California Department of
Resources Recycling and Recovery

Tire-Derived Aggregate: Settlement in Road Slide Repair

Analysis Of Marina Drive, Geysers Road, Sonoma Mountain Road, Palomino Road, Italian Bar Road, Moran Road, And Ortega Ridge Road Repair Projects

Produced Under Contract By:

GHD

2235 Mercury Way, Suite 150
Santa Rosa, CA 95407
Joaquin Wright, Project Manager
GHD #: 12561260

December 2023

State of California
Gavin Newsom
Governor

California Environmental Protection Agency
Yana Garcia
Secretary

Department of Resources Recycling and Recovery
Zoe Heller
Director

Public Affairs Office
1001 I Street (MS 22-B)
P.O. Box 4025
Sacramento, CA 95812-4025
www2.calrecycle.ca.gov/Publications
1-800-RECYCLE (California only) or (916) 341-6300

Publication # DRRR-2024-1745

Prepared as part of contract number DRR 21023

Executive Summary

California has used tire-derived aggregate (TDA) in earthwork construction and civil engineering projects since the 1990s. TDA's lightweight and durable material properties have made it a viable alternative to traditional fill materials, such as soil, particularly for the construction of roadway repairs that decrease the risk of landslides.

However, research on the time-dependent settlement of TDA in roadway repairs is limited, and existing studies lack long-term field performance data. When reliable data is available to predict settlement behavior and design safe road repair using TDA, engineers will be more inclined to incorporate TDA in road repair projects. Using TDA results in longer-lasting repairs and supports California's broader goal of establishing a circular economy. Because of the lack of settlement data for TDA, civil engineers have been less likely to use this material. To address this gap, the California Department of Resources Recycling and Recovery (CalRecycle) conducted a post-construction analysis on the final grades of the first four TDA road and landslide repair projects (TDA Projects) in California: Marina Drive in Mendocino County; Geysers Road in Sonoma County; Sonoma Mountain Road in Sonoma County; and Palomino Road in Santa Barbara County. When constructing road repairs with fill materials that are more compressible than conventional soil, engineers need data on potential settlement to design projects that account for the material's behavior. This study aims to identify the extent and magnitude of time-dependent settlement associated with TDA road repairs.

Over a period of 14 to 16 years, post-construction final grades relative to the TDA fill for these four landslide road repair projects were collected and analyzed. The empirical data collected were used to develop site-specific settlement curves, that were aggregated to develop general TDA settlement curves, which can be used to serve as a tool for engineers to predict settlement when using TDA.

The findings of this study provide valuable support to civil engineers and agencies responsible for road repair and maintenance in their planning efforts. By providing empirical settlement data curves and equations, this study helps engineers feel more confident in using TDA for road repairs.

Based on survey data and field observations from the TDA Projects with a nominal TDA layer thickness of 15-feet, a time-dependent settlement curve was developed. The data shows that the rate of TDA settlement is generally logarithmic, while areas without TDA settle at a linear rate. Notably, the TDA settlement rate (slope of the curve) significantly decreases after 3 years (1,095 days), with approximately 2% strain expected after this period, corresponding to 3.4 inches of settlement for a 15-foot TDA fill.

To limit roadway differential settlement along TDA fill sections, design engineers should integrate TDA settlement insights from this report and adhere to the guidelines outlined in ASTM D6270. This study found that TDA settlement is minimal and decreases within three years of installation, making it a predictable, safe, and reliable material for long-term use in civil engineering projects in California.

Table of Contents

Figures

Tables

Appendices

List of Abbreviations

Act	California Tire Recycling Act
ASTM	American Society of Testing and Materials
CalRecycle	California Department of Resources Recycling and Recovery
Caltrans	California Department of Transportation
CIWMB	California Integrated Waste Management Board
CSBPWD	County of Santa Barbara Public Works Department
EPF	Expanded Polystyrene Foam
ft	foot or feet
GHD	GHD Inc.
in	inches
MENDOT	Mendocino Department of Transportation
MOU	Memorandum of Understanding
MSL	Mean Sea Level
MSTDA	Mechanically Stabilized TDA
psi	Pounds per Square Inch
PTE	Passenger Tire Equivalents
QA	Quality Assurance
QC	Quality Control
State	State of California
TDA	Tire-Derived Aggregate
TDA Projects	Marina Drive in Mendocino County; Geysers Road and Sonoma Mountain Road in Sonoma County; Italian Bar Road in Tuolumne County; Moran Road in Yuba County; and Palomino Road and Ortega Ridge Road in Santa Barbara County

Background

California annually generates approximately 60 million waste tires. To address the need for better waste tire management in the state, the California Legislature enacted Assembly Bill 1843 (Brown, Chapter 974, Statutes of 1989), establishing the California Tire Recycling Act. The Act stipulates the recycling of waste tires by promoting and developing market economies to create a demand for waste tires as an alternative to landfill disposal and illegal stockpiling.

