# ATTACHMENT 1

**Approved December 9, 2011 report**
***Hydromodification Screening for California Crossings***

# HYDROMODIFICATION SCREENING

# FOR

# CALIFORNIA CROSSINGS

**(P06-102, TPM 21046, Log No. 93-19-0006AA)**

**December 9, 2011**

REGISTERED PROFESSIONAL ENGINEER
WAYNE W. CHANG
No. 46548
Exp. 6/30/13
CIVIL
STATE OF CALIFORNIA


**Wayne W. Chang, MS, PE 46548**

**ChangConsultants**

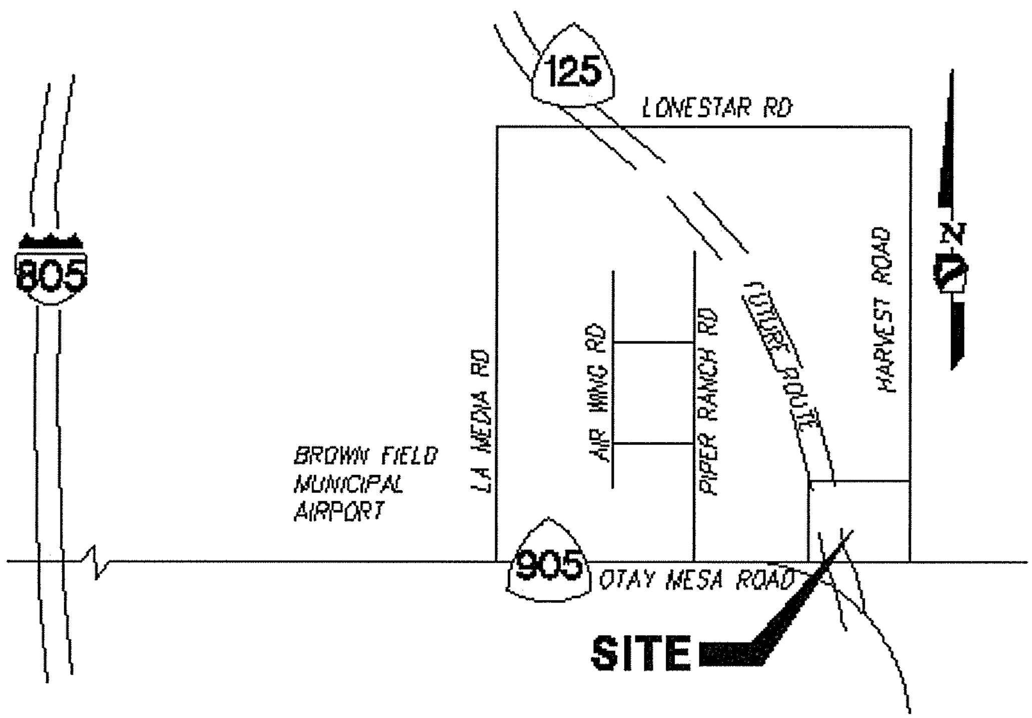
Civil Engineering ◦ Hydrology ◦ Hydraulics ◦ Sedimentation

**P.O. Box 9496**
**Rancho Santa Fe, CA 92067**
**(858) 692-0760**

# -TABLE OF CONTENTS -

## INTRODUCTION

The County of San Diego's March 2011, *Final Hydromodification Management Plan,* and January 8, 2011, *Standard Urban Stormwater Mitigation Plan* (SUSMP) outline low flow thresholds for hydromodification analyses. The thresholds are based on a percentage of the pre-project 2-year flow ($Q_2$), i.e., $0.1Q_2$ (low), $0.3Q_2$ (medium), or $0.5Q_2$ (high). A threshold of $0.1Q_2$ represents a downstream receiving conveyance system with a high susceptibility to erosion. This is the default value used for hydromodification analyses and will result in the most conservative (greatest) on-site facility sizing. A threshold of $0.3Q_2$ or $0.5Q_2$ represents downstream receiving conveyance systems with a medium or low susceptibility to erosion, respectively. In order to qualify for a medium or low susceptibility rating, a project must perform a channel screening analysis based on a "hydromodification screening tool" procedure developed by the Southern California Coastal Water Research Project (SCCWRP). The SCCWRP results are compared with the critical shear stress calculator results from the County of San Diego's BMP Sizing Calculator to establish the appropriate susceptibility threshold of low, medium, or high.




