q-Q', R-R' and S-S'

This area is high risk due to the proximity of the bluff top to the existing track, as little as 10 feet. Over-steepening occurs in several areas. The track-bed support line extends beyond the toe of the bluff. Seepage is generally moderate and slope failures have previously occurred in the area. A major top of slope wall and subdrain system are present in the southern portion. There does not appear to be adequate lateral support for the top of slope wall foundation. Additional borings should be included in this area as part of future studies.

Area from MP 244.43 to 244.46

Risk Priority	Medium
Risk Matrix Sites Included:	8
Cross-Sections Included:	P-P' and V-V'
Slope Stability Analyses Included:	None

This area is medium risk as there is only 10 feet between the tracks and the bluff top. The geologic unit is artificial fill (sand-cement), which increases the surficial stability, and measures appear to have been effective in reducing erosion on this steep slope. In addition, no seepage, foot traffic or existing bluff failures occur on the bluff face. The site of past failures, this section has been downgraded to medium risk because of the construction of a sand-cement buttress that has performed well to date. The track-bed support line extends beyond the toe of slope. The toe of slope protection was not upgraded with the recent buttress construction.

Area from MP 244.46 to 244.51

Risk Priority	High
Risk Matrix Sites Included:	9
Cross-Sections Included:	H-H'
Slope Stability Analyses Included:	H-H'

This area is high risk due to the presence of existing slope failures and over-steepened areas. Seepage and foot traffic are heavy in this area. This is also a major pedestrian access area. The track-bed support line extends beyond the toe. MP 244.47 has the highest total risk of all the sites due to the aforementioned conditions.

Area from MP 244.51 to 244.69 (High Bluff Area)

Risk Priority	Medium
Risk Matrix Sites Included:	10, 11 and 12
Cross-Sections Included:	L-L', G-G''
Slope Stability Analyses Included:	L-L'

This area is overall medium risk due to adequate setback from the top of bluff to the tracks. Over-steepening and moderate seepage occur on the bluff face. Potentially a high-risk area, the general 70-foot track to bluff top increases stability of track bed. The track-bed support line is generally behind the toe of slope. The high bluff has over-steepened areas and seepage zones. Block falls are



anticipated but, not expected to impact rail operations due to setbacks. Water ponds along the tracks from runoff and storm drain discharge.

Area from MP 244.69 to 244.8

Risk Priority	High
Risk Matrix Sites Included:	13, 14, and 15
Cross-Sections Included:	U-U', F-F, and M-M'
Slope Stability Analyses Included:	F-F and M-M'

This area is high-risk due to heavy seepage on the bluff face and storm drain discharge on the top of bluff at the northerly end. Moving southerly to MP 244.76, seepage ends, but the track-bed support line protrudes beyond the toe, maintaining high risk. Major erosion occurs at the undersized storm drain outlet (MP 244.7). Previous failures in this area have been repaired. A soldier pile wall is present in southern section from the 1978 repair and some toe protection exists on the beach.

Area from MP 244.8 to 244.89

Risk Priority	Medium
Risk Matrix Sites Included:	16 and 17
Cross-Sections Included:	E-E'
Slope Stability Analyses Included:	None

This area is medium risk. The track-bed support line extends behind the toe. The area is not over-steepened, seepage does not occur and foot traffic is moderate. This section has adequate track to top distance and adequate track bed support.

Area from MP 244.89 to 244.92

Risk Priority	Medium
Risk Matrix Sites Included:	18
Cross-Sections Included:	None
Slope Stability Analyses Included:	None

This area is medium risk due to the presence of a large erosional gully resulting from removal of a storm drain. The area near the tracks has been backfilled. Over-steepening is moderate and seepage and foot traffic are minor. The track-bed support line is behind toe of bluff; however, a large eroded area reduces lateral support and is of higher priority.



Area from MP 244.92 to 245.21

Risk Priority	Medium
Risk Matrix Sites Included:	19, 20, 21, 22 and 23
Cross-Sections Included:	D-D' and C-C'
Slope Stability Analyses Included:	D-D'

This area is medium risk due to moderate over-steepening of the bluff face. The track to bluff top distance ranges from 150 feet to 105 feet. The track-bed support line is well behind toe of slope. Seepage is minor (possibly due to past drainage improvements) and foot traffic is absent. It should be noted that in the northerly and southerly ends of the area the slope to the east of the tracks presents some risk, even though it is excluded from this study. A ± 10 foot wall at storm drain outlet MP 256.16 protects the fill area from erosion. The wall has performed well-to-date but, on-going maintenance is critical

Area from MP 245.21 to 245.37

Risk Priority	High
Risk Matrix Sites Included:	24 and 25
Cross-Sections Included:	B-B', N-N' and A-A'
Slope Stability Analyses Included:	N-N'

This area is high risk due to moderate over-steepening of the bluff face and the close proximity of the track to the top of the bluff. The projection of the track-bed support line extends beyond the toe of the bluff. In addition, the track to top of bluff distance decreases to 15 feet in the southerly end of this area. Seepage is minor and foot traffic and bluff face over-steepening are generally moderate. Again, a major wall protects the fill area at Anderson Canyon from erosion. The wall has performed well but its maintenance is critical.

Area from MP 245.37 to 245.70

Risk Priority	Low
Risk Matrix Sites Included:	26, 27 and 28
Cross-Sections Included:	O-O'
Slope Stability Analyses Included:	None

This area is low risk due to several factors including: slightly lower bluff heights and neither significant seepage nor foot traffic are present below the tracks. Seepage from the bluffs above the tracks requires mitigation to keep the track bed from being saturated. Minor over-steepening of the bluff face is present and the area has an average track to top of bluff distance of 45 feet. The track-bed support line is well behind toe of slope.



4.0 TRACK-BED SUPPORT

The "Track Bed Support Line" shown on Figure No. 2 is a typical detail which identifies the minimum amount of foundation material required to support the railroad bed without unusual geotechnical conditions (e.g. groundwater seismic loading). This line varies somewhat depending on the nature of the material exposed on the bluff face but in general provides a very good illustration of the areas of the bluff that are in critical need of additional support. We have plotted this line on the site plans and geologic maps to show areas where the track-bed support line is outside the toe and where additional lateral support of the toe is most critical. Similar consideration regarding the top of slope setback is also needed and segments closer than 20 feet to the top of slope are in need of stabilization measures in the upper portions of the bluff to mitigate local instability, and to provide for maintenance and emergency response access.

In addition, because we are examining a 20 year preservation plan, we have anticipated some additional bluff retreat (10 feet) to take place over the next 20 years. The projection from track to toe as shown on Appendix B the risk matrix also illustrates this condition.

The following table illustrates the locations of the bluff where the track bed support line is already beyond the bluff toe and areas where it is projected to be beyond the bluff toe in the year 2020.

Table 2 Track Bed Support Line Summary By Milepost (Length of Bluff Face Where the Track Bed Support Line Falls Beyond the Toe of the Bluff)			
Milepost in Year 2000	Length Along the Bluffs Where the Track Bed Support Line Falls Outside of the bluff Face in 2000	Milepost in Year 2020	Length Along the Bluffs Where the Track Bed Support Line Falls Outside of the bluff Face in 2020
244.19 to 244.50	1,040 feet	244.18 to 244.55	1,955 feet
244.71 to 244.79	20 feet	244.56 to 244.62	315 feet
244.80 to 244.81	55 feet	244.69 to 244.81	635 feet
245.20 to 245.27	370 feet	245.04 to 245.05	55 feet
245.29 to 245.38	475 feet	245.13 to 245.14	55 feet
		245.15 to 245.39	1,270 feet
Total	2,960	Total	4,285

As shown on the above table, there is approximately 3000 linear feet of the bluff that are in need of mitigative measures at the present time. With additional erosion and bluff retreat this is projected to increase to nearly 4300 linear feet by the year 2020.



5.0 RISK MANAGEMENT OPTIONS

The methods of stabilization as presented in this report are, as directed by NCTD, conceptual in nature, and are not specified to any particular segment of the rail alignment. As such, some of the stabilization methods presented for consideration are not suitable for all sites. In addition, some of the methods can be accomplished within the NCTD right of way, while others may not. Repairs undertaken outside of the ROW will require a longer and more difficult permitting period. In addition, some of the recommendations will offer a higher confidence level.

The options presented herein include a do nothing approach, recommendations for periodic monitoring, maintenance and repair of existing facilities, stabilization at the bluff toe, stabilization of the bluff face, stabilization of the bluff top, drainage improvements, and groundwater reduction. In our opinion, final selection of alternatives should include a combination of the methods. Each of the options/recommendations is discussed below:

5.1 Status Quo

Maintaining the status quo, the do nothing approach, is a seemingly inexpensive alternative. However, the potential for increased erosion and bluff failure is high. The costs also increase when one considers the potential for an interruption in service and possible emergency repairs. In addition, the potential for a prolonged disruption in service is high. This is a High Risk alternative.

5.2 Periodic Monitoring

It is our understanding that regular monitoring of the rail alignment is performed by railroad personnel. However, we strongly suggest that because of the close proximity of the rail to the bluff top, that periodic monitoring by a geotechnical professional be performed. This report and the accompanying geotechnical report (Leighton, 2001), will provide a good basis from which to compare changes in site conditions and the installation of a series of survey monuments to allow for more frequent field measurements in selected areas. Additional inspections are also recommended after periods of heavy rainfall, high storm surf, and or seismic events. The recommended monitoring should be performed at least annually and include some photo documentation of site conditions. We would suggest that monitoring be performed in conjunction with whichever alternatives are selected.

In addition to regular monitoring, an action plan should be developed in order to respond if the need for immediate action is determined. In most cases, the threat of failure should be cause to implement the action plan rather than to wait for a failure to occur. The plan should include appropriate lines of communication, permit and budget considerations.

Consideration should also be given to installation of a remote monitoring system along the rail alignment that would trip the rail signals to stop trains in the event of major soil movement resulting from landslides or seismic events.



5.3 Repair of Existing Facilities

A number of existing facilities exist at the site that are in need of ongoing repair and or maintenance. These include the existing sea walls in the northern and southern bluff sections. Wooden sea walls in the northern section are located in areas where the setback of the rails to the bluff toe (Track-Bed Support Line) are already less than minimum distances. With the wall in place and performing effectively, additional erosion and slope retreat due to average waves is unlikely; however, the loss of these walls would likely result in increased erosion and pose a threat to the rail alignment in these areas.

Other sea walls include concrete walls that have generally been constructed across existing fill areas such as at MP 245.16 and at Anderson Canyon (MP 245.36) and at various other storm drain headwalls. These walls are performing adequately but should be evaluated for cracks and deterioration. These walls should be evaluated annually and repaired as necessary. These walls are of special importance because in most of the study area, the base of the bluff is comprised of a dense resistant bedrock unit that acts as a barrier to erosion. However, the major walls (MP 245.16 and MP 245.36) support fill soils and the resistant bedrock base is not present in these areas. The fill soils would be easily eroded if these walls were to be compromised. Given the close proximity of the walls to the rail lines they support, they represent critical structures that need to be maintained.

Other facilities that need ongoing maintenance include the storm drain facilities on the bluff top and face such as the storm drain at 8th street and the outlet point at MP 244.7. According to the 1993 Del Mar Drainage Study by Fraser Engineering, this drain is undersized and may not accommodate peak flows. In several locations, these drains were observed to be leaking and causing surface erosion and an infiltration of water into the underlying soils. In addition, several of the headwalls are severely distressed and in need of repair. Proper maintenance of the existing storm drains will contribute to the improved stability of the existing slopes.

Also present are a system of subdrains apparently installed in 1941 and partially repaired in 1978. In the southern portion of the bluff the drain outlets discharge over the top of the bluff causing additional erosion (MP 244.97). The drains (in the south) appear to be working to reduce ground water seepage as a large volume of water is being discharged and evidence of seepage is significantly less than in the north. Some of the subdrains in the north appear to not be working as seepage is common and ponding of water occurs in areas where subdrains are thought to exist (MP 244.15). A series of subdrains has also been installed behind the top of slope wall at MP 244.4. Other drains in the northern section may locally be functioning. Discharge that may be from subdrains can be observed at MP 244.1 and MP 244.4. While these drains appear to be reducing the amount of observed seepage somewhat, heavy seepage is still presented in the area. Recommendations for control of surface and subsurface water are presented in the later sections of this report.

5.4 Stabilization at Bluff Toe

Stabilization at the bluff toe should be considered in areas where the risk levels are medium to high due in part to the close proximity of the rail to the bluff toe and areas where the track-bed support line is at or beyond the bluff toe. In areas where increased erosion could result in significant damage (where more erodible materials exist, such as compacted fill soils), stabilization at the toe should be considered. Stabilization measures at the bluff toe can serve to preserve or increase lateral support.



Methods for stabilization include wooden and concrete sea walls, steel piles and wood lagging walls, sand cement revetment, rock revetments, and beach replenishment.

Bluff toe stabilization can also be achieved by construction of a sand cement buttress/revetment at the toe. The sand cement mixture can be colored to resemble the natural bluffs and may be designed with compressive strengths that mirror the denser portions of the onsite bedrock. This would result in erosion rates that would be similar to the dense onsite materials. The height of such a repair should extend above the design wave run-up height.

Details for sea wall construction are presented as Figure No. 3, rock revetment details are shown as Figure No. 4, and beach replenishment as Figure No. 5. The sea wall that is generally considered a permanent structure is typically constructed of wood or concrete with foundations extending below the sand base and beyond the influence of marine erosional forces. In addition to mitigating toe erosion, the sea wall also acts as a retaining wall supporting the material above. Where walls are proposed, additional investigation to evaluate the foundation materials in the area of the wall will be required. The rock revetment consists of a large rock essentially piled as a berm along the base of the bluff. The rock is typically installed on a geosynthetic fabric underlayment, controlling the slope erosion by dissipating wave energy. Rock revetments will typically require some maintenance after installation, but are often also considered a permanent structure. Typically, both sea walls (wood and concrete) will last in excess of the 20-year preservation period. A rock revetment can also be maintained over this time period. The soil cement alternative will erode slowly and also provide a limited sand supply to the beach area.

The third method of bluff toe stabilization would be to protect the bluff from additional erosion by beach replenishment. This could be accomplished by importing sand from an outside source or generating sand on site to place along the base of the bluff. Use of import sand may be more easily approved if the sand resembles beach sand. Portions of the onsite bluff materials may also be used for beach nourishment as they likely meet the grain size analyses required for beach sand. In addition, the erosion of bluff is a natural source of sand for beach replenishment. Because of the reddish color of the onsite sandy soils, there would likely be public opposition, but the natural wave action would eventually cleanse the material. Beach replenishment is considered a temporary alternative and may only provide support for a relatively short period of time. One method to retain sand on the beach for longer periods of time would be to install a sand-filled geosynthetic fabric tube (longard tube) that would act as a retention device. A typical detail as presented by the Army Corps of Engineers (USCOE, 1995), is presented as Figure No. 6.

We note that stabilization at the bluff toe is intended to reduce the potential for additional erosion. Because of the typical heights of the bluff this will not stabilize the entire bluff or even halt the retreat of the upper portion of the bluff. Toe protection, if utilized, would need to extend a significant distance above the toe to aid in support of the entire bluff. In general, toe protection will be needed in combination with other stabilization alternatives.

5.5 Stabilization of Bluff Face

In areas where the tracks do not have adequate lateral support as indicated by the "Track-Bed Support Line" shown on Figure No. 2, stabilization of the bluff face should be considered. As a reminder, this reference line is established as a 1.5:1 (horizontal to vertical) projection from the track area. Stabilization of the bluff face can be considered where adequate lateral support is not currently



present, or where additional erosion or failures will move the bluff face landward of the "Track-Bed Support Line or within 20 feet of the from tracks the top of slope." The areas where adequate lateral support do not exist are shown on the geotechnical maps and are summarized in Section 4.0 of this report.

Slope grading can be performed to stabilize the bluff and re-establish eroded and failed areas, as was done previously at several locations within the study area, most recently just north of the terminus of 11th Street (MP 244.5). This repair which has performed well to date consisted of a sand-cement buttress fill that is mantled by a thin veneer of native soils for plant growth. The native soils are supported on the steep slope by a series of buried pipe and board retaining walls. The revegetation of this slope has been only marginally successful with plants only starting to grow on the flatter slope areas. Future slope grading should address these types of landscaping issues in order to minimize slope erosion. A variable slope gradient with native species planted on flatter areas of the upper bluff face with low level irrigation, such as drip irrigation pipe system should be considered for the time required to establish growth.

Slope grading would generally consist of the placement of compacted fill soils on the face of the slope to provide additional lateral support, flatten localized over-steepened areas, and allow for the removal of existing slope failures. Typical grading would start by establishing a key at the base of the area to be filled that extends into competent material. A subdrain could be placed at the back of the key to minimize future groundwater accumulation and at selected higher elevations during the site grading. The slope area could then be extended by fill placed in compacted lifts to the design grades. Prior to, or as part of fill placement, existing failures on the bluff face could be removed and replaced with compacted fill soils.

A typical fill slope would be constructed at a 2 to 1 (horizontal to vertical) inclination with fill soils compacted to 90 percent relative compaction as determined by ASTM D1557. With some of the constraints of the site, steeper slopes may be desirable in order to maintain existing beach widths or to minimize grading. Steeper slopes can be constructed by the incorporation of geogrid reinforcement into the compacted fill soils or by the use of a soil-cement mixture. Where soil cement mixtures are utilized, the soil cement should extend above the wave run-up level calculated for a particular site. With these options, slopes may be constructed at inclinations as steep as 1 to 1 for a general slope and possibly steeper for localized areas. Figure Nos. 7 through 9 provide typical details for slope grading.

Where localized erosional areas exist such as from storm drain erosion of pedestrian traffic the use of a soil cement mixture is particularly good. These materials can be utilized to repair the bluff and can be designed to simulate the color and strength properties of the adjacent bluff and also have similar rates of future erosion.

Also suitable for smaller repairs are pipe and board retaining walls. A typical detail of this type of wall is included as Figure No. 10. These walls are especially good for small slope failures, and repaired areas of pedestrian traffic.

In order to provide a source of material to be utilized as part of a slope grading plan, and also to improve the stability of the central portion, lowering of the bluff top may be considered, see Figure No. 11. Lowering of the area where the bluff top is higher than the tracks (MP 244.48 to MP 244.68) would improve the stability of the central portion of the bluff by reducing weight and providing material for use on the bluff. It would also lessen the likelihood of future blockfalls in this area. This



material which will eventually end up on the beach due to future slope failures may also be considered as beach replenishment. In addition to providing a suitable source of material and improving the stability of that area, local ocean views would also be enhanced. We note that stabilization of the bluff face should in most cases be done in conjunction with some stabilization of the bluff toe as additional erosion will likely impact the repairs if not adequately protected. Where sufficient space is available, slope grading can be utilized to restore the entire slope to a static factor of safety greater than $FS=1.5$ or can be used to improve surficial stability.