To accomplish these provisions, AB 1843 mandated the California Department of Resources Recycling and Recovery (CalRecycle) to manage waste tires within the state by developing and implementing tire recycling programs to create new and sustainable markets for waste tires. One of these markets is the use of waste tire products in civil engineering applications. Tire shreds (tires cut up into specified sizes) used in lieu of soil, gravel, pumice, and expanded polystyrene foam (EPF) in earthwork projects are referred to as tire-derived aggregate (TDA).

CalRecycle retained GHD to assist with the development of sustainable markets for recycled tires in civil engineering applications. Use of TDA in civil engineering applications includes lightweight fill for embankments, mechanically stabilized retaining walls, drainage material for bioswales, infiltration galleries, stress reduction over underground utilities, vibration damping material for light-rail systems, landfill construction material, thermal insulation practices, and erosion control elements.

This report focuses specifically on the use of TDA in landslide repair projects and presents field data gathered from the project’s construction date through September 2023, to inform the design of future landslide repairs utilizing TDA. GHD will assist CalRecycle with providing education, design, and technical assistance in the proper handling and use of TDA to local jurisdictions, state government agencies, and private entities.

Introduction

Previous studies have demonstrated that tire-derived aggregate (TDA) possesses desirable qualities such as being lightweight, highly permeable, thermally insulating, durable, and compressible (CalRecycle, 2011 & 2013). These material properties make TDA a competitive alternative to conventional fill materials used in earthwork construction and civil engineering applications). TDA has been utilized throughout California for various projects including road slide stabilization, lightweight embankment fill, landfill applications, stormwater infiltration galleries, and vibration attenuation for railways.

This report focuses on the use of TDA in road slide repair projects and evaluates the settlement of seven TDA road and landslide repair projects in the state of California:

- Marina Drive in Mendocino County
- Geysers Road in Sonoma County
- Sonoma Mountain Road in Sonoma County
- Palomino Road and Ortega Ridge Road in Santa Barbara County
- Italian Bar Road in Tuolumne County
- Moran Road in Yuba County

The report presents the post-construction final grades relative to the TDA fill for these projects and summarizes the road surface elevations over time, ranging from one to 16 years. These elevation changes are compared to the initial project elevations for both TDA and adjacent soil fill zones.

Different stabilization methods were used depending on the unique circumstance of each site. Post-construction settlement in road repair projects can impact the long-term maintenance and lifespan of a repair. When designing repairs, civil engineers predict and account for potential settlement by referencing settlement curves developed for each material. This approach helps minimize differential settlement under road surfaces, especially when using multiple fill materials. Identifying the extent and magnitude of settlement associated with the individual TDA repair methods will aid agencies responsible for road repair and maintenance in planning efforts and assist in determining the optimal TDA configurations for future projects.

The lightweight fill method has been used and evaluated for the past 16 years, while data collection and analysis for more recent methods such as mechanically stabilized tire-derived aggregate (MSTDA) and soldier pile wall have been initiated over the past two years. Further details on the data gathered from implementing these two new methods, in conjunction with lightweight fill, are outlined.

Benefits of Using TDA

TDA, derived from shredded waste tires, comes in two commercially available types: Type A (3-inch minus) and Type B (12-inch minus). Road embankment stabilization projects, like those discussed in this report, utilize Type B TDA.

Lightweight Fill

Using TDA in landslide repair applications is more beneficial to soil or other lightweight fill materials. These benefits include:

- Enhanced Stability: Slopes repaired using TDA tend to be more stable than those repaired with soil due to TDA's low density, which reduces the driving force and ultimately increases safety.
- Seismic Resistance: TDA backfill behind retaining walls greatly reduces damaging forces induced by seismic waves compared to soil backfill, as demonstrated by seismic testing.
- Reduced Excavation: Lower driving forces with TDA result in shallower and narrower stabilization of key dimensions, reducing excavation quantities.
- Long-Term Performance: TDA's free-draining nature reduces potentially destabilizing pore pressures, leading to better long-term performance compared to soil slopes.
- Sustainability: Reusing waste tires promotes a circular economy, removes tires from the waste stream, and provides environmentally beneficial uses.
- Construction Advantages (compared to soil):
  - Increased placement productivity because density testing is not required; a method specification (ASTM D6270) is used instead.
  - Construction water is not needed to moisture-condition TDA.
  - During the placement of fill, TDA can be placed on slopes steeper than 5:1.
  - Productivity is increased due to thicker TDA lifts during placement (12 inches vs. 8 inches loose, typical for soil).
  - TDA delivery yield is about 30 cubic yards per load, which is significantly more per load than soil or other lightweight aggregates.
  - TDA can be placed in inclement weather.
  - TDA does not require specialized placement and handling equipment (only standard earthwork equipment is used); and
  - The internal strength and lightweight attributes of TDA allow for higher factors of safety.

Mechanically Stabilized

MSTDA offers all the benefits as lightweight fill, and it accommodates substantial grade changes without needing cast-in-place or other types of cantilever walls.

Soldier Pile Wall

Soldier pile wall applications have all the same benefits as lightweight fill, and can downsize solider piles and lagging.

TDA has a lower density and higher internal shear strength than soil, reducing the driving forces of the fill material applied to the wall. Safety can be maintained while the cost of heavy-duty construction materials can be reduced as soldier piles and lagging are safely downsized.

TDA Gradation

In most large fill projects, Type B TDA is recommended for lightweight backfill material. However, MSTDA projects have effectively used Type A TDA for ease of construction.

The requirements on particle size distribution, particle shape, and steel wire exposure are typically achieved by using a shearing device and passing larger shreds through the shearing device twice.

ASTM D6270 describes the limits on the particle size distribution of Type B TDA, which are shown in Figure 1 (USCD 2021).

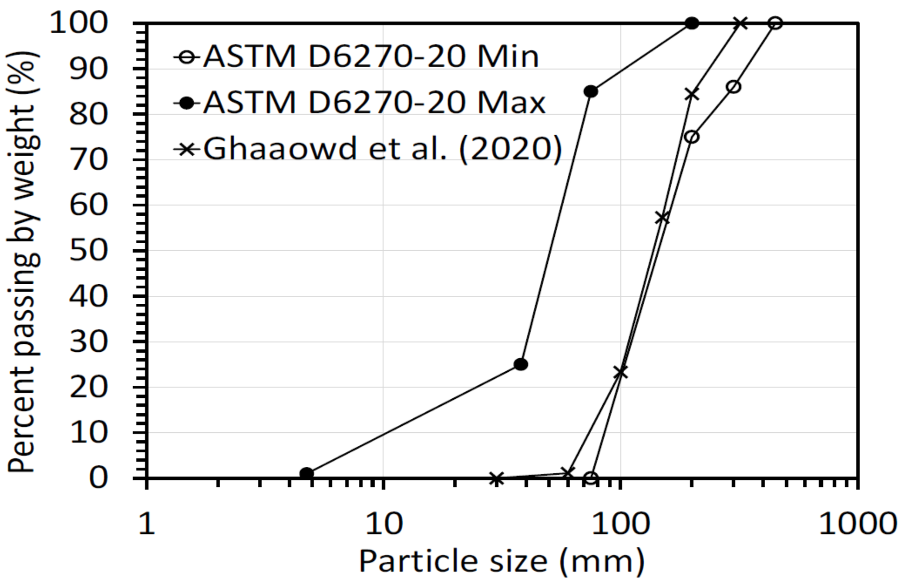


Figure 1. Type B Particle Size Distribution Min and Max

TDA Compression/Settlement

Settlement of road embankments can cause damage to structures and utilities located within the embankment, especially if those facilities are also supported by adjacent soils or foundations that do not settle the same, leading to what is known as differential settlement. Differential settlement in embankments may result in unwanted dips in the roadway and can have adverse effects on the superelevation of curves.

Lightweight Fill

Settlement research has identified two phases of settlement for TDA in roadway embankments: primary settlement and secondary settlement when using the lightweight fill method.

The primary settlement phase is the immediate consolidation that occurs during placement and when surcharge pressures are applied to the TDA lifts or layers. This initial settlement is attributed to the reduction of the pore space or air void volume between the TDA pieces due to initial particle alignment and expected load conditions, which can be imparted by a soil surcharge.

Primary settlement occurs immediately during and shortly after the placement or installation of TDA. The TDA void spaces are reduced by the placement compaction effort and as surcharge pressures are applied to the volume. Because primary settlement incorporates forces from overlying materials, such as an engineered road section, it is important to note that the initial settlement period can be shortened by placing an amount of surcharge greater than the road section unit mass. This technique is used immediately after the TDA fill has been completed.