**Vicinity Map**

This report provides hydromodification screening analyses for the California Crossings project being designed by Project Design Consultants, which is located immediately northeast of the intersection of Otay Mesa Road and State Route 125 (South Bay Expressway) in the county of San Diego (see the Vicinity Map above as well as the Study Area Exhibit and Site Plan in the map pocket). The site covers over 28 acres and is gently sloping to the south and southwest. The site is currently undeveloped and primarily supports natural vegetation consisting of grasses, weeds, and an isolated area with a stand of cacti. There is some off-site runoff onto the site from the north and east.

Surface runoff from the site and tributary off-site areas generally flows in a southerly to southwesterly direction. The runoff is ultimately collected by a double 6-foot wide by 2-foot high reinforced concrete box culvert at the southwest corner of the site (see the Caltrans plans in the map pocket and Figures 1 and 3). The double box culvert conveys the runoff south across Otay Mesa Road and then outlets onto a concrete apron/drop structure and into a stilling basin with concrete banks and a natural bottom (see Caltrans Plan DD-39 and Figures 1 to 4). A third box culvert also outlets into the stilling basin adjacent to the double box culverts. The runoff is conveyed out of the stilling basin in a westerly direction by a naturally-lined trapezoidal channel (see Figure 4). The channel has a 3 meter (9.8 feet) bottom width, 2 to 1 (horizontal to vertical) side slopes, and 1.2 to 2.2 meter (3.9 to 7.2 foot) height. The trapezoidal channel continues west for over 270 feet, bends towards the south through a 50 meter (164 foot) radius, then continues south for approximately 335 feet. Per the Caltrans plans, the southerly segment of the channel gradually widens from 3 to 15 meters (49 feet) and the height steadily decreases from 1.2 to 0 meters. As runoff exits the south end of the channel it spreads broadly over the natural ground surface.

The SCCWRP screening tool requires both office and field work to establish the vertical and lateral susceptibility of a downstream receiving channel to erosion. The vertical and lateral assessments are performed independently of each other although the lateral results can be affected by the vertical rating. A screening analysis was performed to assess the low flow threshold for the point of compliance, which is at the outlet of the box culverts into the stilling basin.

The initial step in performing the SCCWRP screening analysis is to establish the domain of analysis and the study reaches within the domain. This is followed by office and field components of the screening tool along with the associated analyses and results. The following sections cover these procedures in sequence.

## DOMAIN OF ANALYSIS

SCCWRP defines an upstream and downstream domain of analysis, which establish the study limits. The County of San Diego's HMP specifies the downstream domain of analysis based on the SCCWRP criteria. The HMP indicates that the downstream domain is the first point where one of these is reached:

- at least one reach downstream of the first grade control point
- tidal backwater/lentic waterbody
- equal order tributary
- accumulation of 50 percent drainage area for stream systems or 100 percent drainage area for urban conveyance systems (storm drains, hardened channels, etc.)

The upstream limit is defined as:

- proceed upstream for 20 channel top widths or to the first grade control point, whichever comes first. Identify hard points that can check headward migration and evidence of active headcutting.

SCCWRP defines the maximum spatial unit, or reach (a reach is circa 20 channel widths), for assigning a susceptibility rating within the domain of analysis to be 200 meters (656 feet). If the domain of analysis is greater than 200 meters, the study area should be subdivided into smaller reaches of less than 200 meters for analysis. Most of the units in the HMP's SCCWRP analysis are metric. Metric units are used in this report only where given so in the HMP or Caltrans plans. Otherwise English units are used.

*Downstream Domain of Analysis*
The downstream domain of analysis for the study area has been determined by assessing and comparing the four bullet items above. The project runoff will discharge into a double box culvert that outlets into a stilling basin. The stilling basin is the point of compliance (POC) and seen in Figure 4. The downstream domain of analysis will be selected below this POC.

Per the first bullet item, the first permanent grade control below the box culvert discharge point is a riprap grade control just at the outlet of the stilling basin (see Caltrans Plan DD-39). Sediment has deposited over and buried a portion of the riprap. The downstream domain of analysis based on the first bullet item will be one reach (656 feet) downstream of the riprap grade control.

The second bullet item is the tidal backwater or lentic (standing or still water such as ponds, pools, marshes, lakes, etc.) waterbody location. The outlet of the trapezoidal channel discharges onto a broad ground surface that forms a lentic waterbody. The lentic area is seen in the Study Area Exhibit as the patch of green marshy vegetation surrounded by the brown upland-type areas and graded areas. Ponded water is evident in portions of the green marsh. Figures 10 through 12 also show the lentic waterbody, but the vegetation is brown since the photographs were taken in the fall. The southerly and westerly perimeter of the lentic waterbody is surrounded by an earthen berm and/or fencing, which confines surface flow and maintains the lentic feature of this marsh area.