5.6 Bluff Top Stabilization

Where the tracks are already lacking needed lateral support due to undermining of the bluff or where future erosion is anticipated to move the top of bluff face within 10 feet of the "Track-Bed Support Line" additional bluff top stabilization is recommended. Where other concerns preclude disturbance outside the right of way, stabilization of the tracks from the bluff top may be desirable. As previously performed, (Leighton, 1978), a series of soldier piles may be considered for support of the rails. Soldier piles generally consist of a series of concrete encased I-Beams placed in a row adjacent to the track. The depth of the soldier pile row and size would be determined through additional studies. The 1978 repair at 7th Street (MP 244.78) which has performed well since that time, consists of 21 soldier piles that are 18 inches in diameter and extend to a depth of 32 feet below the ground surface. Figure No. 12 illustrates a typical detail of a soldier pile installation. Where there is not sufficient space adjacent to the tracks the soldier piles may be constructed with a short wall at the top of slope, Figure No. 13. If a higher wall is needed the system may be modified by the inclusion of a series of tie-backs, Figure No. 14. Of note with the conventional soldier pile wall, is the ability for modifications to the system after installation. If additional erosion occurs the original system can be modified to include the wall or the tie-back system. The need for revisions would be determined as the need for additional capacity of the original soldier pile system increases. An embedded configuration is provided as Figure 22. Figure 23 illustrates a system utilizing soil nails, which is a rigid-anchor system that can be constructed with or without facing (depending on whether stabilization of the surface is included in the performance objective).

We note that at the existing soldier pile wall the base of the soldier piles does not extend below the beach level. As designed this wall may eventually be subject to wave attack and become undermined. Future soldier pile walls could be designed with a deeper foundation and then erosion protection would not be required. If designed as a freestanding wall with foundations well below beach level, stabilization of the area seaward of the wall is no longer required for stability of the tracks. The wall could be modified as additional erosion occurred and ultimately act as a sea wall. This type of improvement can also be utilized to provide the track area with increased factors of safety of greater than $FS=1.5$. The tie-back system may also be utilized for the repair of over-steepened portions of the bluff. If a tie-back system is proposed on the bluff face, an architectural wall facing could be sculpted with colored concrete to afford the wall a natural appearance.

5.7 Drainage Improvements

Drainage improvements to the bluff could be performed to reduce erosion of the bluff face and top, to improve the overall stability of the bluff by reducing the infiltration of water into the subsurface soils, and control accumulation of ground water. In addition, as noted in the Part I of the project geotechnical report, (Leighton, 2001), there are numerous areas where perched ground water seeps



out of the bluff face. These zones of seepage result in a general overall weakening of the bluff materials and contribute greatly to the surficial failures that are common on the bluff face.

In order to improve the overall stability and reduce the ongoing surface erosion, both surface and subsurface drainage improvements should be considered in all areas of the bluff. Significant improvements have already been made in areas and the effects of these can be readily observed. These include the 1996 drainage improvements in the southern portion of the site where several erosive storm drain outlets were removed, and a lined drainage ditch constructed on the east side of the tracks. According to the Fraser Engineering drainage study (Fraser 1993) consideration should be given to increasing capacity of the storm drains at MP 244.19 and MP 244.7. In addition, subdrains that were previously installed appear to be performing well in areas but may no longer be functioning in others. Although seepage zones are shown on the geotechnical map, any proposed subsurface drainage system should be finalized after additional evaluation of possible water sources and depths.

5.7.1 Surface Drainage Improvements

The area along the bluff top drains by both sheet flow and by earthen swales. Ponding water was observed in several areas that occurs after every significant rainfall. In the northern portion of the bluff, standing water was observed that appears to be a combination of surface runoff and groundwater seepage that is generated by irrigation of upslope properties. In several of the locations where ponding or evidence of past ponding was observed, earthen swales are present. These swales are often blocked by debris and loose soil which blocks the flowline and creates localized areas of ponding.

In other areas storm drains and subdrain outlets discharge on or near the top of slope creating an influx of water and increasing erosion. Some of the storm drain outlets leak and are in need of repair, and others simply discharge directly at the top of bluff (MP 244.70). Surface drainage on street ends above and east of the rail alignment should be reviewed. Storm drain runoff should be discharged by a collective drainage system to the beach.

We would recommend that positive surface drainage be provided or re-established where blocked, such that future surface drainage is directed to a collective drainage system and discharged at the base of the bluff. Outlet pipes should consist of watertight pipes that extend to the base of the bluff. Outlet pipes may be located at the surface or grouted in place through a bored outlet hole, Figure No.15. We would suggest that earthen swales have a gradient of at least 2 percent while lined swales may have a gradient of 1 percent. Improvements such as lined swales should be considered where unlined earthen swales now exist in order to reduce infiltration into the subsurface soils. For environmental reasons it may be desirable to place a concrete or a geosynthetic liner just below a bed of permeable soil in drainage swales so that they appear as a natural occurring drainage. See Figure No. 16.

Where existing storm drains are present at the top of the bluff, we would suggest that they be repaired to prevent leaking and extended to the base of the bluff to minimize future erosion. It may be desirable to reduce the number of outlets that extend to the beach. If storm drain pipes are removed, the area created by the removal of the pipe, and the previous discharge point should be backfilled with compacted soil to control preferential erosion. This would



include the area at MP 244.9 where a storm drain was previously removed, and the area at MP 244.7 where extension of the storm drain to the beach should be considered.

5.7.2 Ground Water Reduction

Subsurface drainage is a major problem along the bluff and a reduction of subsurface water would greatly improve the geotechnical condition of the bluff. The source of the water includes infiltration from surface runoff, but the majority of the water comes from other influences upslope which likely cannot be controlled or eliminated. These sources include surface sources that may be collected and directed to the storm drain system but the majority of the water is likely the result of upslope infiltration of irrigation and storm water. The water flows as perched water through the relatively permeable geologic units that overlie the Delmar Formation and as localized seepage zones within the Delmar Formation where sandy zones or fracture systems are present. Regardless of which option is chosen, the selection of a preferred dewatering method should be based in part on additional site investigations and ground water modeling. As part of these additional investigations, efforts should be made to determine the source of the water if possible.

Reducing subsurface flow to the face of the bluff would be a significant improvement. There are several ways to accomplish this, none of which are 100 percent effective. As shown on Figure Nos. 7 through 9 subdrains can be installed as part of a mass grading alternative in benches excavated along the current bluff face. Grading of the bluff has significant environmental and social impacts and will only be considered in localized areas.

The installation of an interceptor subdrain along the bluff top which extends below the base of the Bay Point Formation would likely collect a great deal of the subsurface flow which is perched along the contact with the underlying Delmar Formation, Figure No.17. This interceptor drain could be installed within the railroad Right of Way (ROW), preferably on the east side of the tracks. As shown on Figure No.18, this drain could be installed in conjunction with a lined drainage ditch to also collect surface flow. In several locations however, such as near our exploratory boring LB-2, located at Milepost (MP 244.48) very heavy seepage was encountered well below the base of the Baypoint Formation to a depth of approximately 28 feet. In this area, what appears to be a sand filled channel within the Delmar Formation is carrying a large flow of subsurface water. Other areas within the Delmar Formation whether they are comprised of sandy horizons within the otherwise impermeable bedrock or fracture zones that transport water may be too deep to economically construct the interceptor subdrain using cut and cover techniques.

Where seepage occurs at depths greater than those easily trenched from the surface such as from 11th to 13th street and near 7th street, a series of dewatering wells and/or horizontal drains can be implemented. Figure No. 19 illustrates a typical dewatering well. This well is essentially a large diameter boring that has a pipe and submersible pump installed and then is backfilled with gravel. This type of dewatering system will dewater the area immediately around the hole only and therefore usually requires a series of closely spaced wells to be installed. This could be constructed within the ROW but would also require electrical power and piping to the well. Ongoing maintenance would also be required.



An option to the pumping well would be to drill a larger diameter boring that could be logged after drilling to identify seepage zones. The hole could then be cased and a series of horizontal drains drilled outward from the center of the well. These horizontal drains which can then drain into the cased boring can extend in excess of 100 feet from the well. To allow a gravity outlet an additional horizontal boring could be drilled out to the bluff face and grouted into place. Figure No. 20 illustrates a typical well design. With this alternative, the wells could also be installed within the ROW but at a much wider spacing than with a pumping well.

Another option would be to identify seepage zones on the bluff face and to drill horizontal drains directly into the bluff, Figure No. 21. These drains would be grouted into place and allow subsurface water to be picked up behind the bluff face. This alternative typically requires a number of drain points and is best to drain localized area. Installation of the horizontal drains on the bluff face will be difficult and some disturbance of the bluff face will occur. Because this alternative is on the bluff face, it will most often be outside of the NCTD ROW.

5.8 Seismic Hazard Mitigation

The installation of a remote monitoring system should be considered along the bluff top in selected high risk areas. This monitoring system should be linked to rail signals. Should a major seismic event occur, the signals could be tripped to alert trains to not enter the bluff zone until adequate inspection has occurred.



6.0 SUMMARY

In summary, there are a number of conceptual stabilization preservation methods that are presented in this report that are suitable for use at this site. Some are better suited than others for certain locations and some offer a higher confidence level for the repair/stabilization. In addition, there may be other methods of repair or combinations of methods that are not discussed in this report that may also be worthy of consideration. In general, we anticipate that the best method for each site will include a combination of options. In any event, the risk areas presented in Part I of the project geotechnical report, (Leighton, 2001), and included as Appendix B, incorporate the risks due to the lack of lateral support (inside the "Track-bed Support Line") combined with other considered factors. In our opinion, the "risk priority" should be a major consideration when planning for future repairs.

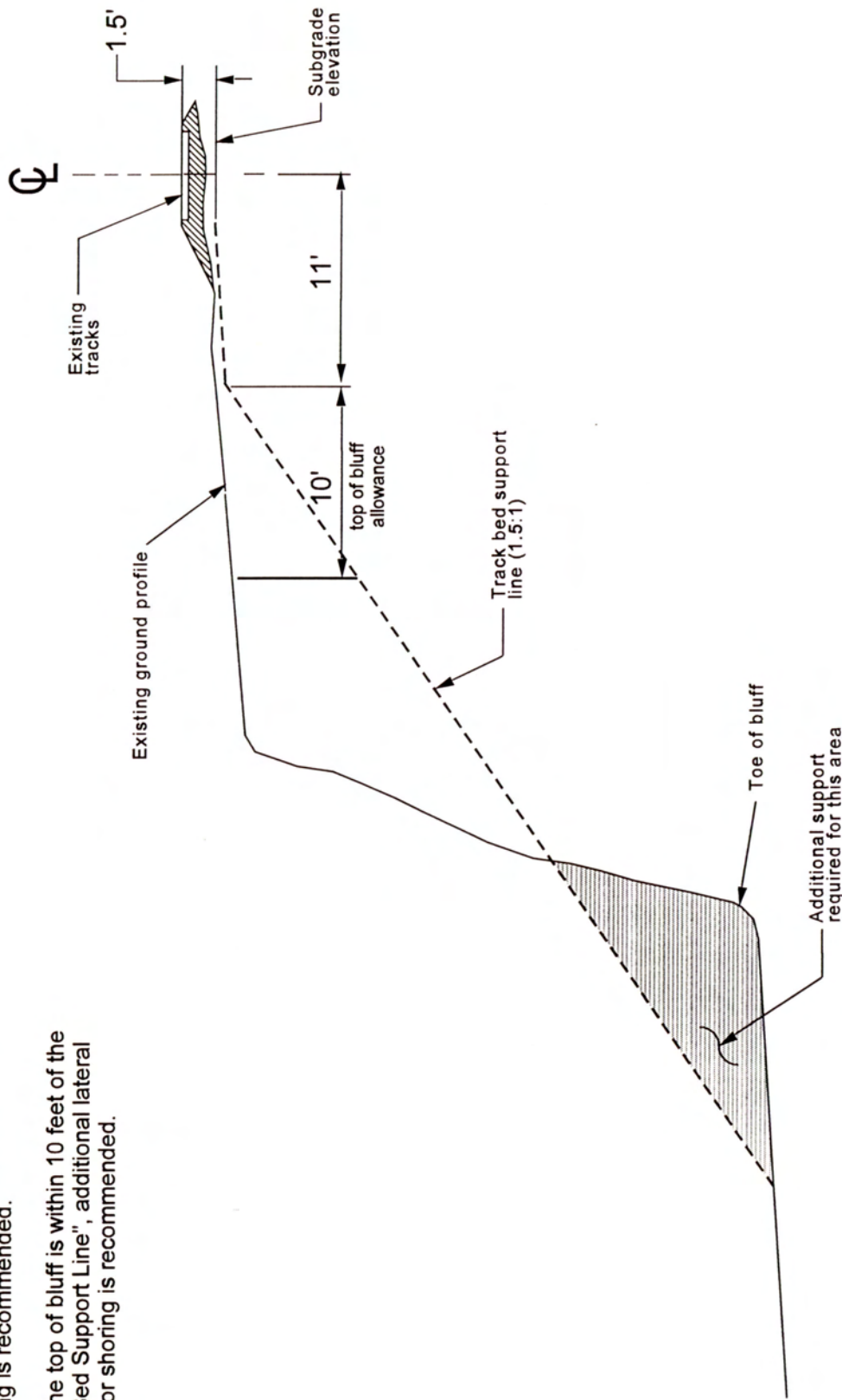
In order to help to evaluate the benefits or deterrents of the various repair alternatives presented, we have prepared a matrix of the conceptual repair alternatives and included that as Appendix C of this report. As noted above, it is most likely that a combination of options will provide the best possible solution.

In closing, we emphasize that the alternatives presented in this report are conceptual in nature and not site specific. This document is intended to be utilized as a tool in selecting the mitigation measures to implement at each site. Actual repair recommendations should be prepared on a site specific basis.



Where the "Track-Bed Support Line" is above toe of bluff, additional lateral support or shoring is recommended.

Where the top of bluff is within 10 feet of the "Track-Bed Support Line", additional lateral support or shoring is recommended.



Modified from: State of California, Department of Transportation Trenching and Shoring Manual, January 1990, Revised December 1996.

TRACK-BED SUPPORT LINE

Project No.

040151-001

Date

January 2001

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Figure No. 2

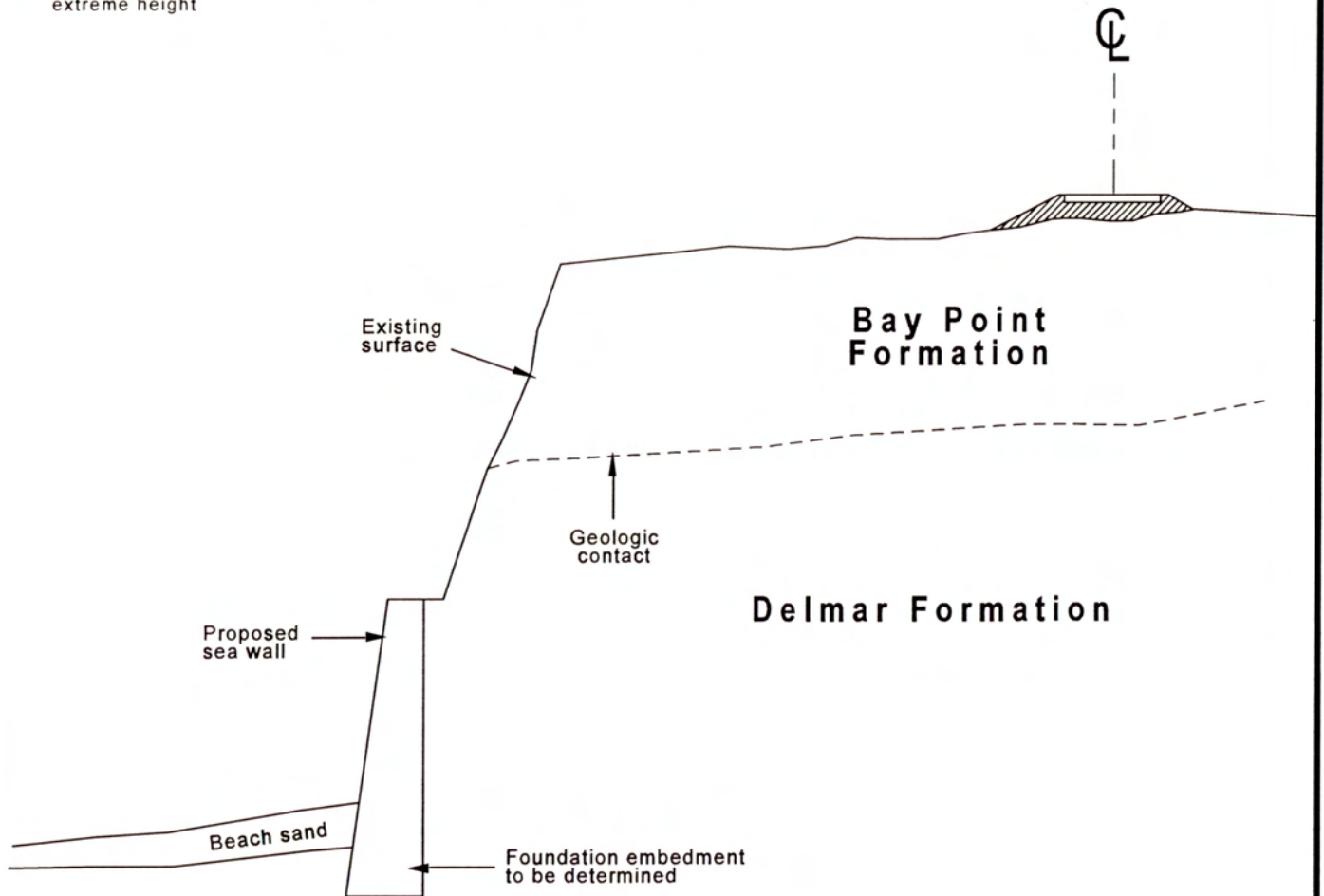


SEA WALL AND SETBACK

Wood or concrete seawalls at base of bluff to halt landward erosion. Walls to be embedded into competent bedrock. May require removal of wall if rail right of way is abandoned.