Given the compressible nature of TDA, it is recommended to overbuild the TDA fill during construction. The amount of overbuild can be determined using the procedure outlined in Appendix D, based on the TDA Usage Guide by CalRecycle. Once the road section fill is complete, the secondary (long-term) settlement phase begins.

Secondary settlement occurs over extended periods and can continue for many years after material placement. It has been postulated that long-term settlement occurs from the relaxation of the TDA pieces and subsequent reduction of void space over time. Long-term settlement considerations are crucial in the design of TDA structures or projects to be placed on TDA structures:

> “Time-dependent compression of TDA will occur over the service life of a typical geotechnical engineering project. Because immediate compression usually occurs prior to placement of settlement-sensitive components, the deformation resulting from the time-dependent compression may ultimately govern the long-term performance and serviceability of a TDA structure. For this reason, time-dependent settlement will be the most important when thick layers of TDA are used in geotechnical systems having long service lives.” (Wartman et al., 2007)

Wartman et al., (2007) investigated the relationship between secondary settlement and time, and developed the following equation to determine time-dependent settlement:

$$\Delta H_t = 3.28 H C_{\alpha\epsilon} log \frac{t_2}{t_1}$$

where ΔH_t = settlement depth, feet

H = thickness of the TDA layer, feet

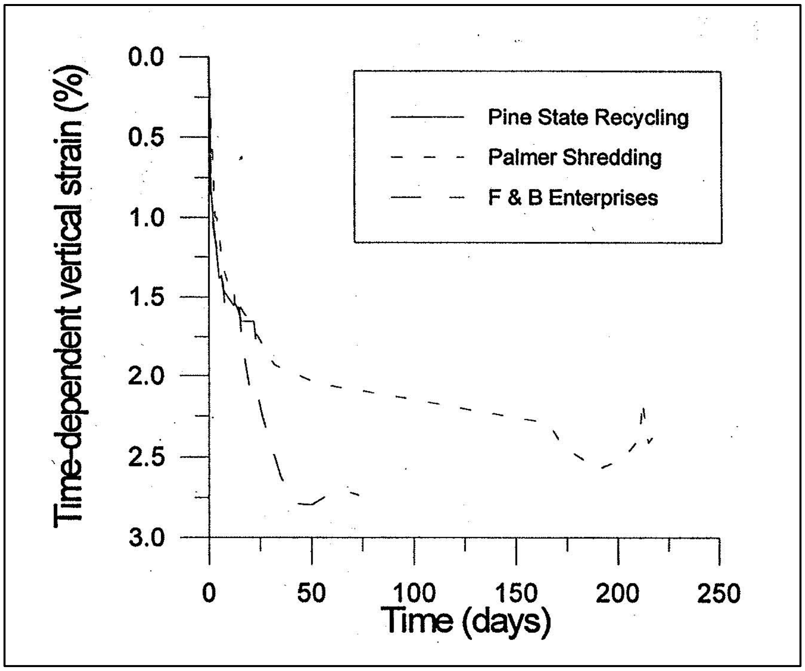
t_1 = time when time-dependent compression begins, days (assumed to be 1 day)

t_2 = time at which the magnitude of time-dependent compression is required, days

$C_{\alpha\epsilon}$ = modified secondary compression index (0.0065 for 100% tire shreds [Type B TDA])

Although the above equation provides a guideline to estimate the time-dependent settlement in TDA sites, it's important to note that the study was based solely on laboratory experiments for an average duration of 4 weeks (Wartman et al., 2007; Ahn et al., 2014).

Additionally, Figure 2 illustrates a compression curve derived from laboratory tests, commonly used to estimate time-dependent settlement in embankment fill and slide repair. Tweedie et al. (1998) tested tire shreds with a maximum size ranging from 1.5 to 3 inches (Type A TDA) in a fill that was 14-feet thick and surcharged with 750 pounds per square feet (psf), which is equivalent to approximately 6 feet of soil. As shown in Figure 2, substantial time-dependent settlement occurred for about 2 months after the surcharge was placed. During the first 2 months, about 2% vertical strain occurred for the 14-foot TDA fill, which is equivalent to more than 3 inches of overall settlement (Humphrey, 2011). Although this curve was derived from Type A TDA data, historically, it was commonly assumed to be like the theoretical curve for Type B TDA.