The final two bullet items are related to the tributary drainage area. The drainage area encompassing the site, its tributary off-site area, and the trapezoidal channel are delineated on the Study Area Exhibit and covers over 85 acres. The trapezoidal channel discharges directly into the lentic waterbody. As a result, a 50 percent or equal order (100 percent) tributary does not apply because the downstream domain of analysis for the 85 acre area will not extend beyond the lentic waterbody, i.e., the downstream domain of analysis stops at the lentic waterbody, which occurs before an equal order tributary is reached.

Based on the above information, the lentic water body just beyond the end of the trapezoidal channel was selected as the downstream domain of analysis point for the POC. The downstream domain of analysis could have been selected as one reach downstream of the riprap grade control located at the stilling basin outlet. However, the lentic waterbody was chosen because it is somewhat more conservative, i.e., a longer study reach is analyzed.

*Upstream Domain of Analysis*

The aforementioned box culverts outlet into the uppermost end of the receiving trapezoidal channel. Since the channel does not extend upstream of the box culverts, the upstream domain of analysis location will be at the stilling basin. The concrete bank of the stilling basin also satisfies the definition of the upstream domain of analysis location because it is essentially a grade control that checks headward migration of the natural channel.

*Study Reaches within Domain of Analysis*

The entire domain of analysis extends along the trapezoidal channel from the stilling basin to the lentic waterbody. The total domain of analysis covers approximately 870 feet. The domain of analysis was subdivided into two study reaches with similar characteristics (see the Study Area Exhibit). Reach 1 (upper reach) is just over 620 feet long with a constant bottom width and side slopes, and extends from the POC to where the trapezoidal channel begins to taper out. Reach 2 (lower reach) is nearly 250 feet long and continues from the beginning of the taper to the lentic waterbody. Each reach is within the 656 feet maximum reach length specified by SCCWRP.

## INITIAL DESKTOP ANALYSIS

After the domain of analysis is established, SCCWRP requires an "initial desktop analysis" that involves office work. The initial desktop analysis establishes the watershed area, mean annual precipitation, valley slope, and valley width. These terms are defined in Form 1, which is included in Appendix A. SCCWRP recommends the use of National Elevation Data (NED) to determine the watershed area, valley slope, and valley width. The NED data is similar to USGS mapping, so it is not very detailed. For this report, Caltrans' as-built design drawings were used for the trapezoidal channel, while 1-foot contour interval topographic mapping prepared for the project was used for the project and surrounding area. A site investigation was performed that confirmed the accuracy of these sources. In addition, PDC provided their most up-to-date engineering drawings for the proposed development.

The watershed area tributary to the proposed project was established by the post-project hydrologic analysis by PDC. The PDC watershed was delineated using the 1-foot contour interval topographic mapping, their post-project engineering plans, and Caltrans' as-built plans. This watershed area is included on the Study Area Exhibit. The watershed area was extended downstream to include Reaches 1 and 2. The areas extended downstream were also based on the topographic mapping and Caltrans plan. A site investigation was performed to delineate part of the southeasterly portion of the watershed because recent topographic mapping was not available for this area. Based on the watershed delineations, the drainage areas tributary to the downstream end of Reaches 1 and 2 are 85.17 and 85.59 acres (0.1331 and 0.1337 square miles), respectively.

The mean annual precipitation was obtained from the closest rain gage to the site with extensive historic data. This was the Western Regional Climate Center's Chula Vista gage (see Appendix

A). The average rainfall measured at this gage for the period of record from 1918 to 2010 is 9.75 inches.

The valley slope of Reaches 1 and 2 were determined from the Caltrans' as-built drawings for the trapezoidal channel. The valley slope is the longitudinal slope of the channel bed along the flow line, so it is determined by dividing the elevation difference within a reach by the flow path. The valley width is the bottom width of the trapezoidal channel. The valley width within Reach 1 is constant. The valley width with Reach 2 gradually tapers out as the channel extends to the south. The valley slope and valley width within each reach are summarized in Table 1.

| Reach | Valley Slope, m/m | Valley Width, m |
|---|---|---|
| 1 | 0.0056 | 3 |
| 2 | 0.0056 | 3 to 15 |

**Table 1. Summary of Valley Slope and Valley Width**

These values were input to a spreadsheet to calculate the simulated peak flow, screening index, and valley width index outlined in Form 1. The input data and results are tabulated in Appendix A. The analysis for Reach 2 was based on the average channel width within the taper which is 9 meters. This completes the initial desktop analysis.