IMPROVEMENT

Will improve or maintain factor of safety for deep seated stability at toe; will improve surficial stability at lower portion of bluff; may not contribute to stability of upper portion of bluff unless wall is of extreme height



FORM OF MITIGATION

- ☒ Toe
- ☒ Surficial
- ☒ Deep-seated

SEA WALL AT BLUFF TOE

Project No.
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Date
January 2001

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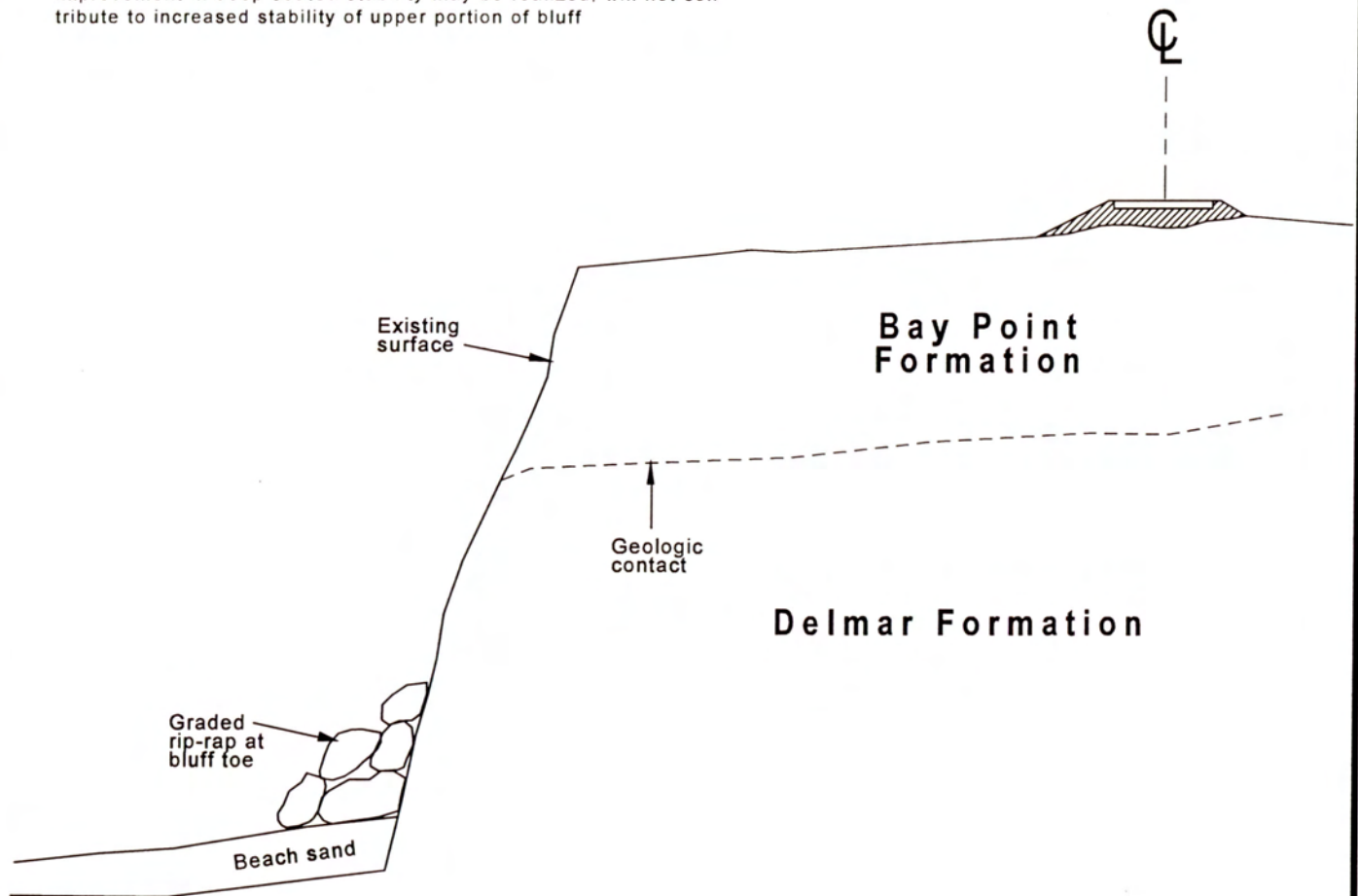
Figure No. 3

ROCK REVETMENT

Rock revetment at base of bluff to consist of large (2.8 ton) rock placed on geotextile fabric. Will reduce wave energy and bluff erosion. Some maintenance required.

IMPROVEMENT

Will increase surficial stability of toe area by reducing potential for continued erosion, with large amounts of rip-rap for a minor improvement in deep seated stability may be realized; will not contribute to increased stability of upper portion of bluff



FORM OF MITIGATION

- ☒ Toe
- ☒ Surficial
- ☐ Deep-seated

REVETMENT AT BLUFF TOE

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Date
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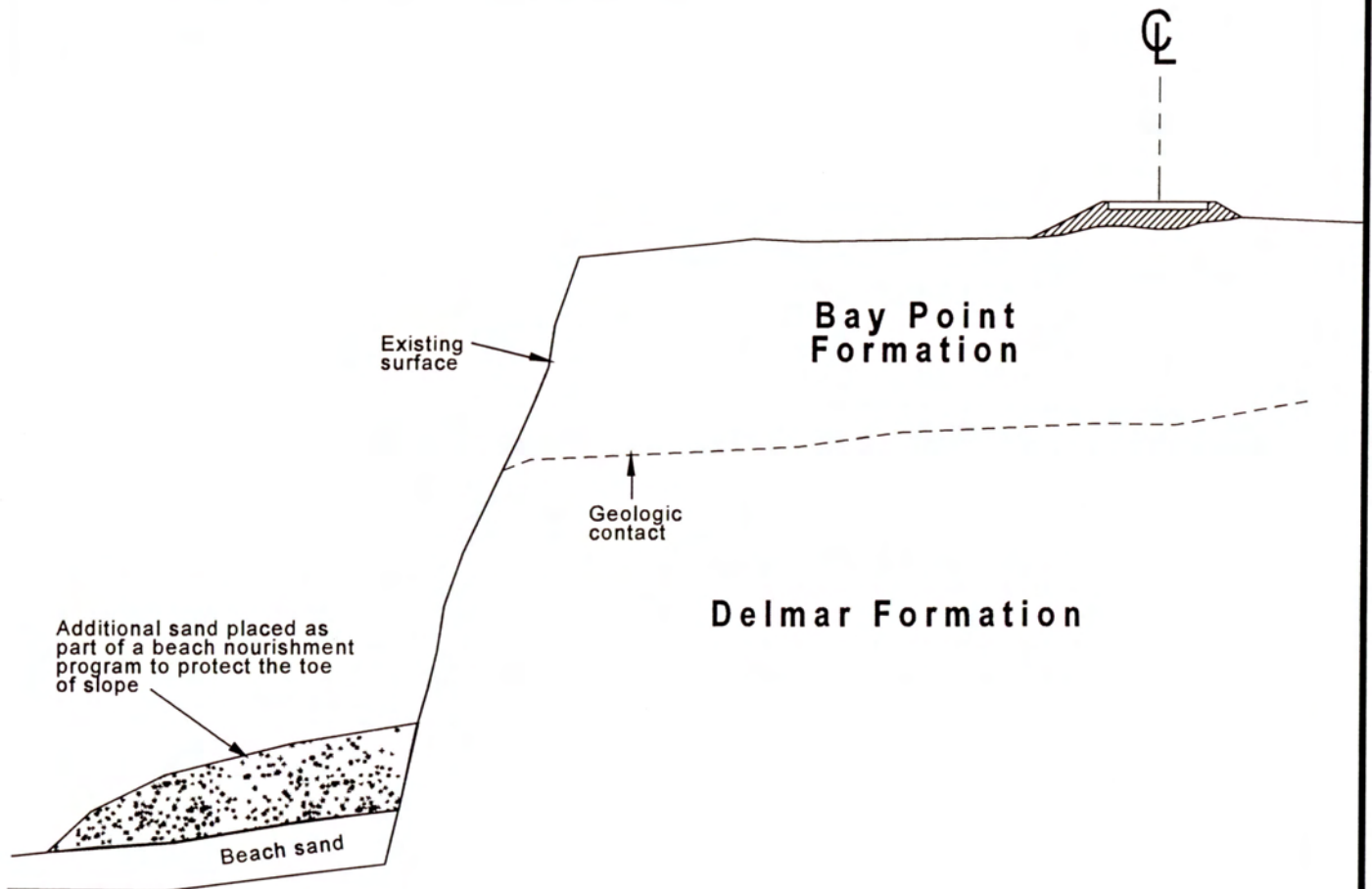
Figure No. 4

BEACH NOURISHMENT

Additional sand placed on beach to protect toe of slope. Sand placement will be subject to seasonal migration of sand and should be considered short term. Will require additional sand as erosion occurs.

IMPROVEMENT

Will add a buffer to erosion at toe; no measureable increase in factor of safety.



FORM OF MITIGATION

- ☒ Toe
- ☐ Surficial
- ☐ Deep-seated

BEACH NOURISHMENT

Project No.
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Date
January 2001

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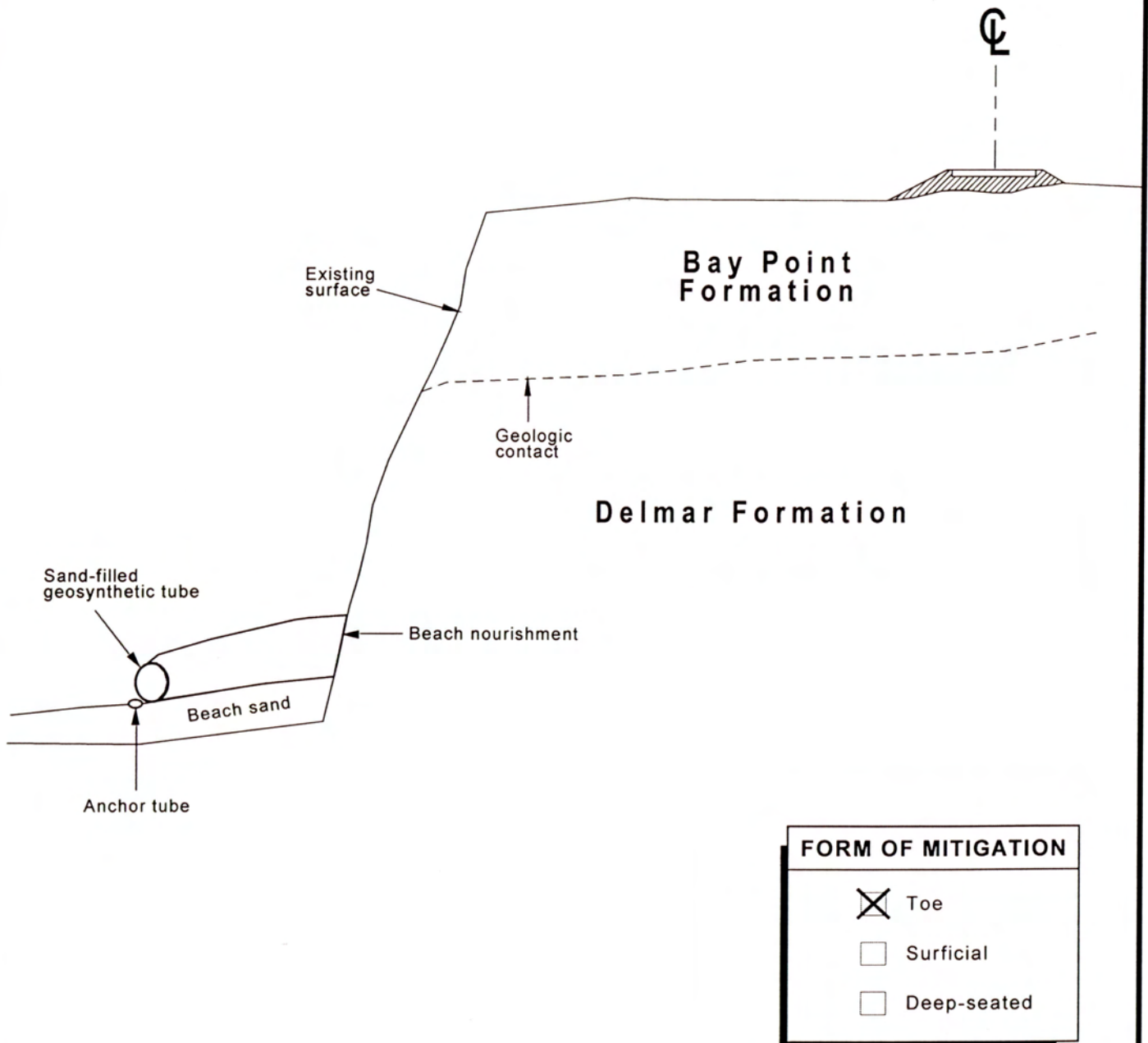
Figure No. 5

BEACH NOURISHMENT WITH GEOSYNTHETIC TUBE

Sand placed as toe protection as shown on Figure No. 5. Geosynthetic tube (longard tube) to protect minimize depletion of sand.

IMPROVEMENT

Will reduce potential for erosion at toe; no measurable increase in factor of safety.



BEACH NOURISHMENT
WITH GEOGRID TUBE

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Date
January 2001

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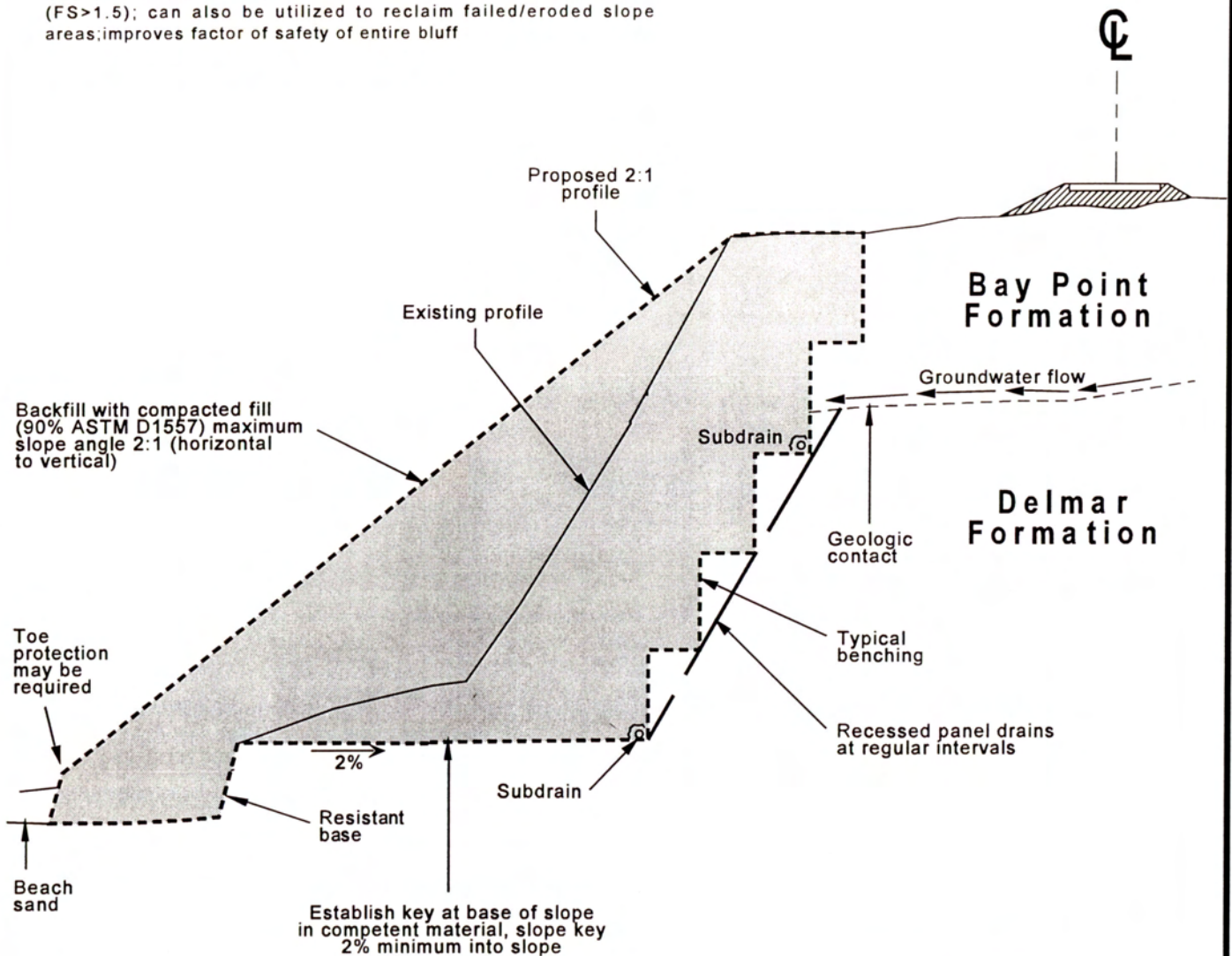
Figure No. 6

SLOPE GRADING

Regrade slope to flatter gradient to remove fractures and to provide support for oversteepened areas.

IMPROVEMENT

Can be utilized to restore slope free to a stable configuration ($FS > 1.5$); can also be utilized to reclaim failed/eroded slope areas; improves factor of safety of entire bluff



FORM OF MITIGATION

- ☒ Toe
- ☒ Surficial
- ☒ Deep-seated

SLOPE GRADING

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Date
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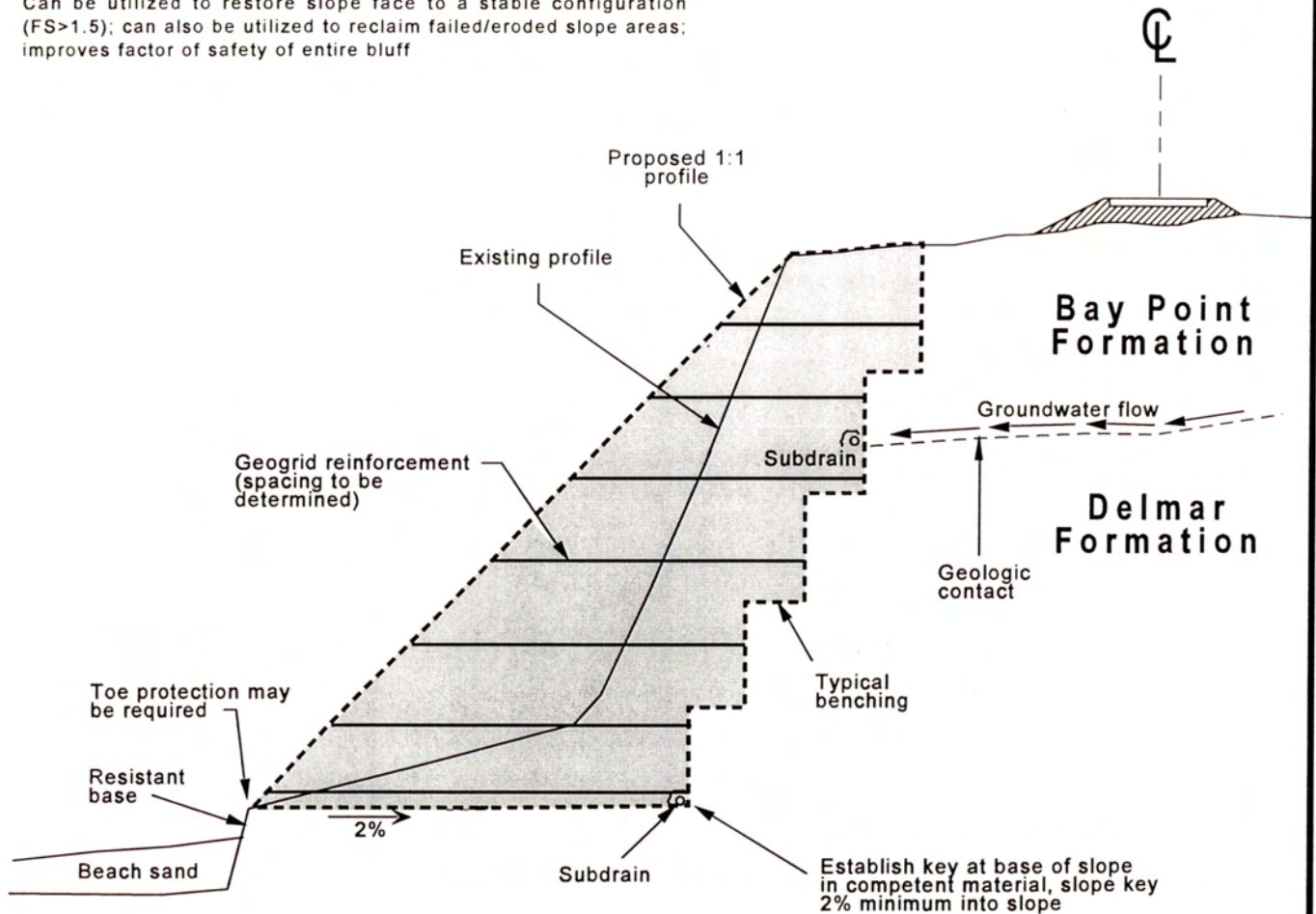
Figure No. 7

SLOPE GRADING WITH GEOGRID

Backfill with geogrid reinforced soil 1:1 (horizontal to vertical) maximum slope angle.