(Tweedie et al. 1998)

Figure 2. Time-dependent Settlement of 14-ft thick Type A TDA Fill Subjected to a Surcharge of 750 psf

Over the past 16 years, CalRecycle has monitored the long-term settlement of four road embankment repair sites that implemented the lightweight fill method with Type B TDA. The empirical data collected from these projects suggest that the settlement curves shown in Figure 2 may be conservative. Furthermore, the time-dependent settlement equation developed by Wartman et al. (2007) does not account for long-term field performance data. Therefore, CalRecycle's monitoring program intends to use the empirical data sets collected from these project sites to develop site-specific settlement curves. These settlement curves will serve as guidelines for TDA settlement in road embankments and similar projects.

Mechanically Stabilized TDA (MSTDA) and Soldier Pile Walls with TDA Backfill

CalRecycle is currently monitoring the settlement of newly constructed road repair sites that implemented MSTDA. Additionally, CalRecycle is monitoring the settlement of a retaining wall site that utilized soldier pile wall techniques with TDA backfill. However, there are only two years of road surface elevation data available for these sites, which may not be sufficient for a comprehensive evaluation of time-dependent settlement.

Slide Repair Projects Utilizing TDA

One of GHD's primary objectives under its scope of work with CalRecycle is to advocate for and demonstrate the beneficial uses of waste tires in various civil engineering applications. Utilizing TDA in landslide repairs is among the several civil engineering applications promoted by CalRecycle, offering significant potential to be a sustainable and cost-effective strategy for waste diversion. In pursuit of this objective, CalRecycle and GHD have been actively involved in many civil engineering projects, seven of which are summarized in this report and detailed further in the subsequent sections, as illustrated in Table 1.

Table 1. California Slide Repair Projects Utilizing TDA

Site	Total TDA Depth (feet)	Tires Used (tons)	Passenger Tire Equivalents	Construction Completion Date
Marina Drive *Mendocino County*	15	1,312	131,200	September 2007
Geysers Road *Sonoma County*	15	1,537	153,700	December 2008
Sonoma Mountain Road *Sonoma County*	15	3,303	330,300	August 2008
Palomino Road *Santa Barbara County*	3	200	20,000	September 2010
Moran Road *Yuba County*	10	232	23,200	April 2019
Ortega Ridge Road *Santa Barbara County*	10	850	85,000	June 2019
Italian Bar Road *Tuolumne County*	10	610	61,000	July 2020

Appendix A provides the site vicinity and location maps for each of the slide repair project sites discussed in this report.

Marina Drive

The Marina Drive Project Site located north of Ukiah in Mendocino County, in Calpella, underwent repair in the summer of 2007 with assistance from CalRecycle. Assistance included the production of design documents and construction management services for the repair of the landslide-damaged section of Marina Drive. According to the Mendocino Department of Transportation (MENDOT), the damaged section had been progressively failing since the early 1960s. When progressive failures were large enough to create a traffic hazard, MENDOT re-established the road grade by filling slumped and transitional areas with soil, base rock, and asphalt. This temporary repair approach resulted in approximately 7 feet of additional material overlying the original road section. Overlaying material to repair landslide-damaged roadways is the most common method currently employed by California counties to keep progressively failing road sections open. However, this approach is inherently detrimental to the overall stability of a failing slope as adding mass can exacerbate road instability.

In 2007, the Marina Drive Slide Repair Project addressed the root cause of the landslide problem. Instead of overlaying the original road section with additional material, the failed slope/section of the road was reconstructed with two layers of TDA: a lower layer approximately 10 feet thick and an upper layer approximately 5 feet thick. To minimize soil infiltration into the TDA, each TDA layer was wrapped in geotextile fabric. As a heat-absorption barrier, a 3-foot-thick soil layer was placed between the TDA layers. A cover layer of onsite soil was placed over the top TDA layer for drainage control.

CalRecycle was fully involved with the project's design and construction, ensuring the design and TDA installation adhered to ASTM D6270 standards.

The design team successfully facilitated the cost-effective reconstruction of the road alignment and enhanced the stability of the road's supporting slope through the incorporation of TDA in the design process. Key aspects of the design and construction efforts included:

- Evaluation of cohesive and compressive soil strengths,
- Cross-sectional slope stability modeling,
- Implementation of slope flattening techniques,
- Keyway design and construction, and
- Design and installation of erosion preventative drainage and control measures.

This repair project, the first of its kind in California, served as a flagship project. It successfully utilized the lightweight and high permeability characteristics of TDA, while also demonstrating the cost-effectiveness of TDA as an alternative to traditional soil repairs. The project incorporated approximately 1,312 tons of TDA, equivalent to approximately 131,200 passenger tire equivalents (PTE).