## FIELD SCREENING

After the initial desktop analysis is complete, a field assessment must be performed. The field assessment is used to establish a natural channel's vertical and lateral susceptibility to erosion. SCCWRP states that although they are admittedly linked, vertical and lateral susceptibility are assessed separately for several reasons. First, vertical and lateral responses are primarily controlled by different types of resistance, which, when assessed separately, may improve ease of use and lead to increased repeatability compared to an integrated, cross-dimensional assessment. Second, the mechanistic differences between vertical and lateral responses point to different modeling tools and potentially different management strategies. Having separate screening ratings may better direct users and managers to the most appropriate tools for subsequent analyses.

The field screening tool uses combinations of decision trees and checklists. Decision trees are typically used when a question can be answered fairly definitively and/or quantitatively (e.g., $d_{50}$ < 16 mm). Checklists are used where answers are relatively qualitative (e.g., the condition of a grade control). Low, medium, high, and very high ratings are applied separately to the vertical and lateral analyses. When the vertical and lateral analyses return divergent values, the most conservative value shall be selected as the flow threshold for the hydromodification analyses.

*Vertical Stability*

The purpose of the vertical stability decision tree (Figure 6-4 in the County of San Diego HMP) is to assess the state of the channel bed with a particular focus on the risk of incision (i.e., down cutting). The decision tree is included in Figure 16. The first step is to assess the channel bed resistance. There are three categories defined as follows:

1. Labile Bed – sand-dominated bed, little resistant substrate.

2. Transitional/Intermediate Bed – bed typically characterized by gravel/small cobble, Intermediate level of resistance of the substrate and uncertain potential for armoring.

3. Threshold Bed (Coarse/Armored Bed) – armored with large cobbles or larger bed material or highly-resistant bed substrate (i.e., bedrock).

Figures 13 and 14 show photographs of the bed material within the study reach. A gravelometer is included in the photographs for reference. Each square on the gravelometer indicates grain size in millimeters (the squares range from 2 mm to 180 mm). Based on the photographs and site investigation, the bed material and resistance is generally within the transitional/intermediate bed category. There was no evidence of a threshold bed condition. However, some bed areas contained smaller grain sizes typically found in a labile bed. A pebble count was performed (see discussion near the end of this section) that determined the median ($d_{50}$) bed material size to be 8 millimeters (mm) in Reach 1 and 2. Figure 6-4 in the County HMP indicates that a $d_{50}$ less than 16 mm is within the labile bed category. The figure also identifies that the bed material in a labile bed is "loosely-packed." Although the Reach 1 and 2 channels have an 8 mm median size, the channels do not meet the criteria of containing loosely-packed material. The channels were engineered and were as-built by Caltrans in 2010 (see attached Caltrans plans). As a result, the channels were designed and compacted in accordance with established engineering and construction standards.

In addition to the material size and compaction, there are several factors that establish the erodibility of a channel such as the flow rate (i.e., size of the tributary area), grade controls, channel slope, vegetative cover, channel planform, etc. The Introduction of the SCCWRP *Hydromodification Screening Tools: Field Manual* identifies several of these factors. When multiple factors influence erodibility, it is appropriate to perform the more detailed SCCWRP analysis, which is to analyze a channel according to SCCWRP's transitional/intermediate bed procedure. This requires the most rigorous steps and will generate the appropriate results given the range of factors that define erodibility. The transitional/intermediate bed procedure takes into account that bed material may fall within the labile category (the bed material size is used in SCCWRP's Form 3 Figure 4), but other factors may trend towards a less erodible condition. Dr. Eric Stein from SCCWRP, who co-authored the *Hydromodification Screening Tools: Field Manual* in the *Final Hydromodification Management Plan* (HMP), indicated that it would be appropriate to analyze channels with multiple factors that impact erodibility using the transitional/intermediate bed procedure. Consequently, this procedure was used to produce more accurate results.

Transitional/intermediate beds cover a wide susceptibility/potential response range and need to be assessed in greater detail to develop a weight of evidence for the appropriate screening rating. The three primary risk factors used to assess vertical susceptibility for channels with transitional/intermediate bed materials are:

1. Armoring potential – three states (Checklist 1)

2. Grade control – three states (Checklist 2)

3. Proximity to regionally-calibrated incision/braiding threshold (Mobility Index Threshold – Probability Diagram)

These three risk factors are assessed using checklists and a diagram (see Appendix B), and the results of each are combined to provide a final vertical susceptibility rating for the intermediate/transitional bed-material group. Each checklist and diagram contains a Category A, B, or C rating. Category A is the most resistant to vertical changes while Category C is the most susceptible.

Checklist 1 determines armoring potential of the channel bed. The channel bed along each of the two reaches is within Category B, which represents intermediate bed material within unknown armoring potential due to a surface veneer and dense vegetation. The soil was probed and penetration was relatively difficult through the underlying layer. This resistant layer is likely because the channel was recently constructed as an engineered channel.