IMPROVEMENT

Can be utilized to restore slope face to a stable configuration (FS>1.5); can also be utilized to reclaim failed/eroded slope areas; improves factor of safety of entire bluff



FORM OF MITIGATION

- ☒ Toe
- ☒ Surficial
- ☒ Deep-seated

SLOPE GRADING (GEOGRID REINFORCED SLOPE)

Project No.
040151-001

Date
January 2001

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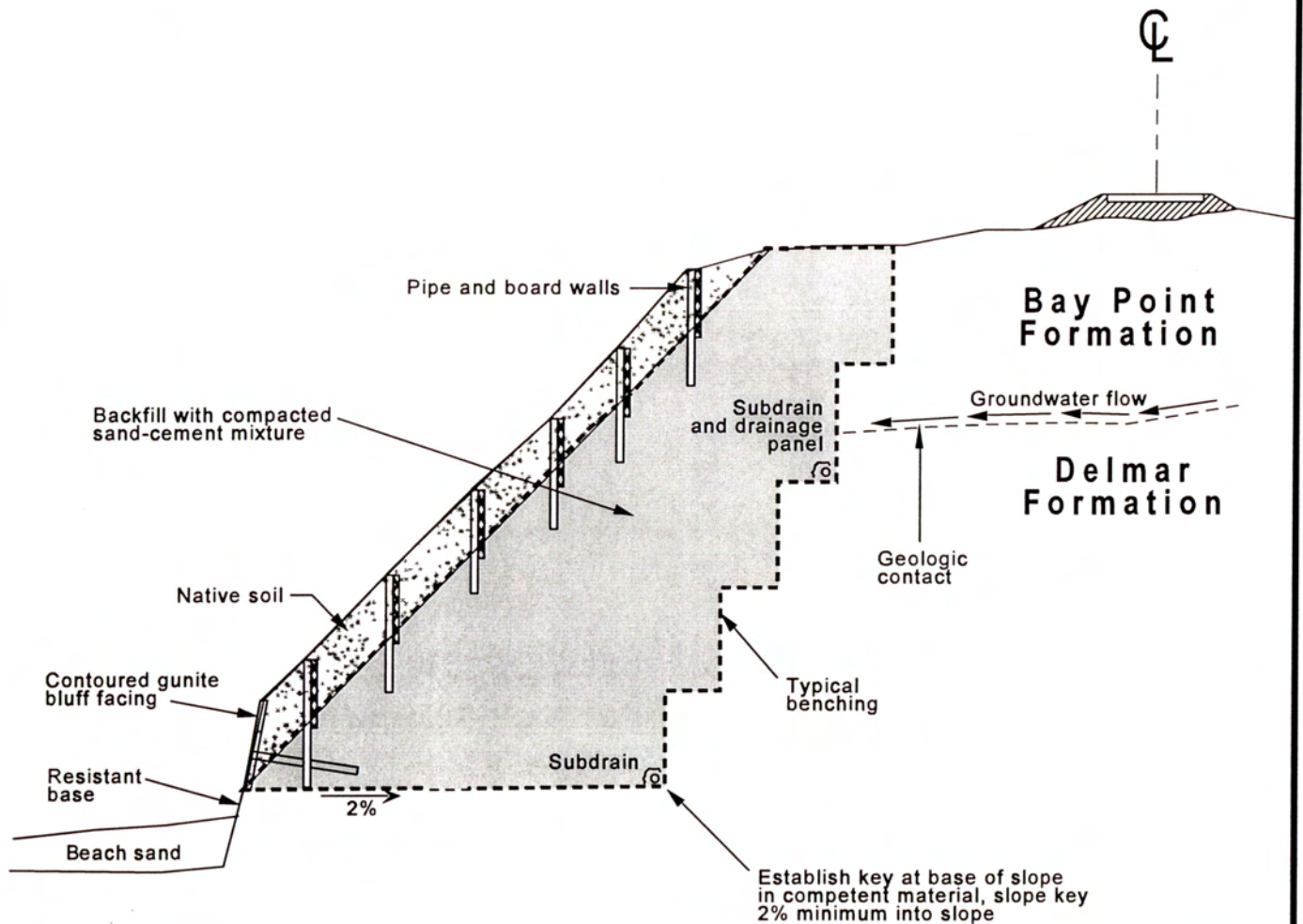
Figure No. 8

SLOPE GRADING WITH SOIL CEMENT

Backfill with soil-cement or sand-cement mixture, 1:1 (horizontal to vertical) maximum slope angle for soil cement mixture. Pipe and board walls to retain plantable soil on slope face are optional.

IMPROVEMENT

Can be utilized to restore slope face to a stable configuration (FS>1.5); can also be utilized to reclaim failed/eroded slope areas; improves factor of safety of entire bluff



FORM OF MITIGATION

- ☒ Toe
- ☒ Surficial
- ☒ Deep-seated

SLOPE GRADING (SOIL CEMENT BUTTRESS)

Project No.
040151-001

Date
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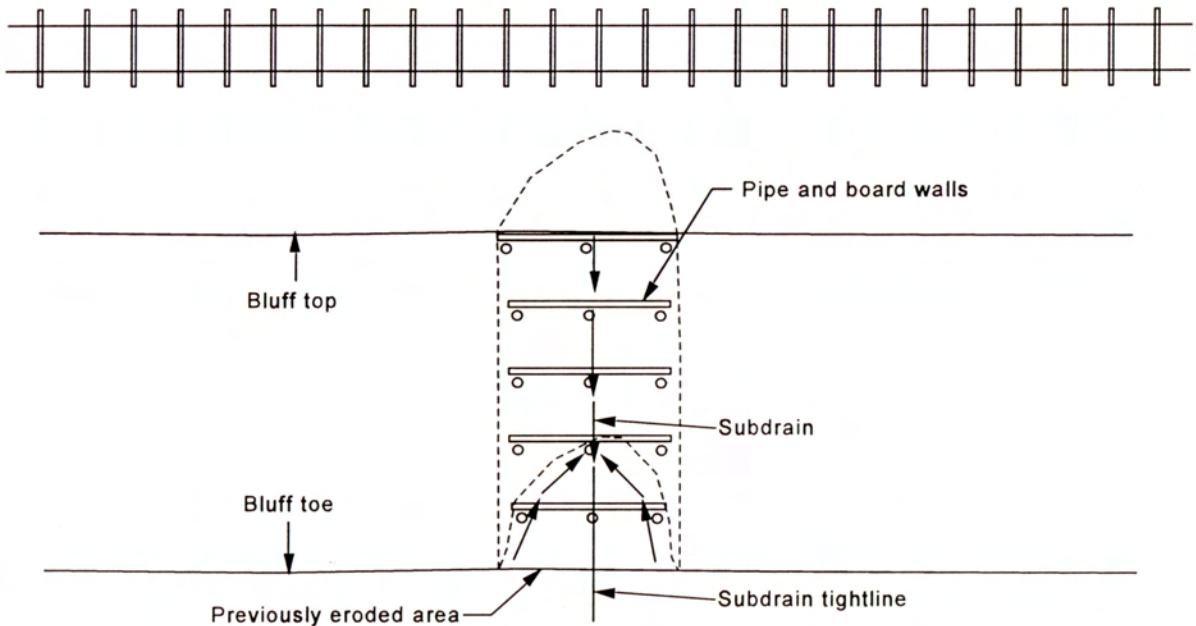
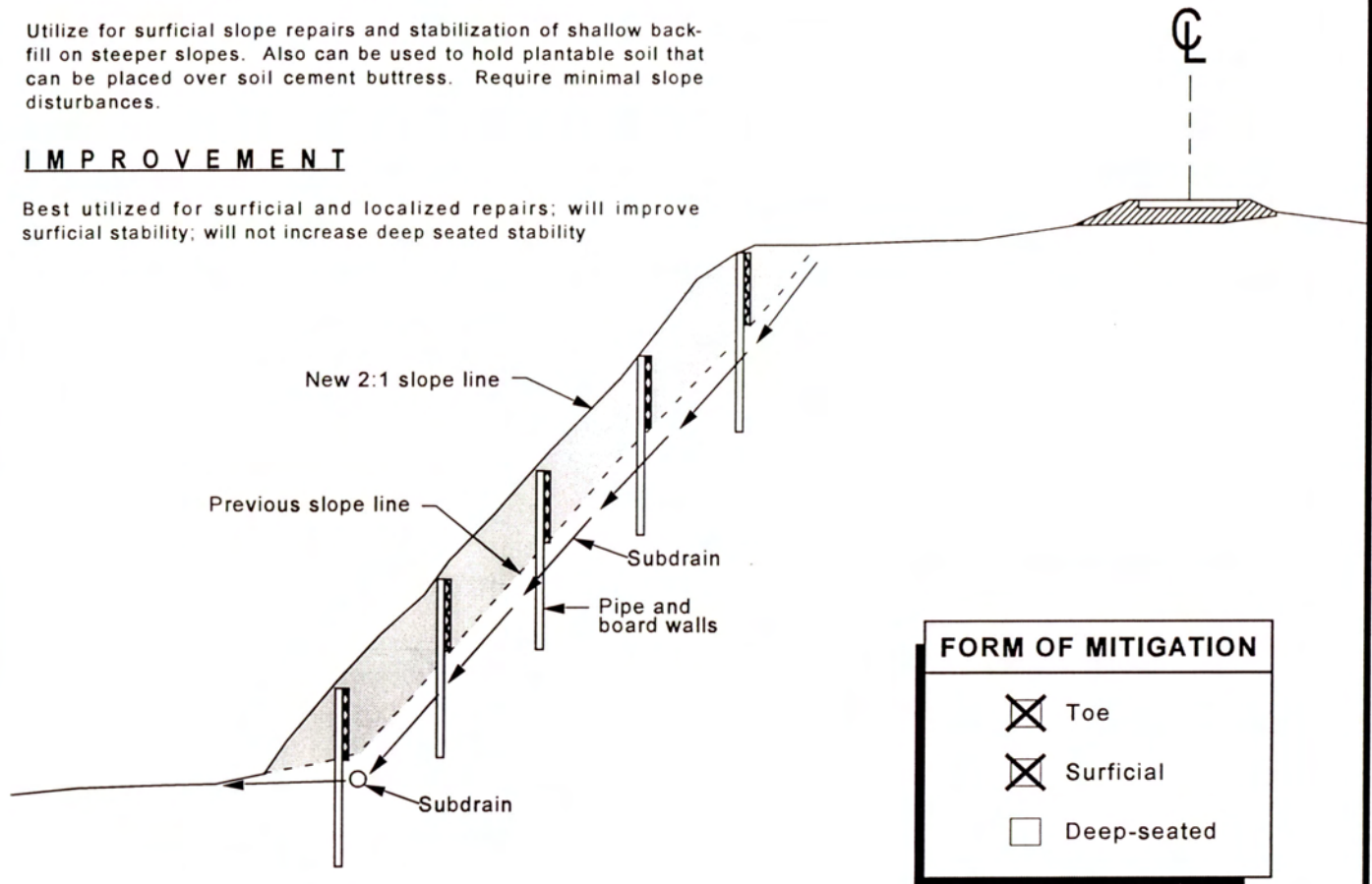
Figure No. 9

PIPE AND BOARD WALLS

Utilize for surficial slope repairs and stabilization of shallow back-fill on steeper slopes. Also can be used to hold plantable soil that can be placed over soil cement buttress. Require minimal slope disturbances.

IMPROVEMENT

Best utilized for surficial and localized repairs; will improve surficial stability; will not increase deep seated stability



PIPE AND BOARD WALLS

Project No.
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Date
January 2001

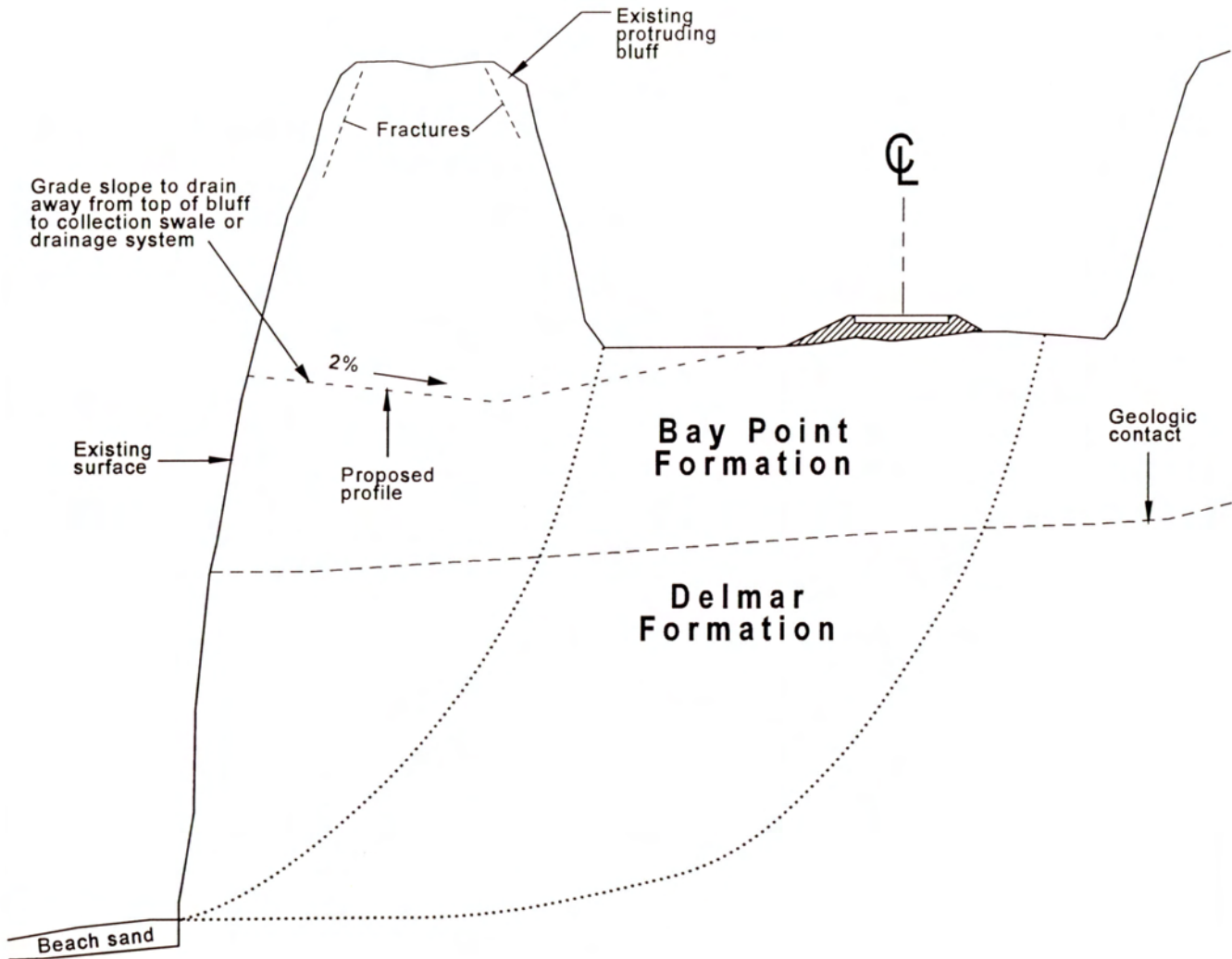
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Figure No. 10

BLUFF TOP GRADING (CENTRAL PORTION OF BLUFF)

Improve stability of bluff face by reducing driving forces (weight). Generates material that can be used for slope repair/possible beach nourishment. Also reduces short term potential for block falls, improves views, provides possible source of beach nourishment and maintains positive drainage.



IMPROVEMENT

Improves stability of bluff face by removing weight from bluff top; may not improve overall factor of safety for deep seated stability

FORM OF MITIGATION

- ☐ Toe
- ☐ Surficial
- ☒ Deep-seated

BLUFF TOP GRADING (CENTRAL PORTION OF BLUFF)

Project No.
040151-001

Date
January 2001

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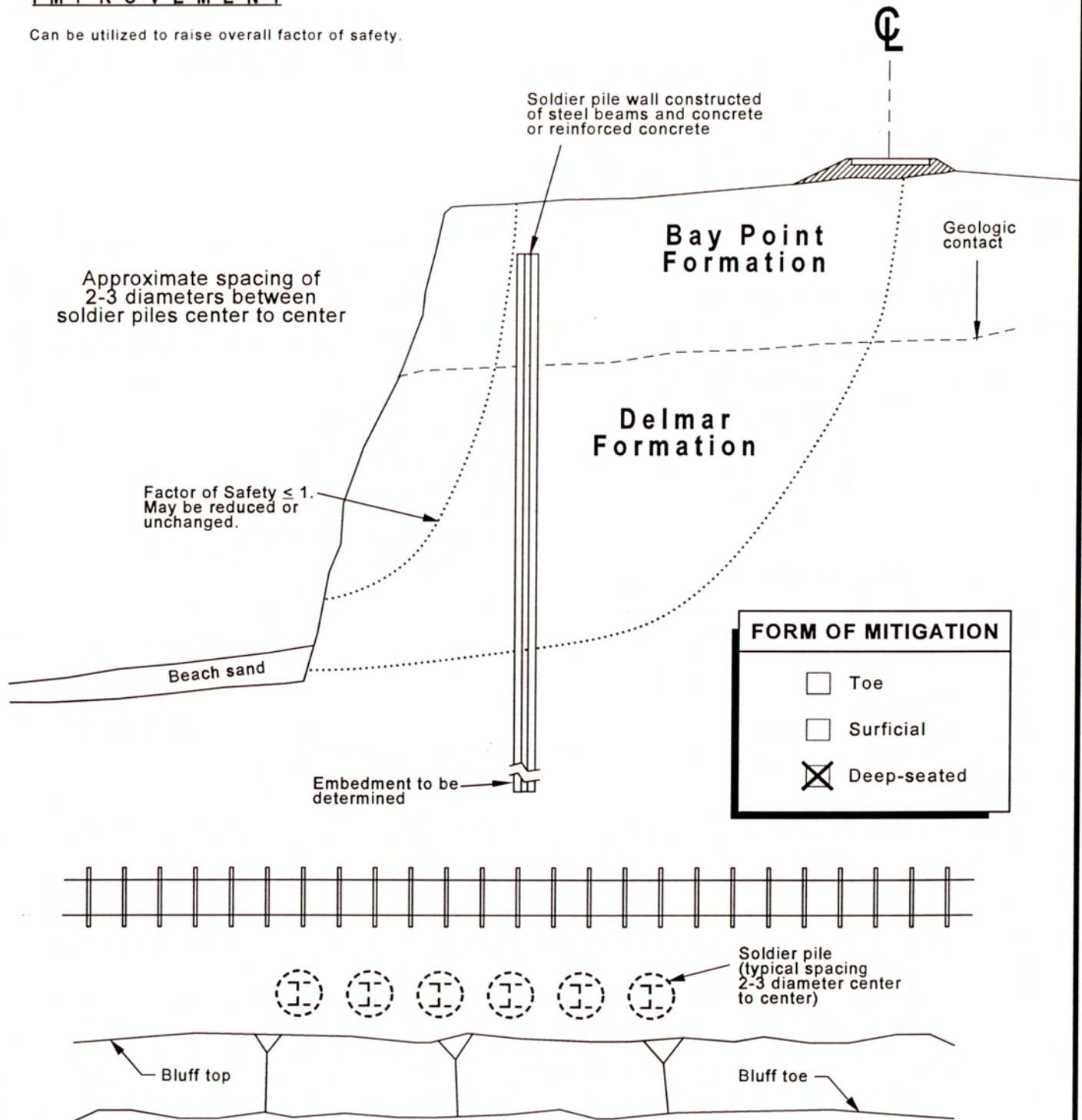
Figure No. 11

SOLDIER PILE WALL

Can be utilized to support rail, where a projection from the tracks to the toe or local stability calculations indicate inadequate lateral support. Can be modified as needed for increased capacity. Can be constructed entirely within R.O.W.