Geysers Road

The Geysers Road Project Site is situated in Sonoma County southeast of Geyserville, approximately 1.7 miles north of the Geysers Road and Red Winery Road intersection. In 2006, approximately 250 feet of Geysers Road failed due to a landslide, requiring the slope and roadway to be reconstructed. The landslide was attributed to poor historical compaction of the native soil and excess ground moisture.

Redesigning the embankment and roadway using a traditional soil backfill would have likely required a larger excavation, leading to a more expensive repair. As an alternative, the county collaborated with CalRecycle to reconstruct the road section using TDA. CalRecycle assisted Sonoma County by providing design services for the repair of a landslide-damaged section of Geysers Road. CalRecycle provided the design, TDA delivery, and TDA placement quality control services. Sonoma County performed construction services. CalRecycle funded the design and support activities of this project through its waste tire management program.

The failed slope/section of the road was reconstructed with two layers of TDA: a lower layer approximately 5 feet thick, and an upper layer approximately 10 feet thick. To minimize soil infiltration, each TDA layer was wrapped in geotextile fabric. As a heat-absorption barrier, a 3-foot-thick soil layer was placed between the TDA layers. A cover layer of onsite soil was placed over the top TDA layer for drainage control.

Construction of the slope repair occurred between August 13 and December 8, 2008. A bypass lane was constructed to ensure traffic flow, preventing any disruption during the construction period. Approximately 1,537 tons of TDA were utilized for this project, equivalent to 153,700 PTE.

Sonoma Mountain Road Site

The Sonoma Mountain Road Project Site is located northeast of Glen Ellen in Sonoma County. In the winter of 2006, approximately 250 feet of the embankment supporting Sonoma Mountain Road failed, resulting in significant damage that required a portion of the two-lane road to be closed to vehicular traffic, thereby limiting access for residents and commuters.

To reconstruct the roadway, Sonoma County opted for the use of TDA. The TDA fill portion of the repair work was executed as a joint venture under a Memorandum of Understanding (MOU) between CalRecycle and Sonoma County. Pursuant to the MOU, CalRecycle committed to funding the procurement of TDA material, delivery, placement oversight, and peer review of geotechnical, stability, design, and construction management efforts by the county for the project during the summer of 2008. The TDA material was supplied by three vendors: Tri-C, Waste Recovery West, Inc., and West Coast Rubber Recycling. Sonoma County assumed responsibility for engineering, design, and construction activities. Kleinfelder Engineering performed slope stability modeling, erosion control, geotechnical engineering, and construction quality assurance, under contract with Sonoma County. Argonaut Constructors of Santa Rosa was the prime construction contractor for Sonoma County.

The failed slope/section of the road was reconstructed to include two layers of TDA, with the lower layer approximately 10 feet thick and the upper layer approximately 5 feet thick. To prevent soil infiltration into the TDA, each layer was enveloped in geotextile fabric. Additionally, a 3-foot-thick soil layer was placed between the TDA layers to serve as a heat-absorption barrier. For drainage control, a cover layer of onsite soil was placed over the top TDA layer.

Construction of the slope repair occurred between September 2008 and May 2009. This project incorporated approximately 3,303 tons of TDA, equivalent to 330,300 PTE.

Palomino Road

The Palomino Road Project Site is situated just outside the city limits of Santa Barbara within Santa Barbara County. Palomino Road was originally constructed by cutting the hillside soil away and then building the road base back up again. However, a section of the road had experienced settlement and cracking leading to progressive failure over approximately 25 years due to highly expansive clay soils, necessitating multiple repairs in the past.

According to the county of Santa Barbara Public Works Department (CSBPWD), the road experienced significant damage during the early 2009 Jesusita Fire, during which numerous public safety vehicles used Palomino Road for evacuations and firefighting. As the progressive failures posed a traffic hazard, CSBPWD closed one lane of the road (approximately 300 feet).

In the summer of 2010, CalRecycle partnered with Santa Barbara County to repair the damaged section of Palomino Road. The failed portion of the road was reconstructed with one layer of TDA, approximately 3 feet thick, reinforced with triaxial geogrid and wrapped in geotextile fabric. The TDA layer was then covered with 8 inches of compacted base over 2 feet of compacted cover soil, followed by 4 inches of asphalt. For drainage control, perforated 4” subdrain pipes were installed at the bottom of the TDA fill volume, daylighting to the adjacent slope via 4” solid pipe sections.