Checklist 2 determines grade control characteristics of the channel bed. This is based on the spacing of the grade controls. Category A on Checklist 2 is based on a spacing of $2/S_v$. $S_v$ is 0.0056 from the Form 1 analysis in Appendix A, so $2/S_v$ is 357 meters or 1,171 feet. There is a riprap grade control at the upper end of Reach 1, but this only prevents scour protection for the upstream stilling basin. The lentic waterbody is considered to be a grade control for Reach 1 and 2 because the ponded water will prevent upstream headcutting. If water ponds up high enough within the lentic waterbody, the release point is through a riprap-lined spillway located near the southeast corner of the lentic waterbody (see the Study Area Exhibit and Figure 15). The riprap-lined spillway is another grade control. The total length of Reaches 1 and 2 are approximately 620 and 250 feet, respectively (870 feet total). The additional distance to the spillway is 300 feet or 1,170 feet total. These lengths are less than $2/S_v$ so both reaches are within Category A on Checklist 2. A field walk along the study area did not reveal evidence of headcutting or mass wasting (see figures), so the grade controls are effective.

The Mobility Index Threshold is a probability diagram that depicts the risk of incising or braiding based on the potential stream power of the valley relative to the median particle diameter. The threshold is based on regional data from Dr. Howard Chang of Chang Consultants and others. The probability diagram is based on $d_{50}$ as well as the Screening Index determined in the initial desktop analysis (see Appendix A). $d_{50}$ is derived from a pebble count in which a minimum of 100 particles are obtained along transects at the site. SCCRWP states that if fines less than ½-inch thick are at a sample point, it is appropriate to sample the coarser buried substrate. The $d_{50}$ value is the particle size in which 50 percent of the particles are smaller and 50 percent are larger. The pebble count results for Reach 1 and 2 are included in Appendix B. The results show a $d_{50}$ of 8 millimeters for each area. The screening index for Reach 1 and 2 are tabulated in Appendix A. Plotting the $d_{50}$ and screening index values on the Mobility Index

Threshold diagram shows that both Reach 1 and 2 have a less than 50 percent probability of incising or braiding (even less than 10 percent), which falls within Category A.

The overall vertical rating is determined from the Checklist 1, Checklist 2, and Mobility Index Threshold results. The scoring is based on the following values:

Category A = 3, Category B = 6, Category C = 9

The vertical rating score is based on these values and the equation:

$$\begin{aligned} \text{Vertical Rating} &= [(\text{armoring} \times \text{grade control})^{1/2} \times \text{screening index score}]^{1/2} \\ &= [(6 \times 3)^{1/2} \times 3]^{1/2} \\ &= 3.6 \end{aligned}$$

Since the vertical rating is less than 4.5, each reach has a low threshold for vertical susceptibility.

*Lateral Stability*

The purpose of the lateral decision tree (Figure 6-5 from County of San Diego HMP included in Figure 17) is to assess the state of the channel banks with a focus on the risk of widening. Channels can widen from either bank failure or through fluvial processes such as chute cutoffs, avulsions, and braiding. Widening through fluvial avulsions/active braiding is a relatively straightforward observation. If braiding is not already occurring, the next logical step is to assess the condition of the banks. Banks fail through a variety of mechanisms; however, one of the most important distinctions is whether they fail in mass (as many particles) or by fluvial detachment of individual particles. Although much research is dedicated to the combined effects of weakening, fluvial erosion, and mass failure, SCCWRP found it valuable to segregate bank types based on the inference of the dominant failure mechanism (as the management approach may vary based on the dominant failure mechanism). A decision tree (Form 4 in Appendix B) is used in conducting the lateral susceptibility assessment. Definitions and photographic examples are also provided below for terms used in the lateral susceptibility assessment.

The first step in the decision tree is to determine if lateral adjustments are occurring. The adjustments can take the form of extensive mass wasting (greater than 50 percent of the banks are exhibiting planar, slab, or rotational failures and/or scalloping, undermining, and/or tension cracks). The adjustments can also involve extensive fluvial erosion (significant and frequent bank cuts on over 50 percent of the banks). Neither mass wasting nor extensive fluvial erosion was evident within any of the reaches during a field investigation. The banks are intact in the photographs included in the figures. The relatively uniform vegetative cover on the banks is evidence of the absence of large lateral adjustments.

The next step in the Form 4 decision tree is to assess the consolidation of the bank material. The banks were moderate to well-consolidated. This determination was made because the banks were difficult to penetrate with a probe. In addition, the banks showed limited evidence of crumbling and were composed of well-packed particles (see figures). This is likely due to the fact that the channel was recently constructed by Caltrans in accordance with engineering standards for compaction and stability.