IMPROVEMENT

Can be utilized to raise overall factor of safety.



SOLDIER PILE STABILIZATION

Project No.
040151-001

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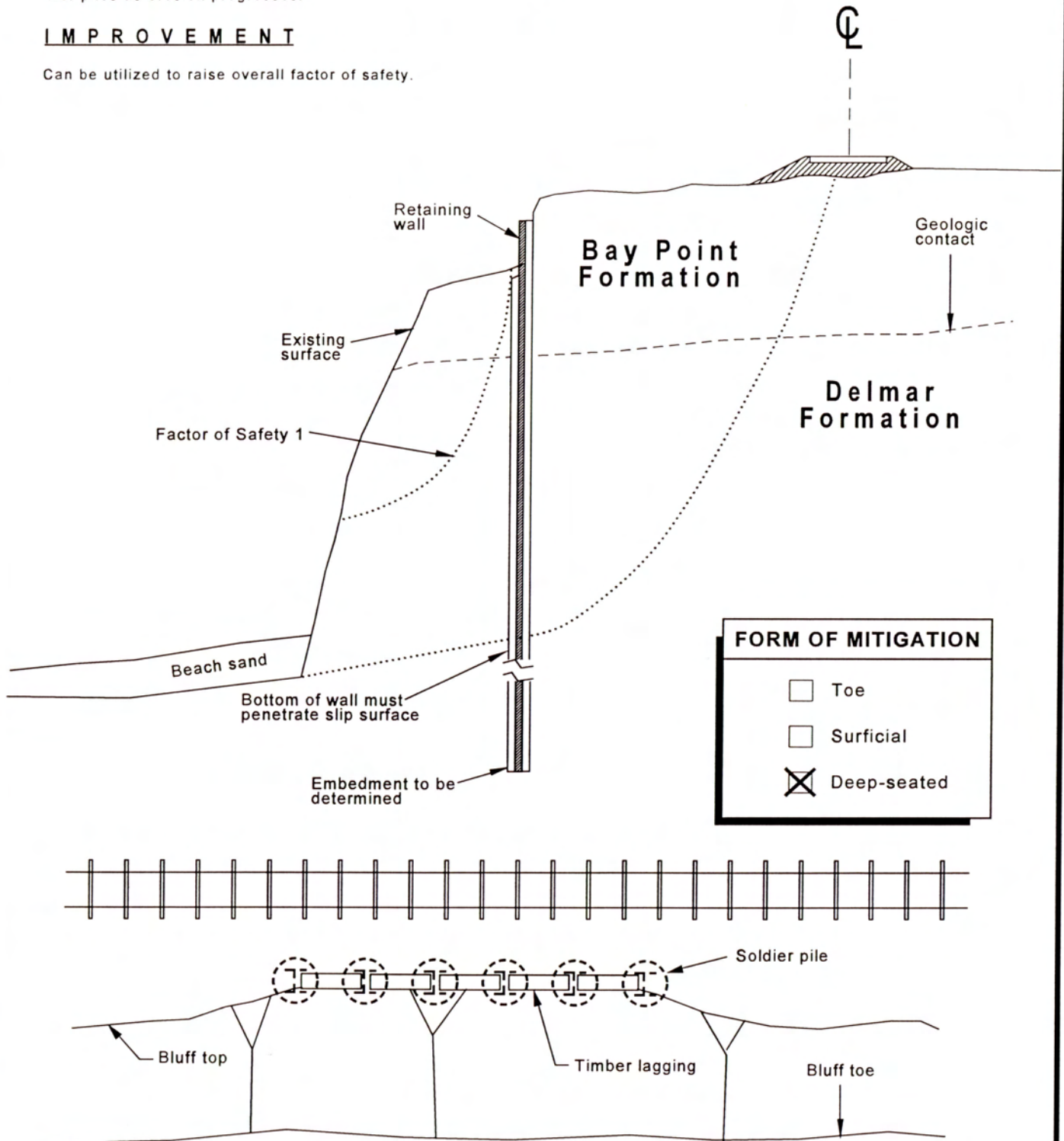
Figure No. 12

SOLDIER PILE WALL WITH LAGGING

Wall can be designed with lagging type wall or modified from soldier piles as erosion progresses.

IMPROVEMENT

Can be utilized to raise overall factor of safety.



SOLDIER PILE WALL WITH LAGGING

Project No.
040151-001

Date
January 2001

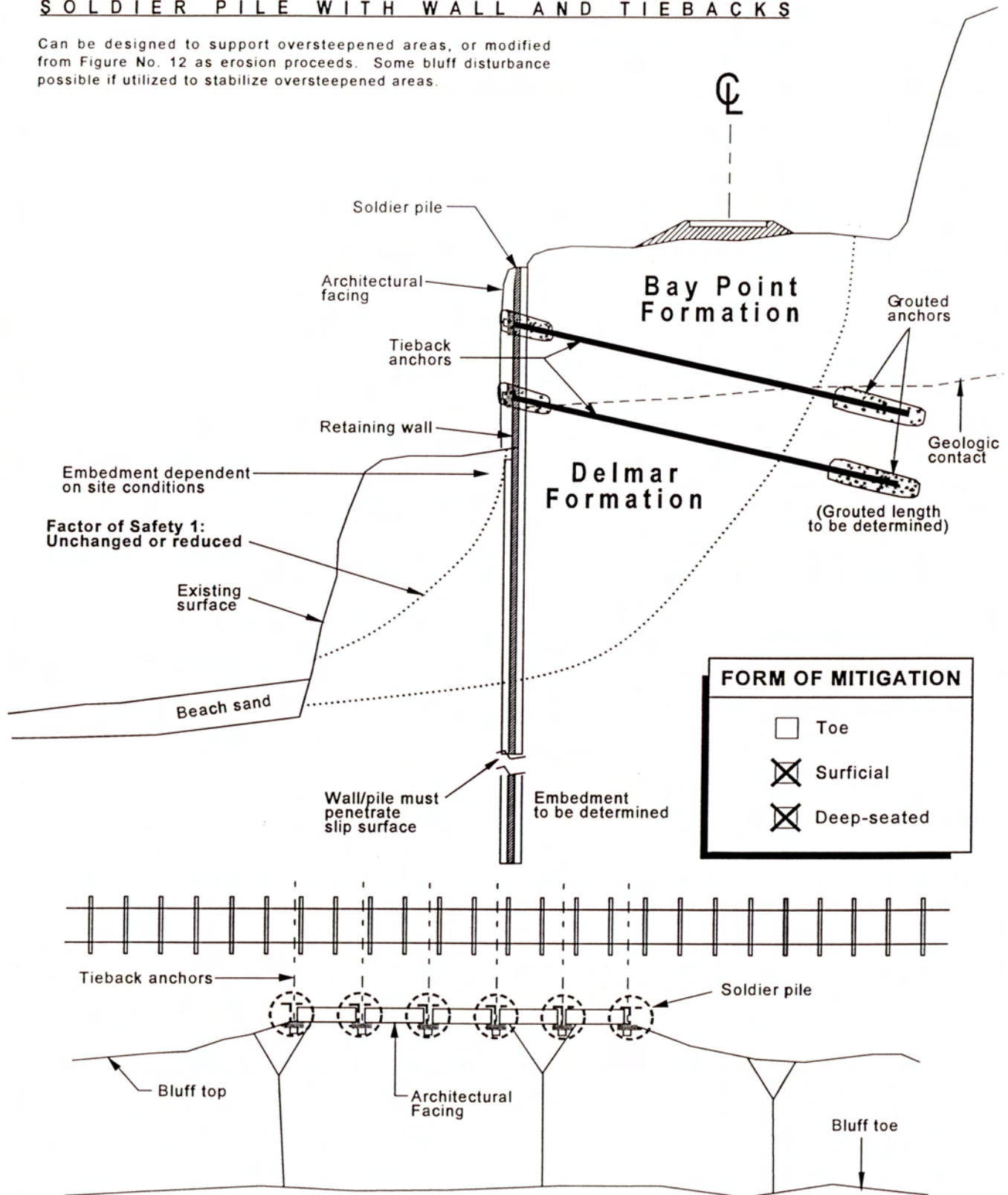
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Figure No. 13

SOLDIER PILE WITH WALL AND TIEBACKS

Can be designed to support oversteepened areas, or modified from Figure No. 12 as erosion proceeds. Some bluff disturbance possible if utilized to stabilize oversteepened areas.



SOLDIER PILE WITH WALL AND TIEBACK

Project No.

040151-001

Date

January 2001

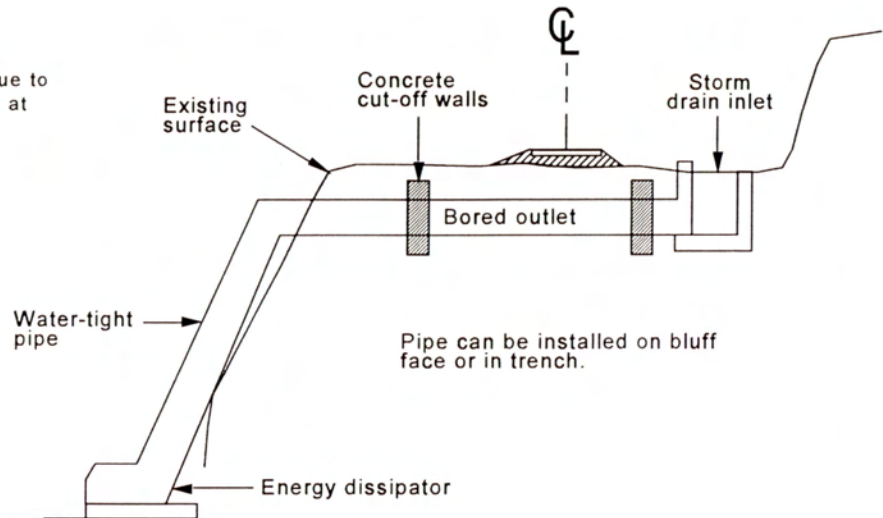
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Figure No. 14

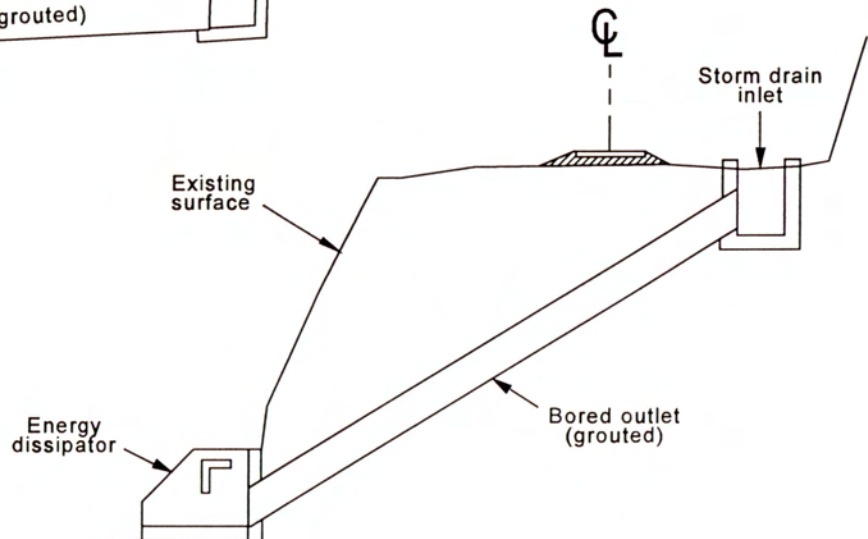
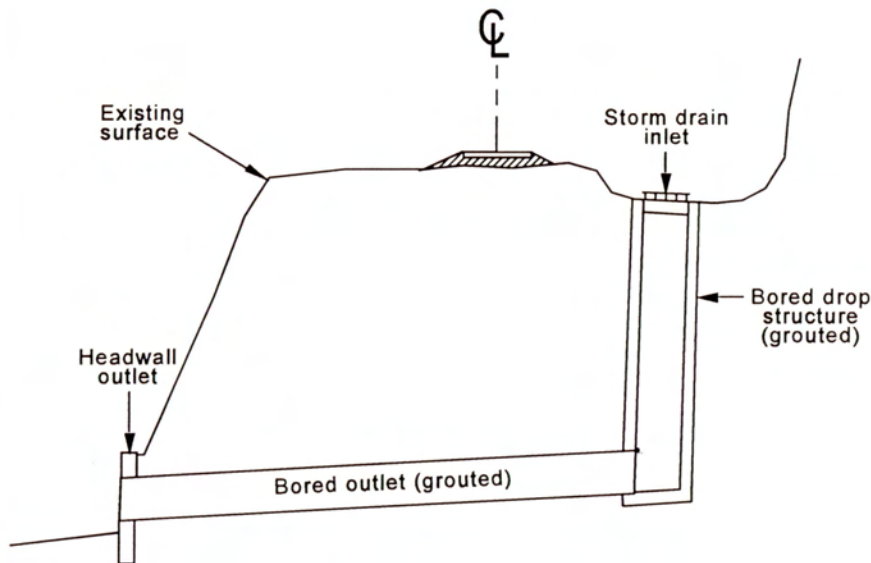
IMPROVEMENT

Minor improvements in factor of safety due to improved drainage, also reduced erosion at bluff top



FORM OF MITIGATION

- ☐ Toe
- ☒ Surficial
- ☒ Deep-seated



STORM DRAIN OUTLETS

Project No.
040151-001

Date
January 2001

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Figure No. 15

SURFACE DRAINAGE

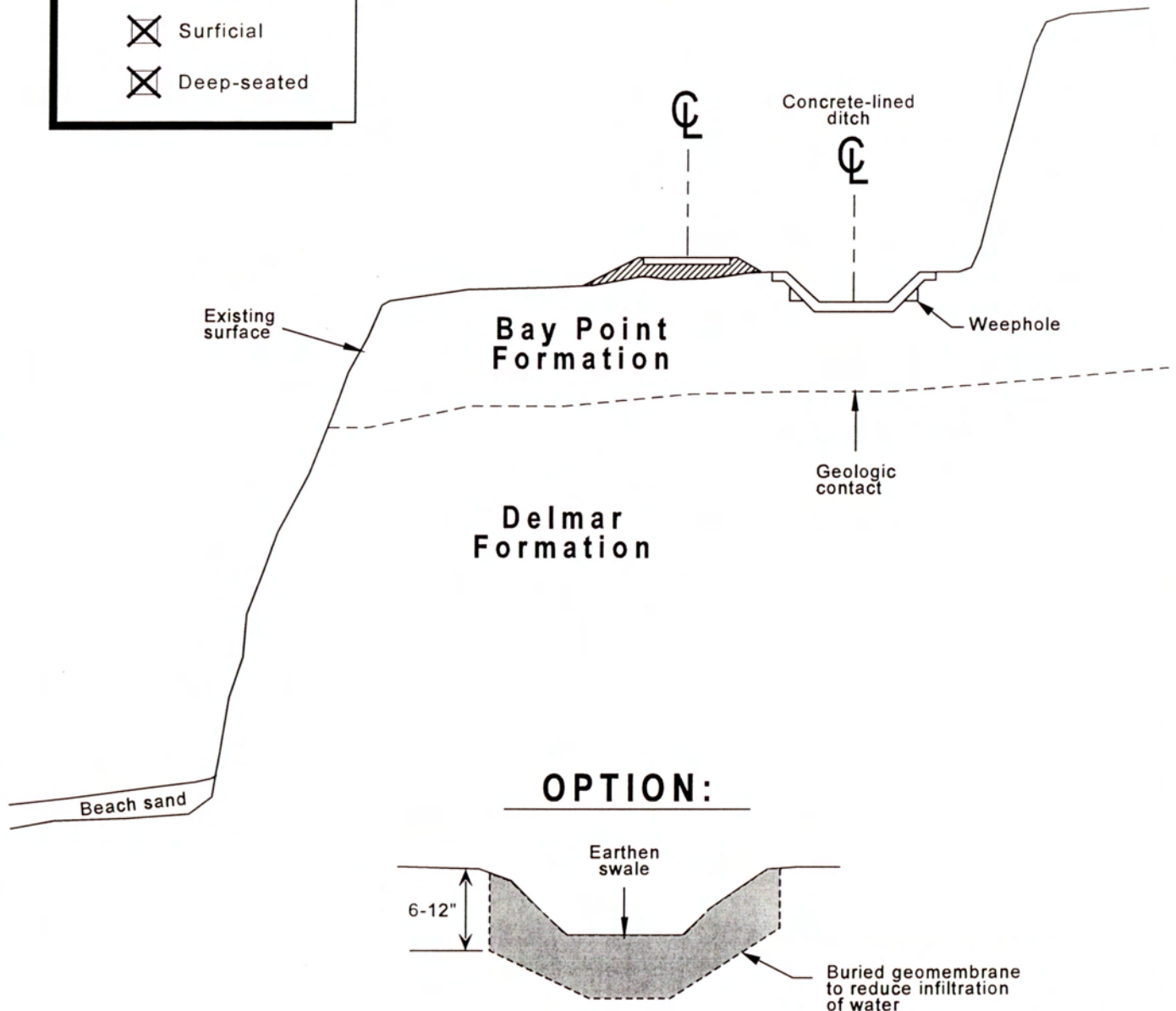
Drainage swales to be lined with concrete with weepholes to collect near-surface seepage. Swales to have a minimum gradient of at least 1% and discharge to a collective drainage system. For a natural appearance, swales may be dirt lined with buried geomembrane to reduce infiltration of water.

IMPROVEMENT

Minor improvements in factor of safety due to improved drainage, also reduced erosion at bluff top

FORM OF MITIGATION

- ☐ Toe
- ☒ Surficial
- ☒ Deep-seated



SURFACE DRAINAGE

Project No.
040151-001

Date
January 2001

Leighton and Associates, Inc.