Key aspects of the design and construction included:

- Evaluation of cohesive and compressive soil strengths,
- Cross-sectional slope stability modeling,
- Limiting construction activity to road surface and existing right of ways,
- Geogrid design and construction, and
- Design and installation of erosion prevention drainage and control measures.

This project implemented approximately 200 tons of TDA, which equates to approximately 20,000 PTE.

The Palomino Road repair differs from the other three previous road slide repairs in California in that the TDA fill layer is only 3 feet deep, whereas the other repairs involved typical TDA fill depths of 15 feet.

Moran Road

The Moran Road Project Site is in a rural area of Yuba County, on the western side of New Bullards Bar Reservoir, approximately one-half mile west of the reservoir itself. The road consists of both asphalt and gravel sections, although it was entirely asphalt in the past. It had not been resurfaced recently. As the road nears the reservoir, it is predominately constructed on a cut into the adjacent hillside. The failed section of the road is built on sandy, sloughy materials with low strength. The project's design aimed to install metal soldier piles with wood lagging and TDA backfill. The lightweight and permeable properties of TDA resulted in lower lateral forces on the soldier pile wall than other onsite or traditional backfills, contributing to a longer-lasting repair.

Key aspects of the design and construction included:

- Evaluation of cohesive and compressive soil strengths,
- Cross-sectional slope stability modeling,
- Limiting construction activity to existing right of ways,
- Pile wall design and construction, and
- Design and installation of erosion prevention and drainage control measures.

This project was part of the CalRecycle TDA grant program and was completed in April 2019. It incorporated approximately 232 tons of TDA, which equates to approximately 23,200 PTE.

Ortega Ridge Road

The Ortega Ridge Road Project Site is in the community of Montecito, just south of the city of Santa Barbara, in Santa Barbara County. Ortega Ridge Road was originally constructed in the late 1960s. The subgrade material is comprised of relatively uncompacted clay shale that expands and shrinks based on moisture levels. During dry weather and heavy loading, the clay consolidation causes the road subgrade elevation to sink and the surface asphalt to crack and fail, eventually leading to unsafe road conditions and lane closures.

This project was designed to address long-term settlement of the roadway section due to highly expansive clay soils. These properties led to sloughing in the embankment, causing settlement of the roadway surface and drainage features. The use of lightweight fill was desirable to reduce loading on underlying earthen materials. TDA was considered due to its low density and drainage ability. A MSTDA wall concept was designed in coordination with CalRecycle, Santa Barbra County, and GHD. The project used over 850 tons of TDA, which is approximately 85,000 PTE, and was constructed in the summer of 2019.

Santa Barbara County utilized a new design technique known as MSTDA to repair Ortega Ridge Road. TDA is lightweight and free draining with high internal strength characteristics, making it an ideal material for road repairs. In the MSTDA design approach, these properties are enhanced by integrating reinforcing geogrid sheets with

TDA, resulting in an exceptionally stable, lightweight, and free-draining subgrade for the repaired road section.

The reinforced TDA layers are approximately 2 feet thick and incorporate embedded plastic geogrid reinforcing elements, along with geotextile fabric to separate the TDA from the exterior rock facia, existing soils, and surface road section.

Key aspects of the design and construction included:

- Cross-sectional slope stability modeling,
- Limiting construction activity to road surface and existing right of ways,
- Plastic geogrid reinforcement design and construction, and
- Design and installation of drainage and stormwater control measures.

This project utilized over 850 tons of TDA, equivalent to approximately 85,000 PTE.

Italian Bar Road

The Italian Bar Road Project Site is located just outside the city of Columbia in Tuolumne County. Italian Bar Road was originally constructed by cutting into the hillsides adjacent to the south fork of the Stanislaus River back in the 1800s to provide access for gold miners. Currently, the road features a gravel surface, which is maintained by the county. However, during the precipitation events of 2017, multiple sections experienced road edge failures, reducing the road sections to one lane and facing potential complete failure.

In the summer of 2020, Tuolumne County addressed seven rural road failures by using TDA as a lightweight backfill material. Among these repairs, two adopted MSTDA design approaches to remediate the outside road lane failures. These repairs involved reconstructing the outside lane of the road sections by incorporating multiple layers of TDA with welded wire reinforcements. This integration forms the foundation of the MSTDA design technique, which combines reinforcing elements with TDA to produce a highly stable, lightweight, and free draining subgrade for the repaired road section.