Form 6 (see Appendix B) is used to assess the probability of mass wasting. Form 6 identifies a 10, 50, and 90 percent probability based on the bank angle and bank height. The Caltrans as-built drawings indicate that the trapezoidal channel was constructed with bank angles having a 2 to 1 (horizontal to vertical) slope or 26.6 degrees. Form 6 shows that the probably of mass wasting and bank failure has less than 10 percent risk for a 26.6 degree bank angle or less regardless of the bank height.

The final two steps in the Form 4 decision tree are based on the braiding risk determined from the vertical rating as well as the Valley Width Index (VWI) calculated in Appendix A. If the vertical rating is high, the braiding risk is considered to be greater than 50 percent. Excessive braiding can lead to lateral bank failure. For the Reaches 1 and 2 the vertical rating is low, so the braiding risk is less than 50 percent. Furthermore, a VWI greater than 2 represents channels unconfined by bedrock or hillslope and, hence, subject to lateral migration. The VWI calculations in the spreadsheet in Appendix A show that the VWI for each reach is less than 2.

From the above steps, the lateral susceptibility rating is low (red circles are included on the Form 4: Lateral Susceptibility Field Sheet decision tree in Appendix B showing the decision path).

## CONCLUSION

The SCCWRP channel screening tools were used to assess the downstream channel susceptibility for the California Crossings project. The project runoff will be collected by existing double box culverts at the southwesterly corner of the site. The box culverts cross Otay Mesa Road and discharge into an existing stilling basin. This is the point of compliance. A naturally-lined trapezoidal channel conveys the runoff in a westerly to southerly direction and into a lentic waterbody. The downstream channel assessment for the trapezoidal channel was performed based on office analyses and field work. The results indicate a low threshold for vertical and lateral susceptibilities for the two study reaches.

The HMP requires that these results be compared with the critical stress calculator results incorporated in the County of San Diego's BMP Sizing Calculator. The BMP Sizing Calculator critical stress results are included in Appendix B for Reach 1 and 2. Based on these values, the critical stress results returned a low threshold. Therefore, the SCCWRP analyses and critical stress calculator demonstrate that the project can be designed assuming a low susceptibility to erosion, i.e., $0.5Q_2$.