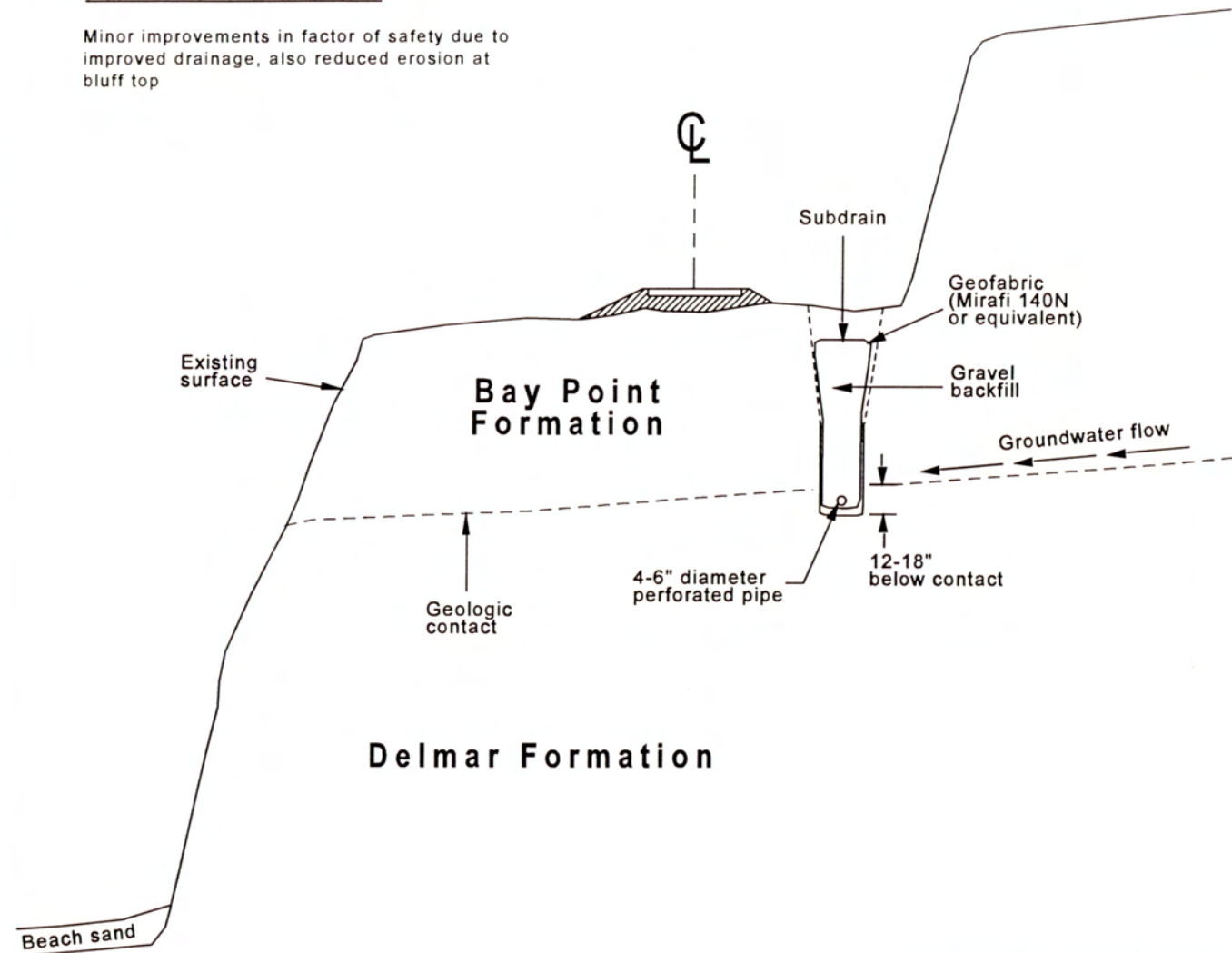
Figure No. 16

INTERCEPTOR SUBDRAIN

Gravel-filled trench excavated 12 to 18 inches into Delmar Formation. Utilize 6-inch perforated pipe (SCH#40) installed holes down. Backfill with clean 3/4-inch gravel, wrapped by filter fabric (Mirafi 140N or equivalent) to within 18-inches of finish grade. Drain to fall at a minimum of 1% to a storm drain or other collective drainage system.

IMPROVEMENT

Minor improvements in factor of safety due to improved drainage, also reduced erosion at bluff top



FORM OF MITIGATION

- ☐ Toe
- ☒ Surficial
- ☒ Deep seated

**INTERCEPTOR
SUBDRAIN**

Project No.
040151-001

Date
1-7-01

Leighton and Associates, Inc.



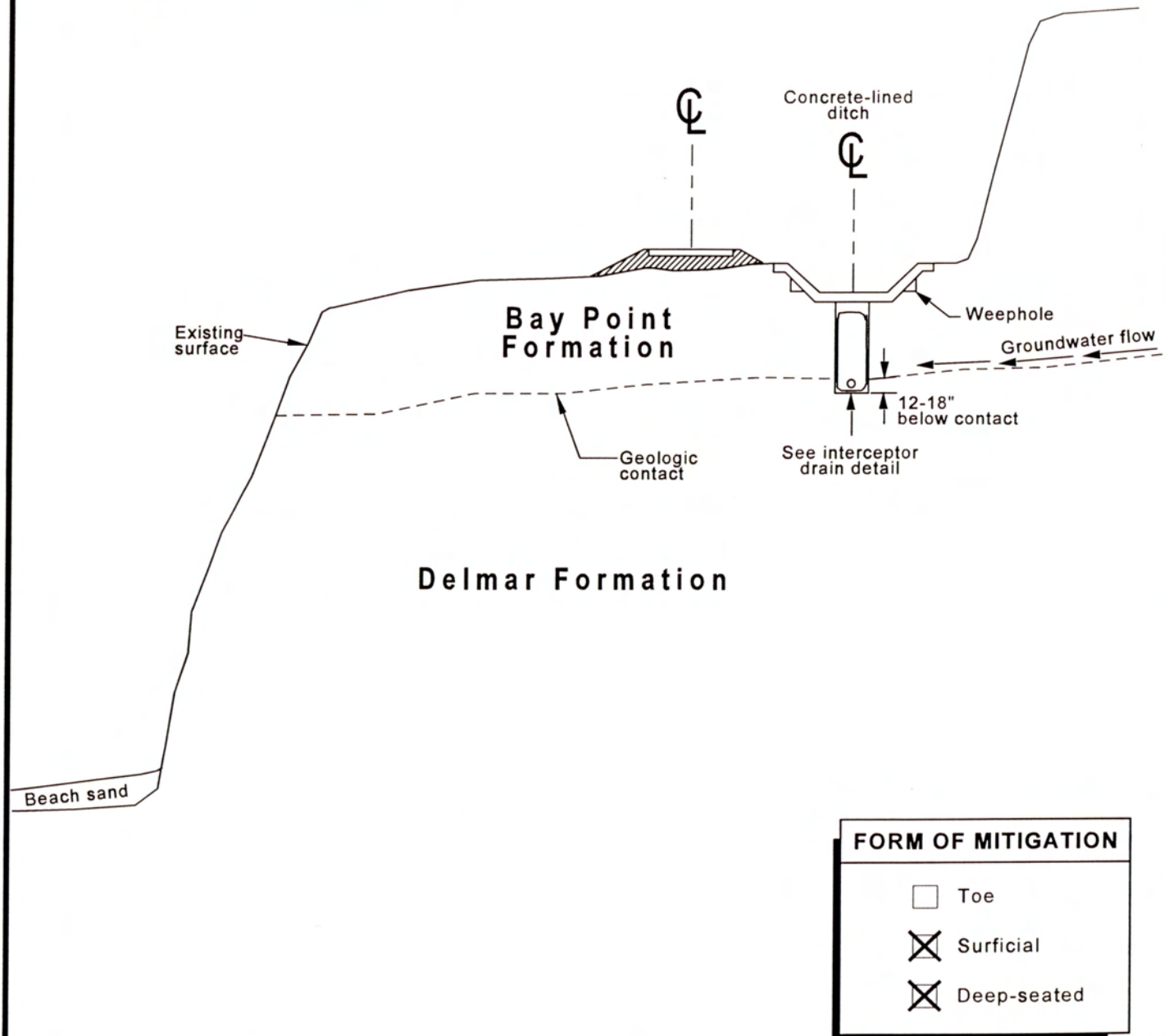
Figure No. 17

CONCRETE-LINED DITCH WITH INTERCEPTOR SUBDRAIN

To control surface runoff weep holes and collect groundwater flows along Bay Point Formation and Delmar Formation contact. Can be completed within R.O.W. Provides significant drainage improvement.

IMPROVEMENT

Minor improvements in factor of safety due to improved drainage, also reduced erosion at bluff top



CONCRETE-LINED DITCH WITH INTERCEPTOR SUBDRAIN

Project No.
040151-001

Date
January 2001

Leighton and Associates, Inc.



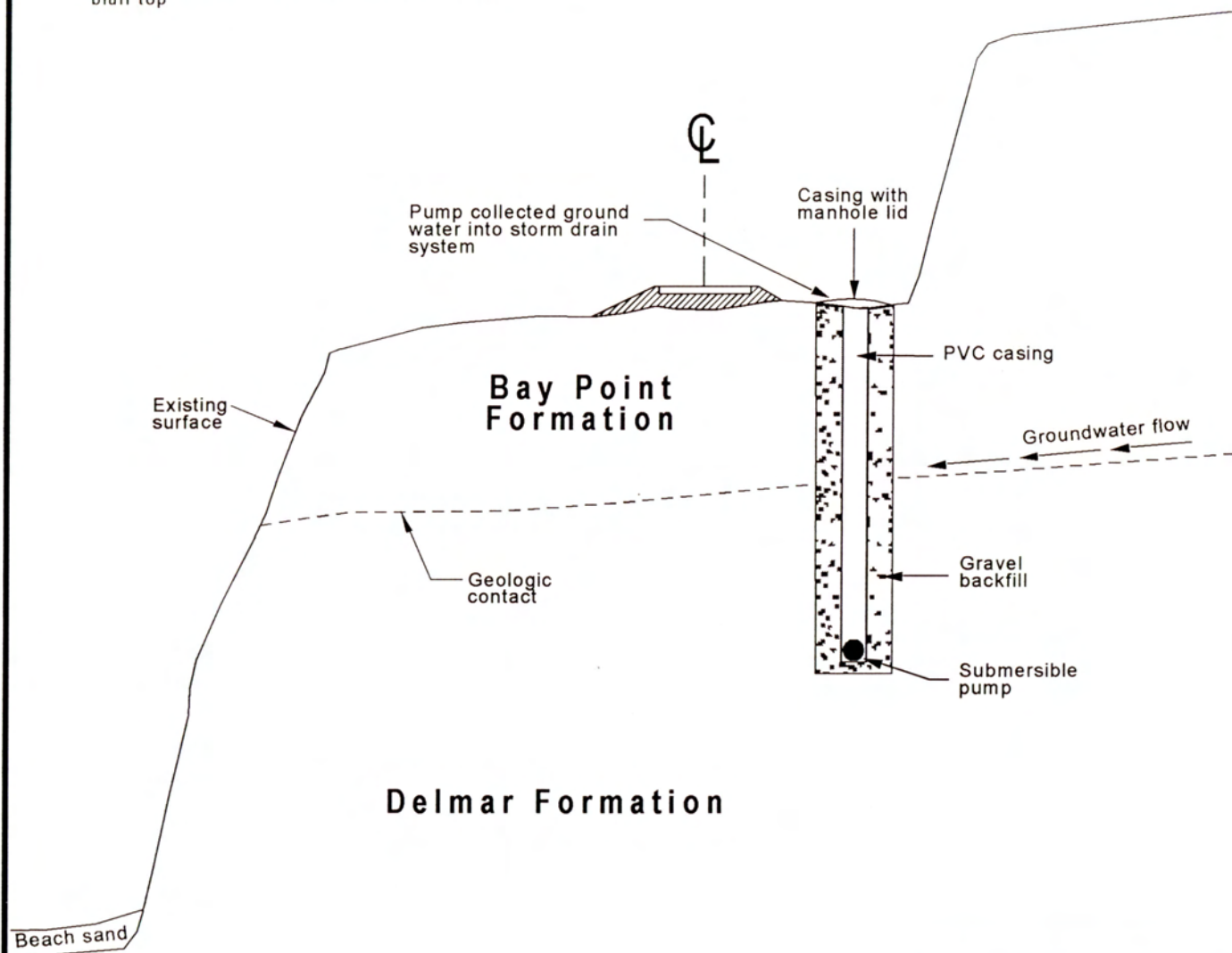
Figure No. 18

DEWATERING WELL AND PUMP

Vertical well installed to collect groundwater. Will require electrical connection for submersible pump and outlet piping. Can be constructed within R.O.W. Will require periodic maintenance.

IMPROVEMENT

Minor to moderate improvements in factor of safety due to improved drainage, also reduced erosion at bluff top



Estimated spacing: 20 to 50 feet in areas of heavy seepage

FORM OF MITIGATION

- ☐ Toe
- ☒ Surficial
- ☒ Deep-seated

DEWATERING WELL AND PUMP

Project No.
040151-001

Date
January 2001

Leighton and Associates, Inc.



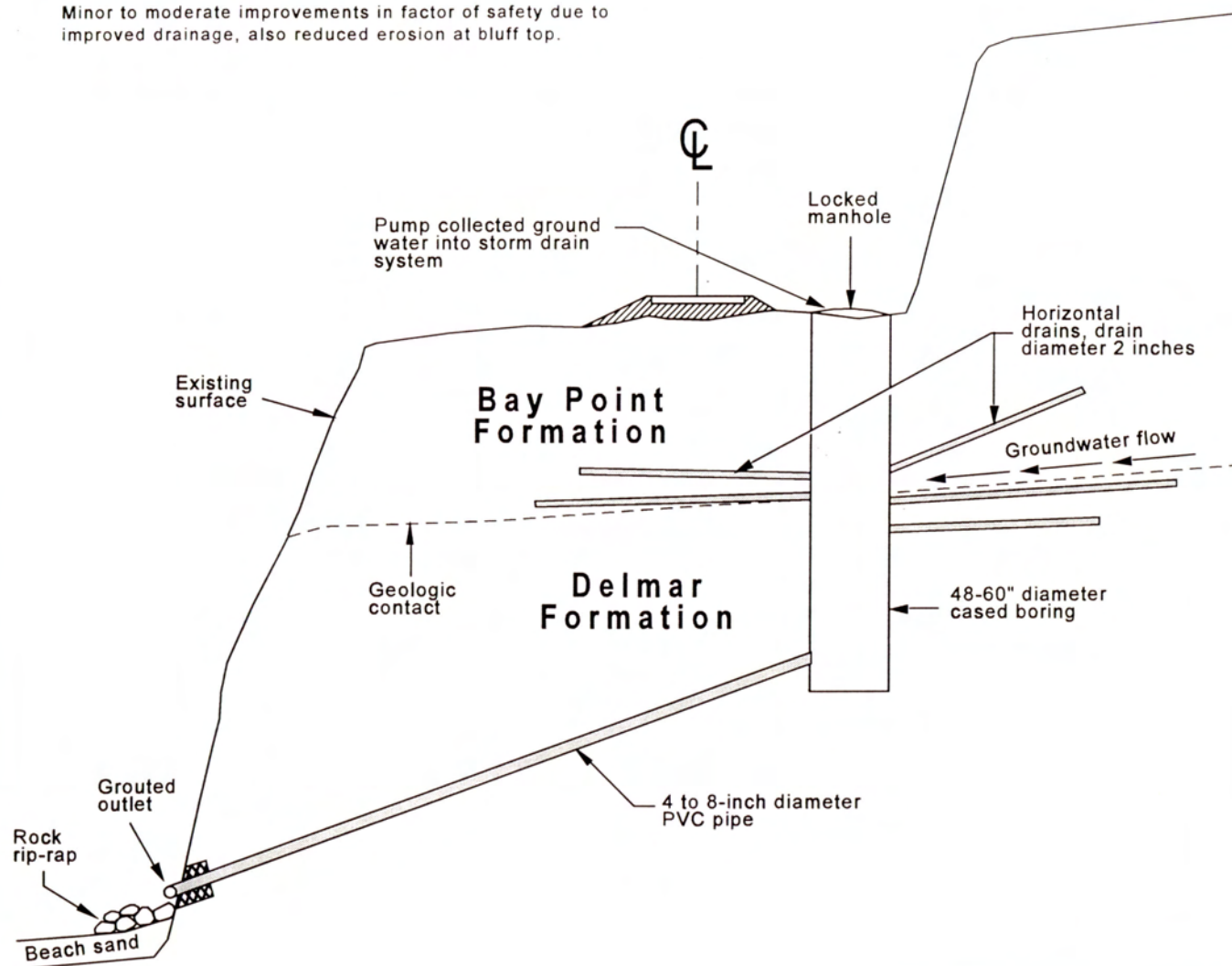
Figure No. 19

DEWATERING WELL (GRAVITY)

48- to 60-inch diameter cased boring with horizontal drains drilled out of boring. Can map seep zones during drilling and drill horizontal drains after casing. In addition, a gravity outlet could be drilled to bluff face. Horizontal drains can be drilled out in excess of 100 feet. Can be constructed within R.O.W.

IMPROVEMENT

Minor to moderate improvements in factor of safety due to improved drainage, also reduced erosion at bluff top.



Estimated spacing: 200 feet in areas of heavy seepage

FORM OF MITIGATION

- ☒ Toe
- ☒ Surficial
- ☒ Deep-seated

DEWATERING WELL
(GRAVITY)

Project No.
040151-001

Date
January 2001

Leighton and Associates, Inc.



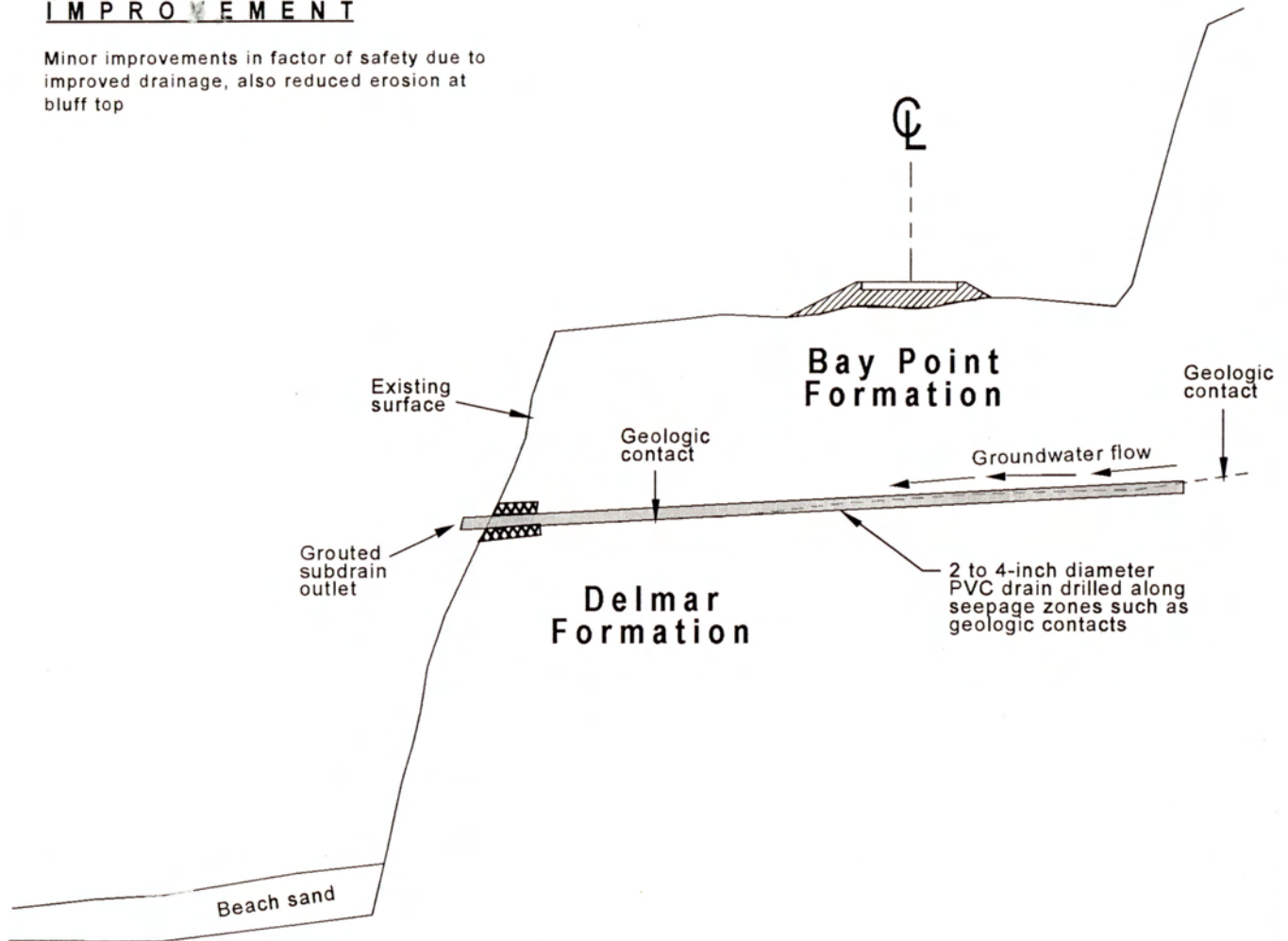
Figure No. 20

HORIZONTAL DRAINS ON BLUFF FACE

Installed by Hydroauger on bluff face in zones of observed seepage. Disturbance on bluff face may be required for installation. Allows for gravity flow of water. Can be connected by pipes to base of bluff. Outlet pipe to be grouted in place. Outlets can be connected by manifold system and extended to base of bluff.

IMPROVEMENT

Minor improvements in factor of safety due to improved drainage, also reduced erosion at bluff top



FORM OF MITIGATION

- ☒ Toe
- ☒ Surficial
- ☒ Deep seated

HORIZONTAL DRAINS

Project No.

040151-001

Date

1-7-01

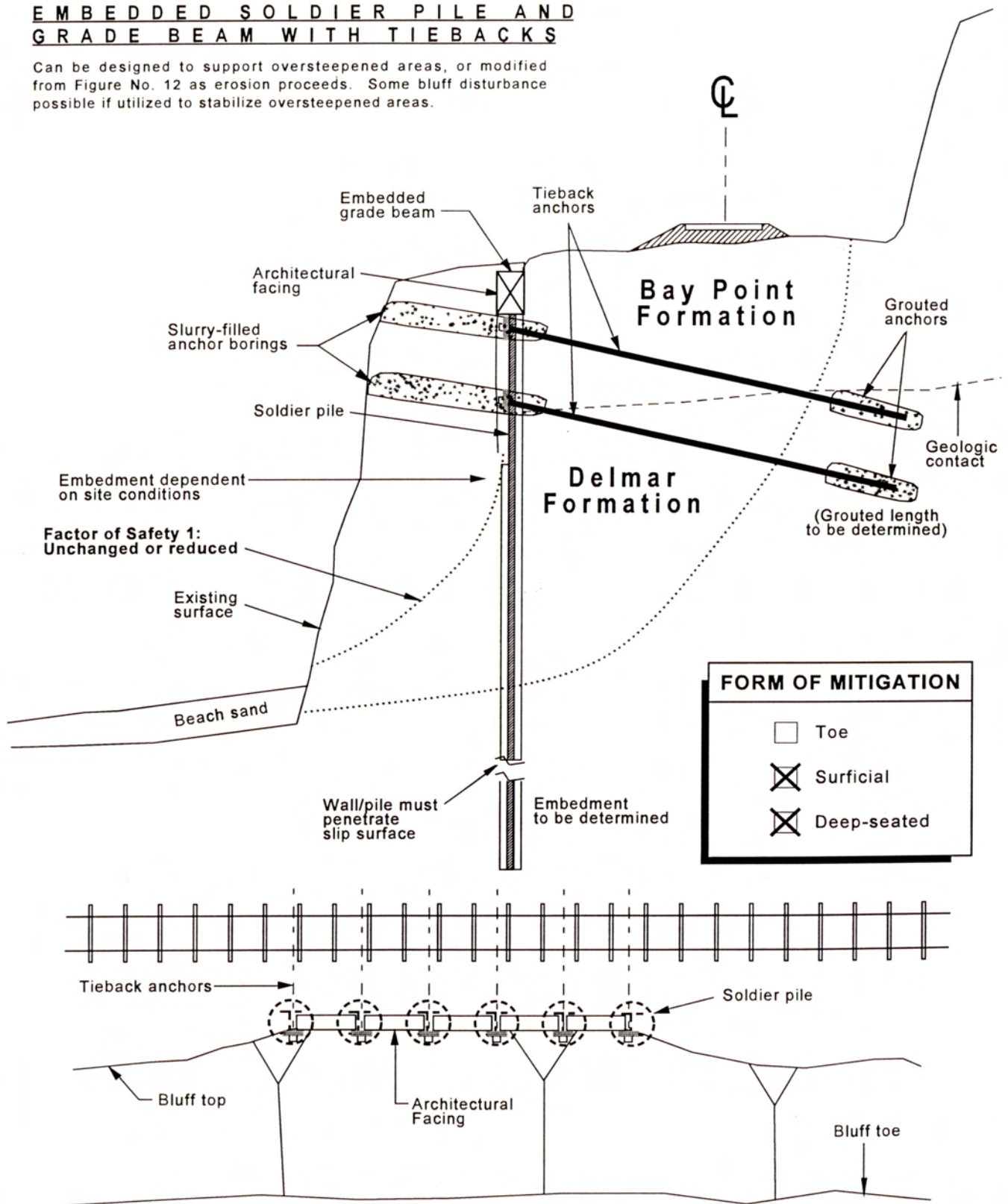
Leighton and Associates, Inc.



Figure No. 21

EMBEDDED SOLDIER PILE AND GRADE BEAM WITH TIEBACKS

Can be designed to support oversteepened areas, or modified from Figure No. 12 as erosion proceeds. Some bluff disturbance possible if utilized to stabilize oversteepened areas.



EMBEDDED SOLDIER PILE AND GRADE BEAM WITH TIEBACKS

Project No.
040151-001

Date
January 2001

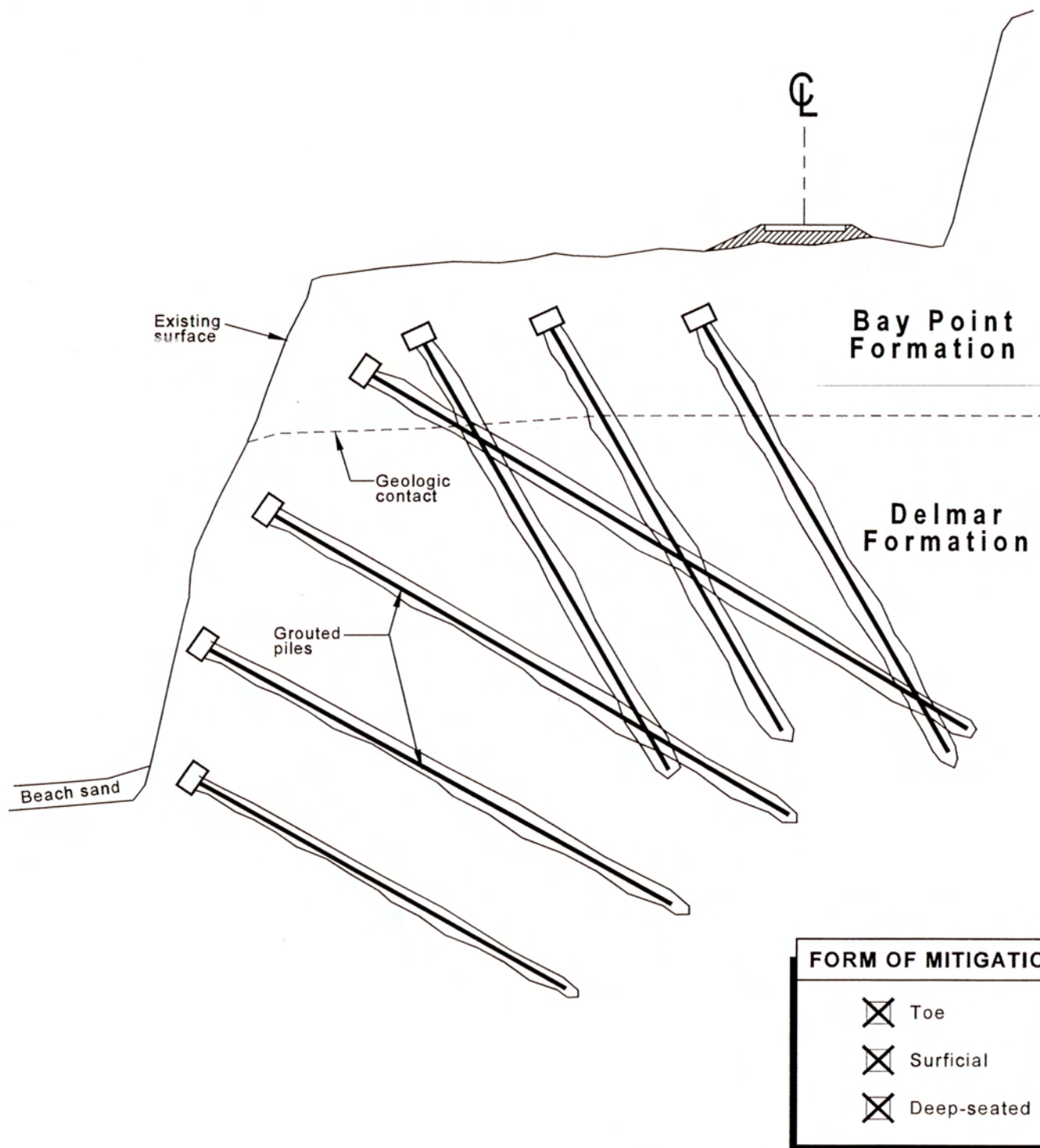
Leighton and Associates, Inc.



Figure No. 22

EMBEDDED SOIL NAIL/MICROPILE REINFORCEMENT

Can improve deep-seated stability. Embedded portion may become exposed and require architectural facing.



EMBEDDED SOIL NAIL/ MICROPILE REINFORCEMENT

Project No.

040151-001

Date

January 2001

Leighton and Associates, Inc.



Figure No. 23

APPENDIX A

REFERENCES

- Bennett and Griggs, Coastal Protection Structures and Their Effectiveness, UCSC.
- California Building Standards Commission (CBSC), 1998, California Building Code, Volumes 1 and 2.
- California Coastal Commission, 1985, A Conference on Coastal Erosion, California's Battered Coast.
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- Everts, Craig, 1988, Guidelines For Shoreline Protection, April 1988.
- Ewing and Sherman, 1997, California's Coastal Natural Hazards.
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- , 1978, Preliminary Geotechnical Investigation of Landslides at Seventh and Thirteenth Streets Del Mar Bluffs, Project No. 478008-1, dated January 30, 1978.
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- Medall, Aragon, and Higley, 1998, Del Mar Bluffs Geotechnical Investigation(DRAFT), Volume I and II, dated November 11, 1998
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- State of California Department of Transportation, 1990, Trenching and Shoring Manual Revision 11, January 1990.
- The City of Del Mar, 1993, Land Use Plan, City of Del Mar Local Coastal Program, dated March 18, 1993

References (Continued)

U.S. Army Corps of Engineers, 1996, Reconnaissance Report, Encinitas Shoreline, San Diego County, California, dated March 1996.

———, 1995, Engineering and Design, Coastal Geology, Engineer Manual 1110-2-1010 dated January 31, 1995.

———, 1995a, Engineering and Design, Design of Coastal Revetments Seawalls and Bulkheads, Engineer Manual 1110-2-16H, dated June 30, 1995.



APPENDIX B

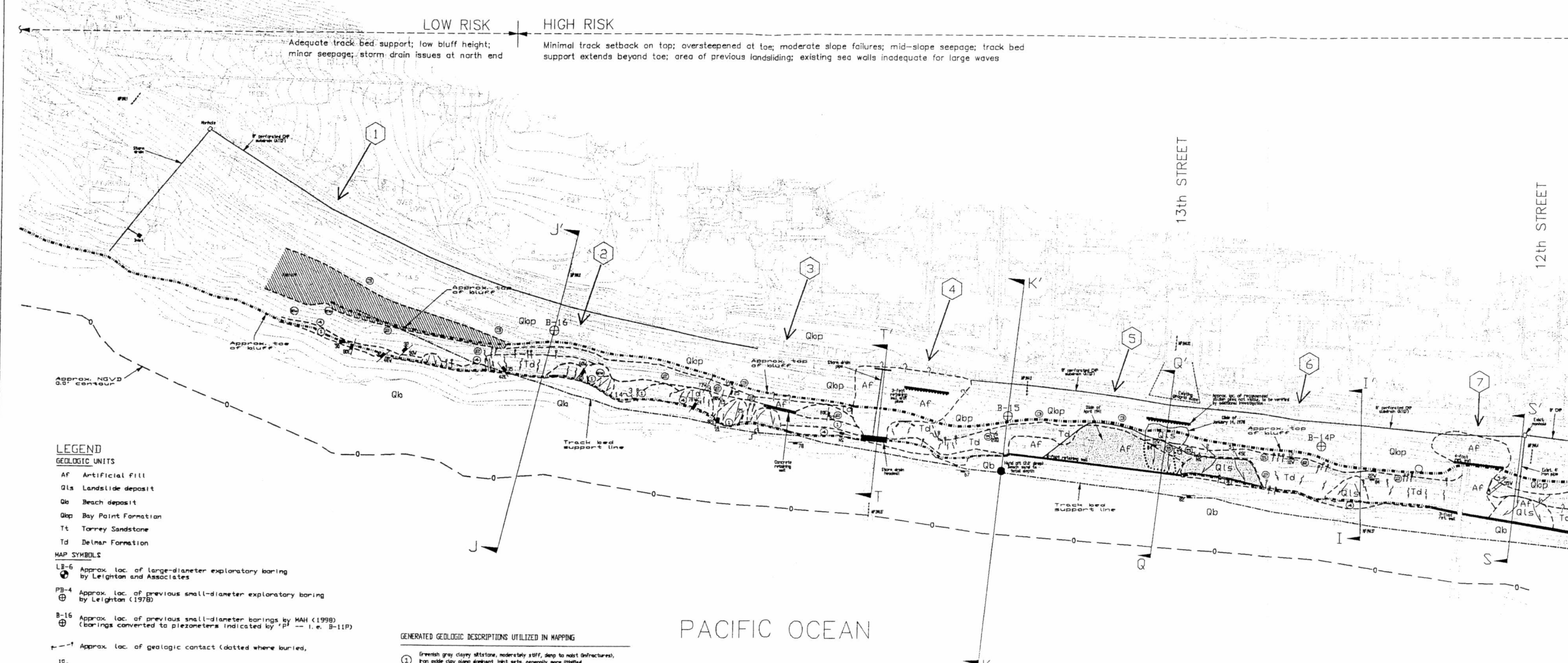
Summary of Risk Assessment

Risk Matrix

As part of our previous geotechnical evaluation (Leighton, 2000), we prepared the Risk Matrix Table included in this Appendix. The Risk Matrix was prepared utilizing 28 separate locations, spaced throughout the study area, each ranked on a variety of factors. The locations of the individual sites are shown on the Site Plan and Geologic maps included with the previous report, and on the "Risk Priority Maps" which follow Table No. 4 in this Appendix. The lateral limits of the area represented by each risk matrix site were then established based on our knowledge of the site conditions and geologic mapping. The limits of each individual risk area are illustrated on the "Risk Priority Maps" and summarized on the following table.