**Figure 1. Box Culvert Outlets into Stilling Basin**

**Figure 2. Stilling Basin (Box Culverts to Left of Photograph)**

**Figure 3. Box Culverts and Stilling Basin (Site is Behind Upper Road)**

**Figure 5. Looking Upstream (East) Towards Upper End of Reach 1**

**Figure 6. Looking Downstream (West) Towards East-West Segment of Reach 1**

**Figure 7. Looking Downstream (West) Towards East-West Segment of Reach 1Approaching Bend**

**Figure 8. Looking West Towards Beginning of Bend in Reach 1**

**Figure 9. Looking Upstream (North) Towards North-South Segment of Reach 1**

**Figure 10. Looking Downstream (South) Towards Reach 2 and Lentic Waterbody**

**Figure 11. Looking West Towards Lentic Waterbody**

**Figure 12. Looking South within Lentic Waterbody**

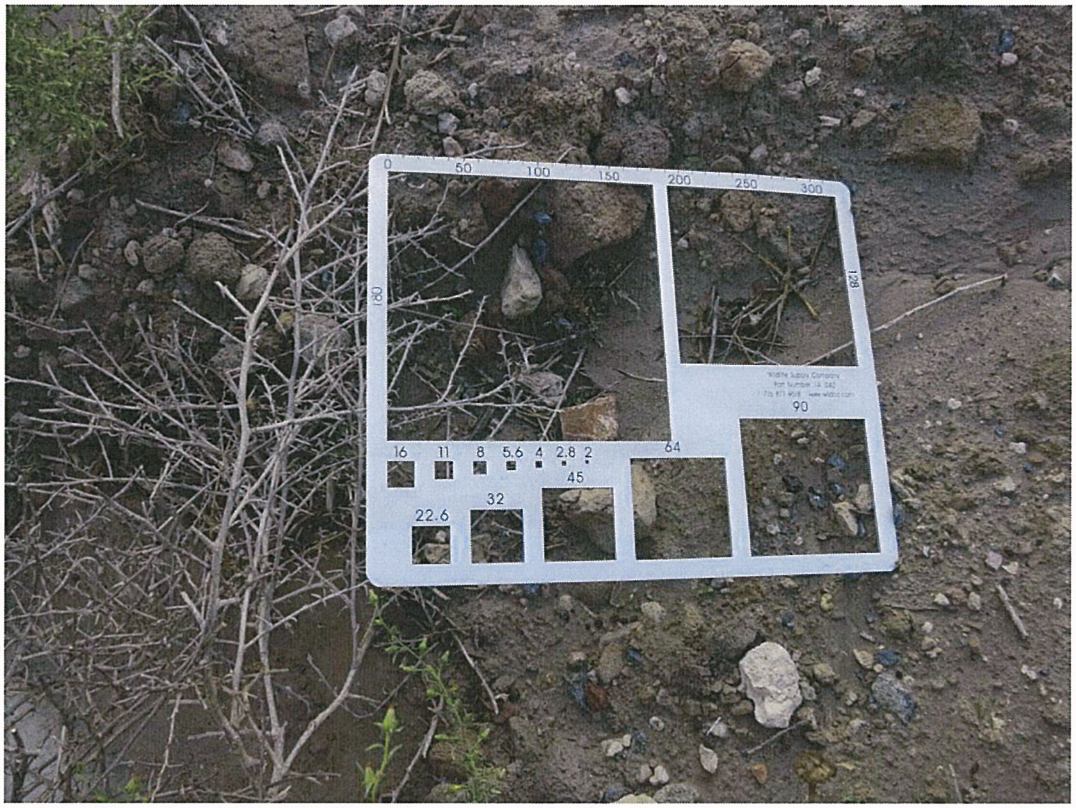



**Figure 13. Gravelometer on Channel Bed Near Upstream End of Study Area**


**Figure 14. Gravelometer on Channel Bed Near Downstream End of Study Area**

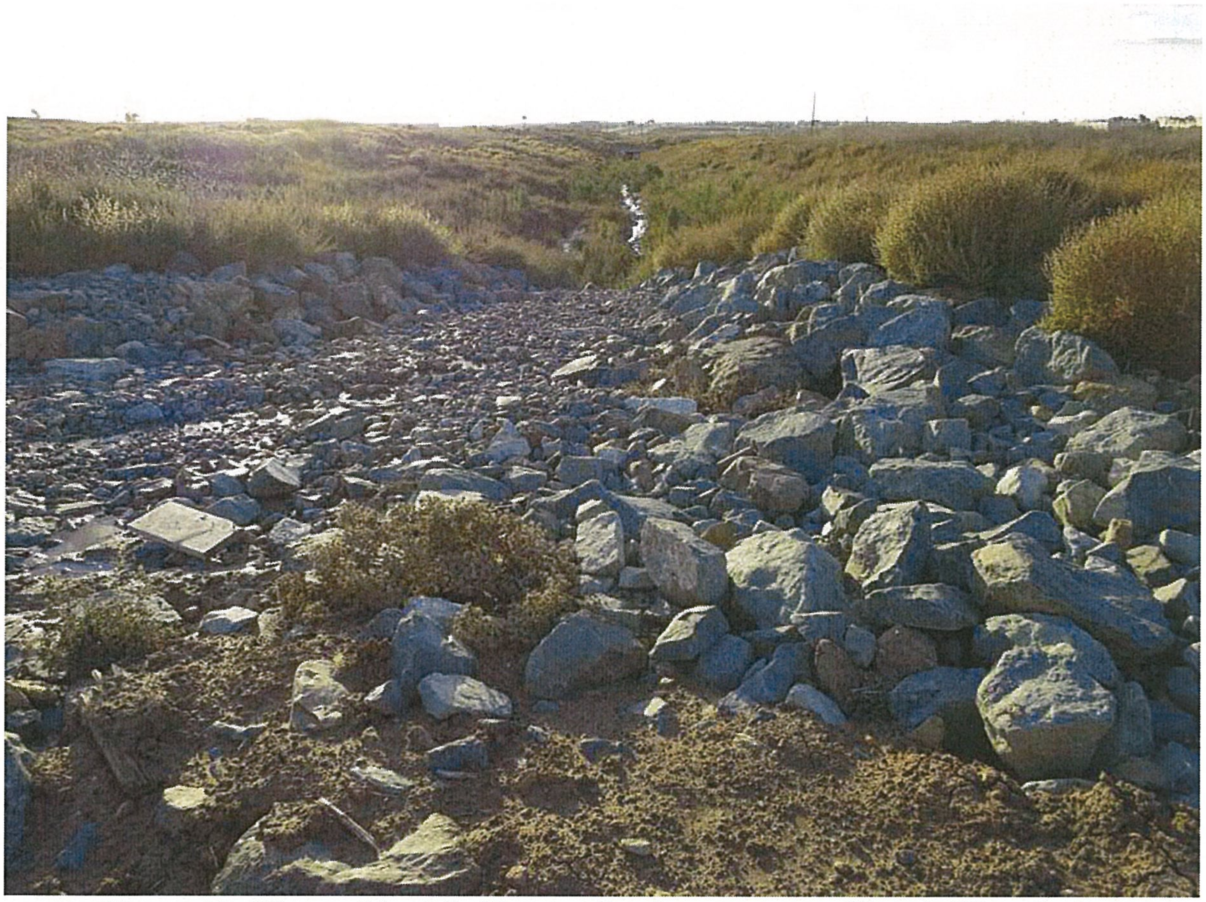


**Figure 15. Riprap-Lined Spillway at Southeast corner of Lentic Waterbody**

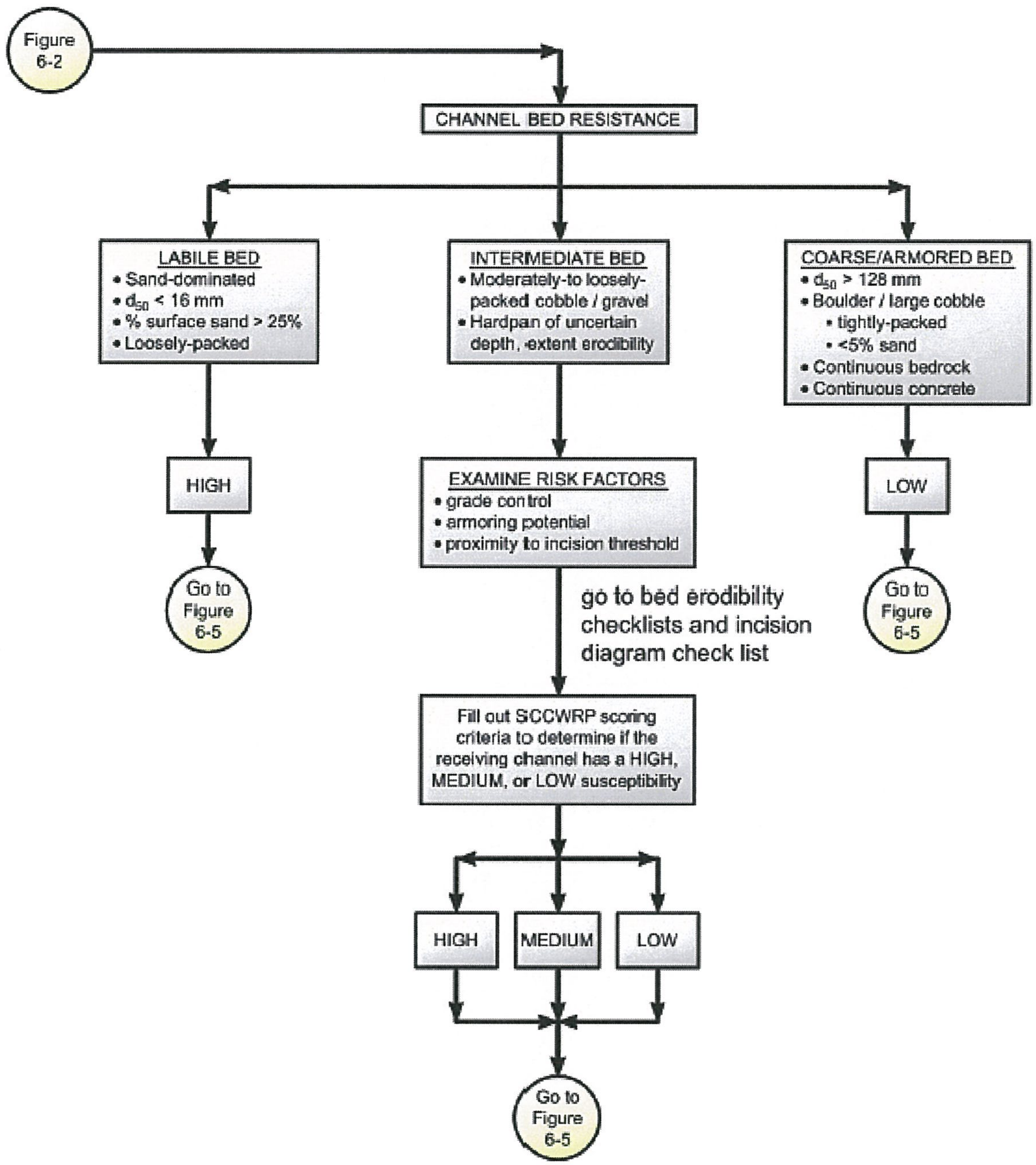



*Figure 6-4. SCCWRP Vertical Susceptibility*

**Figure 16. SCCWRP Vertical Channel Susceptibility Matrix**