Year 2000	Year 2020
▪ <u>Low Risk Priority Areas</u> 244.10 to 244.19 245.37 to 245.70	▪ <u>Low Risk Priority Areas</u> 244.10 to 244.19 245.50 to 245.70
▪ <u>Medium Risk Priority Areas</u> 244.43 to 244.46 244.51 to 244.69 244.80 to 245.21	▪ <u>Medium Risk Priority Areas</u> 244.62 to 244.69 244.77 to 244.79 244.83 to 245.17 245.38 to 245.50
▪ <u>High Risk Priority Areas</u> 244.19 to 244.43 244.46 to 244.51 244.69 to 244.80 245.21 to 245.37	▪ <u>High Risk Priority Areas</u> 244.19 to 244.62 244.69 to 244.77 244.79 to 244.83 245.17 to 245.38

North



- LEGEND**
- GEOLOGIC UNITS**
- AF Artificial fill
 - Qls Landslide deposit
 - Qb Beach deposit
 - Qkp Bay Point Formation
 - Tt Torrey Sandstone
 - Td Delmar Formation
- MAP SYMBOLS**
- LB-6 Approx. loc. of large-diameter exploratory boring by Leighton and Associates
 - PB-4 Approx. loc. of previous small-diameter exploratory boring by Leighton (1978)
 - B-16 Approx. loc. of previous small-diameter borings by MAH (1998) (borings converted to piezometers indicated by 'P' - i.e. B-16P)
 - - - Approx. loc. of geologic contact (dotted where buried)
 - 10° Strike and dip of bedding
 - 3/ Strike and dip of bedding, uncertain
 - 5/ Strike and dip of undulatory bedding
 - 58° Strike and dip of joints
 - 67° Fault, showing trend and plunge
 - I Seepage
 - J-J' Geologic cross-section
 - 1 Risk matrix site

- GENERATED GEOLOGIC DESCRIPTIONS UTILIZED IN MAPPING**
- ① Greenish gray clayey siltstone, moderately stiff, deep to most (structures), iron oxide clay along dominant joint sets, generally more (dotted) south of MP 244.38 with lesser clay content
 - ② Yellowish light brown fine sandy silt, stiff to very stiff, dry to S damp, (dotted) in areas as nuclear land
 - ③ Non-stiffed version of 2
 - ④ Reddish brown fine to medium sandstone with trace silt, very loose to very dense dry to damp
 - ⑤ Gray/light brown fine to medium sandstone, dense, sharp gradual (facing seawards)

NOTE:

Subdrains shown on map based on review of ATSF documents (ATSF, 1978); not all subdrains observed during field mapping

MATCHLINE (SEE SHEET 2 OF 5)

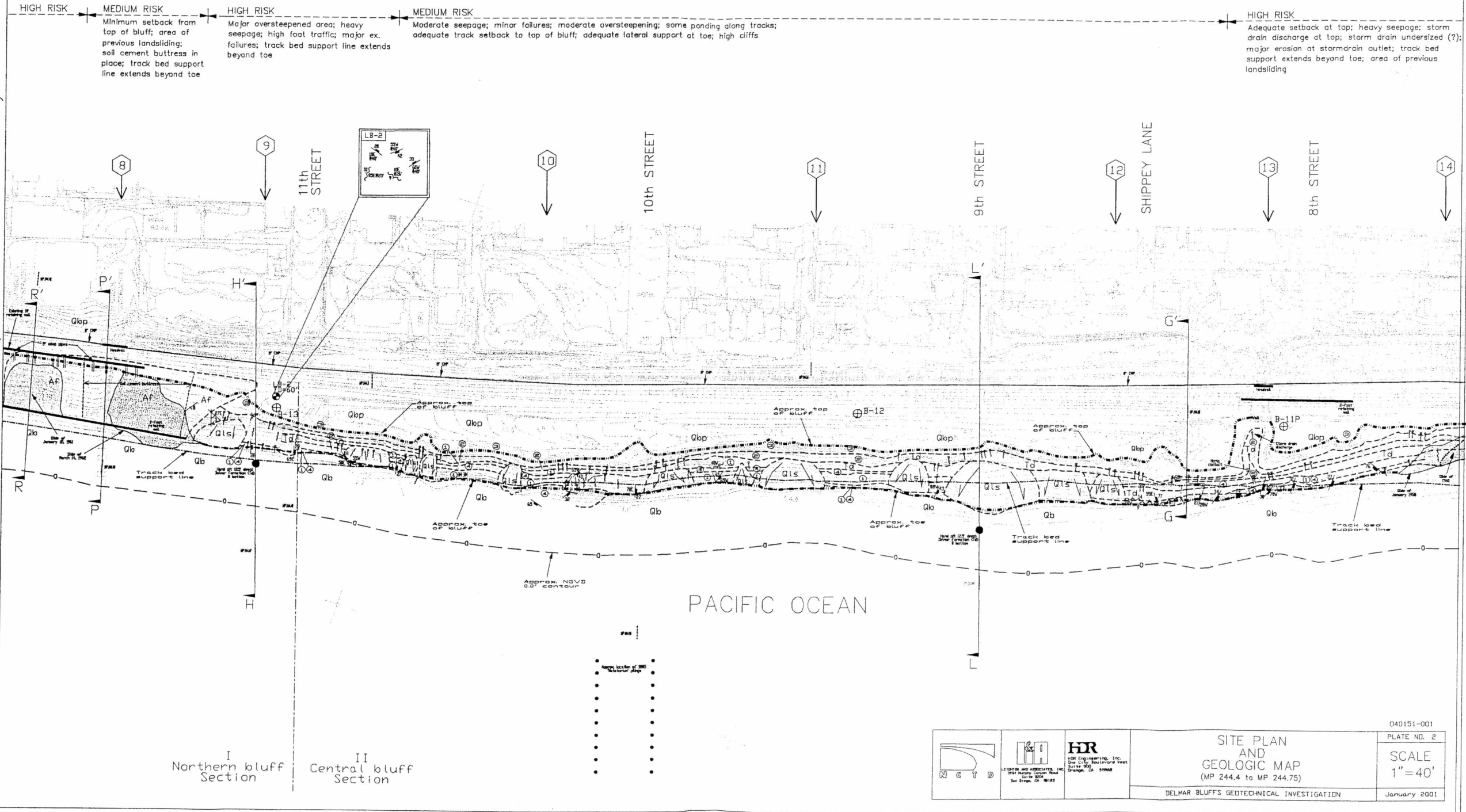
	SITE PLAN AND GEOLOGIC MAP (Coast Blvd. to MP 244.4)	040151-001
		PLATE NO. 1
		SCALE 1"=40'
DELMAR BLUFFS GEOTECHNICAL INVESTIGATION		January 2001

See Plate No. 1 for Legend.

North

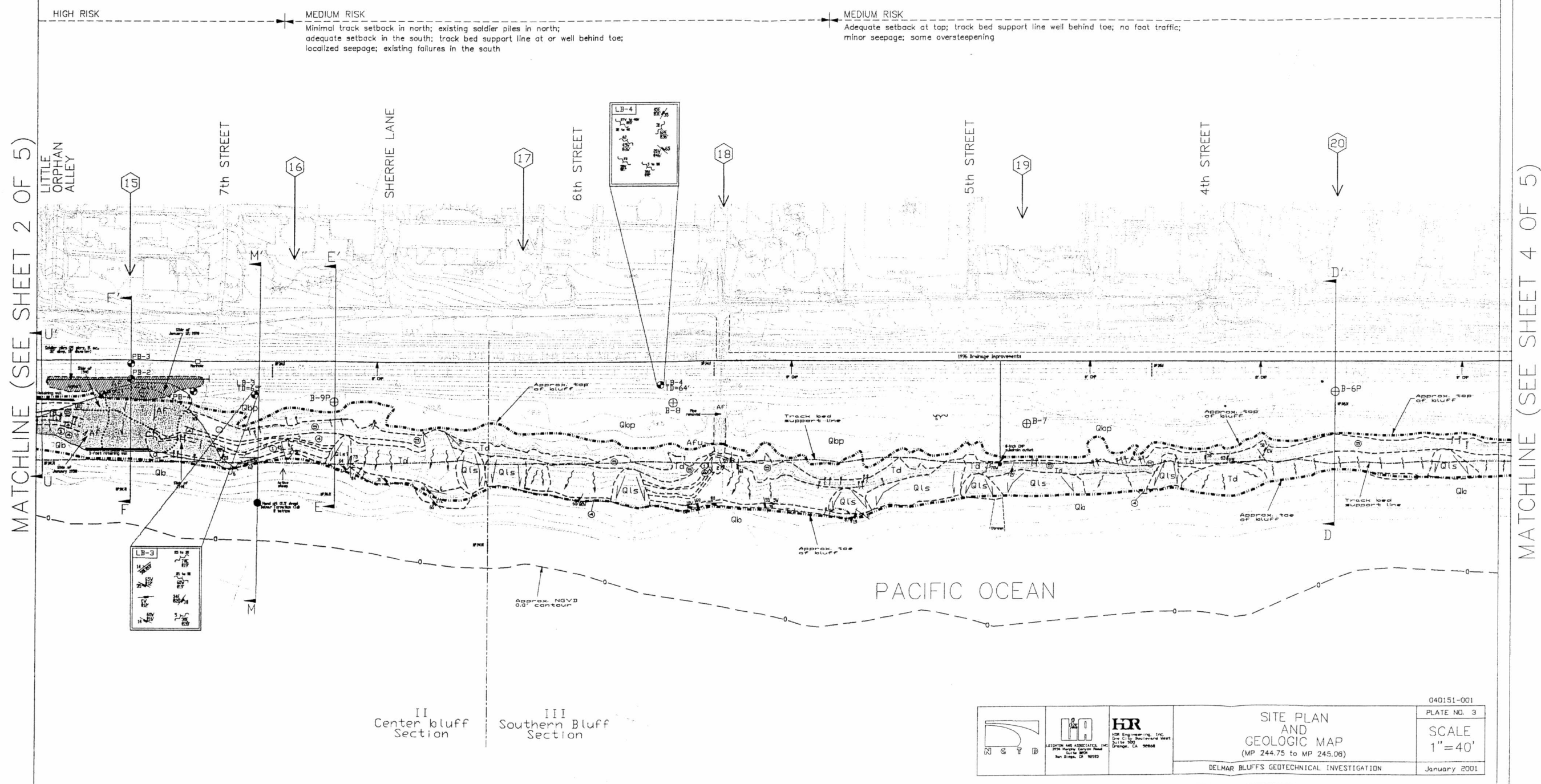
MATCHLINE (SEE SHEET 1 OF 5)

MATCHLINE (SEE SHEET 3 OF 5)



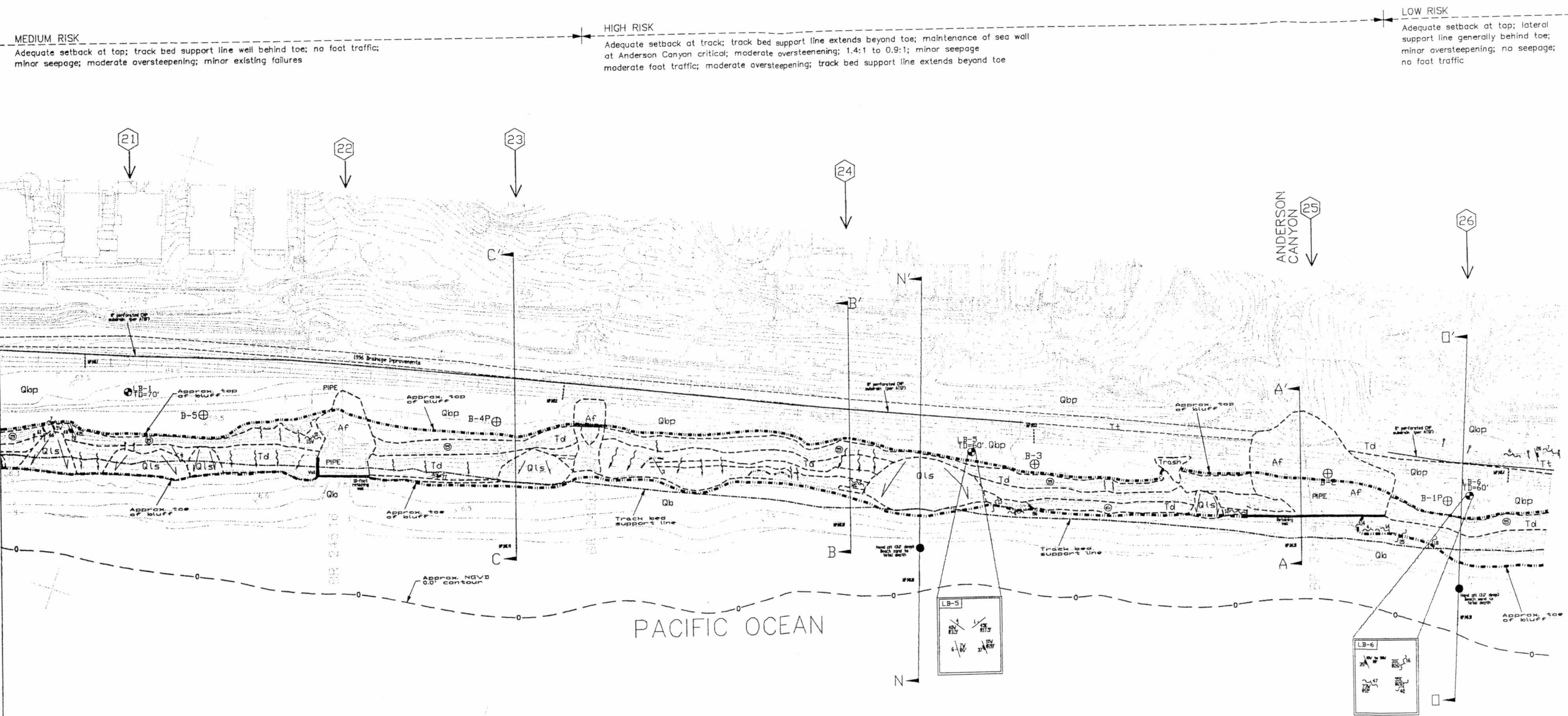
	SITE PLAN AND GEOLOGIC MAP (MP 244.4 to MP 244.75)	040151-001
		PLATE NO. 2
DEL MAR BLUFFS GEOTECHNICAL INVESTIGATION		SCALE 1"=40'
		January 2001

North



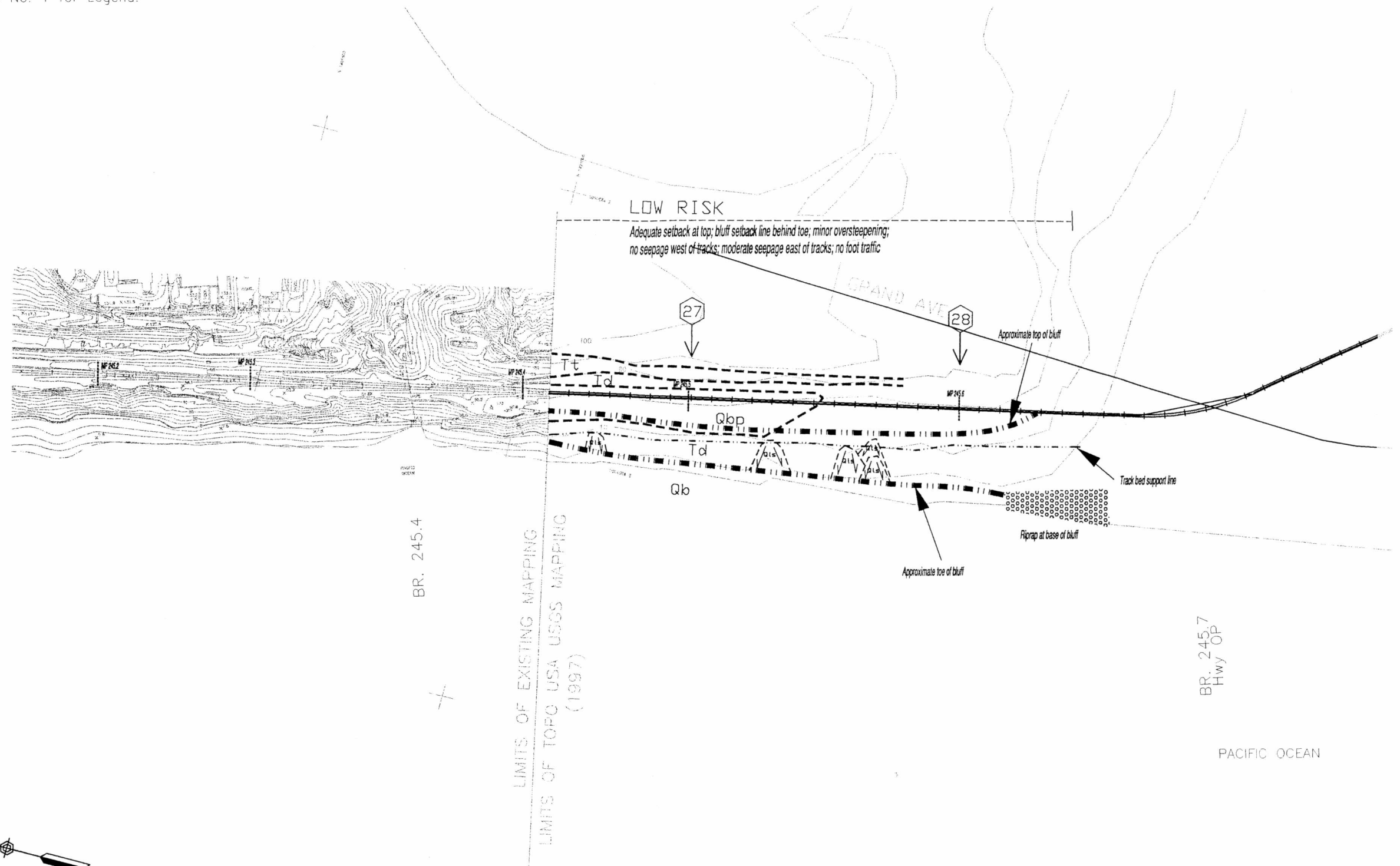
See Plate No. 1 for Legend.

North



	SITE PLAN AND GEOLOGIC MAP (MP 245.06 to MP 245.4) DELMAR BLUFFS GEOTECHNICAL INVESTIGATION	040151-001
		PLATE NO. 4
		SCALE 1"=40' January 2001

See Plate No. 1 for Legend.



			SITE PLAN AND GEOLOGIC MAP (MP 245.4 to Hwy. 101 Overcrossing)	040151-001 PLATE NO. 5 SCALE 1"=100' January 2001
DELMAR BLUFFS GEOTECHNICAL INVESTIGATION				

Conceptual Repair Alternatives

Construction Repair Alternative	Can Be Constructed Within R.O.W.	Meets Duration Requirements	Ability to Gain Approval	Environmental Appeal	Bluff Disturbance Required	Beach Disturbance Required	Impact to Public Areas	Impact to Habitat	Ease of Construction	Effectiveness	Emergency Response Likely	Confidence Level	Remarks
Satus Quo	N/A	No	N/A	High	No	No	No	No	N/A	Low	High	Low	Risky, Potential Huge Cost
Periodic Monitoring	N/A	No	N/A	High	No	No	No	No	N/A	Low	High	Low	High Cost Due to Response Time
Sea Wall at Bluff Toe	No	High	Low	Low	Low	Moderate	High	Moderate	High	High	Low	High	
Revetment	No	High	Low	Low	Low	Moderate	High	Moderate	High	High	Low	High	Easily Removed at a Later Date
Beach Nourishment	No	Moderate	Moderate	High	No	Low	Low	Low	High	Low	Moderate	Low	Short Term (5 Years)
Beach Nourishment with Geogrid Tube	No	Moderate	Moderate	High	No	Moderate	Moderate	Low	High	Moderate	Moderate	High	
Slope Grading	Partial	High	Moderate	Moderate	High	Low	High	High	High	High	Low	High	
Slope Grading with Geogrid	Partial	High	Moderate	Low	High	Low	High	High	High	High	Low	High	
Slope Grading with Soil Cement	Partial	High	Moderate	Low	High	Low	High	High	High	High	Low	High	
Pipe & Board Walls	Partial	High	Moderate	Moderate	Moderate	No	Moderate	Moderate	High	High	Moderate	High	System Can be Modified Over Time
Bluff Top Grading	Partial	Moderate	Low	Low	High	No	High	High	Moderate	Moderate	Moderate	Moderate	
Soldier Piles	Yes	High	High	Moderate	No	No	Low	Low	High	High	Low	High	
Soldier Pile with Wall	Yes	High	High	High	No	No	Low	Low	High	High	Low	High	
Embedded Soldier Pile and Grade Beam with Tie-Backs	Yes	High	High	High	Moderate	No	Low	Low	High	High	Low	High	
Soldier Pile with Wall and Tiebacks	Yes	High	High	Moderate	Moderate	No	Low	Low	High	High	Low	High	
Embedded Soil Nails/Micro-Piles	Yes	Moderate	High	High	Moderate	No	Low	Low	High	Moderate	Low	Moderate	
Storm Drain Outlets	No	Moderate	Moderate	High	Moderate	Low	Low	Low	High	High	High	High	
Surface Drainage	Partial	Moderate	High	High	Low	No	Low	Low	High	High	Moderate	Low	
Interceptor Subdrain	Yes	Moderate	High	High	No	No	Low	Low	High	High	Low	Moderate	Drainage Improved in Combination with Other Alternative
Concrete Lined Ditch with Subdrain	Yes	Moderate	High	High	No	No	Low	Low	High	High	Low	Moderate	
Dewatering Well with Pump	Yes	Low	High	Low	No	No	Low	Low	Low	Low	Low	Low	
Gravity Dewatering Well	Yes	Moderate	High	High	No	No	Low	Low	Moderate	Moderate	Low	Moderate	
Horizontal Drains	No	Low	High	Moderate	Moderate	No	Low	Low	Low	Low	Moderate	Low	