The reinforced TDA layers are approximately 2 feet thick and feature embedded Hilfiker welded wire reinforcements, with geotextile fabric separating the TDA from the outer rock facia, existing soils, and surface road section.

Key aspects of the design and construction included:

- Cross-sectional slope stability modeling,
- Limiting construction activity to existing right of ways,
- Welded wire reinforcement design and construction, and
- Design and installation of erosion prevention and drainage control measures.

This project was part of the CalRecycle TDA grant program and was completed in July of 2020. It incorporated approximately 610 tons of TDA, which equates to approximately 61,000 PTE.

Post-Construction Survey and Monitoring

Post-Construction Survey

GHD has compiled the existing data available (from various survey data sets) and developed a drawing set for each project site. The drawings illustrate the final grade with 1-foot topographic contours, multiple cross sections cut perpendicular to the slope through TDA layers, lateral sections cut parallel to the roadway alignment, and the approximate location of drain system features. Additionally, the drawings illustrate the relationship between the TDA fill areas and the road surface and cross-sections. These drawings are included in Appendix A.

Survey Accuracy

To properly interpret the data values in the context of these road surface projects, it's essential to understand the tolerance of the survey data points. When surveying with a modern total station survey instrument, the error margin typically falls within 0.016 feet plus 2 parts per million of the distance measured. This becomes crucial when analyzing the survey reference point data. If the measured change in survey reference point elevations falls within the margin of error, they do not signify a valid change in the elevation of that position. The calculated minimum accuracy for each project site is shown in Table 2.

Table 2. Survey Reference Point Tolerance Levels

Location	Accuracy*	Equivalent
Marina Drive	0.02 feet	0.24 inches
Geysers Road	0.02 feet	0.24 inches
Sonoma Mountain Road	0.03 feet	0.36 inches
Palomino Road	0.03 feet	0.36 inches
Italian Bar Road	0.03 feet	0.36 inches
Moran Road	0.03 feet	0.36 inches
Ortega Ridge Road	0.03 feet	0.36 inches

*Approximate

Monitoring Plan

To effectively monitor and track any potential movement and/or settlement, initial post-construction surveys were conducted, and photo documentation was collected for each site. Survey nail reference points were installed immediately after the final asphalt layer was placed to ensure consistent surveying over time. Using the post-construction as-built survey information, a unique survey system was established, including road surface coordinates as well as coordinates for various features such as pipe locations and project slopes. By tracking these coordinates over time, it is possible to monitor the settlement of the road surface.

Due to construction activities or vehicular traffic, some survey nails may be damaged or destroyed over time. However, these reference points can be replaced or relocated using the remaining survey system reference points.

GHD conducted settlement monitoring of the project sites through surveys and photo documentation. The road surface coordinates correlate to the survey nail reference points installed during previous monitoring events. This reference point data provides reproducible cross-sectional and longitudinal-sectional elevations, allowing for comparison of the road surface over time and illustrating the settlement characteristics of the road repair projects.

Photographs

In addition to the survey information, GHD compiled a photo log to document the condition of the existing TDA projects (Appendix B). Photos were taken for the following purposes:

- Documenting the existing overall condition of the area at the time of the survey.
- Capturing specific baseline control points for future reference.
- Recording existing control points, utilities, and site features of interest.
- Providing visual documentation of any changes, such as cracks in asphalt; and
- Creating a photographic time series of points of interest.

Historical Survey Summary

The site surveys completed to date for the TDA repair sites are summarized in Table 3.

Table 3. Repair Site Historical Survey Summary

TDA Repair Site Location	TDA Depth (feet)	Year Construction Completed	Survey Completed Monitoring Events										
			1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
Marina Drive	15	2007	Jan 2008	Apr 2009	Jan 2010	Mar 2010	Nov 2010	Jun 2012	Jan 2014	Jun 2015	Nov 2016	Jul 2018	Nov 2021
Geysers Road	15	2008	Apr 2009	Jan 2010	Mar 2010	Nov 2010	May 2012	Jan 2014	Jul 2015	Oct 2016	Jun 2018	Nov 2021	Jan 2023
Sonoma Mountain Road	15	2008	Nov 2009	Nov 2010	Jul 2012	Jan 2014	Jun 2015	Nov 2016	Jun 2018	Dec 2021	N/A	N/A	N/A
Palomino Road	3	2010	Sep 2010	Oct 2010	Dec 2010	Jan 2011	Jun 2012	Feb 2014	Oct 2015	Nov 2016	Aug 2018	Jun 2022	N/A
Moran Road	10	2019	Jun 2022	Sep 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ortega Ridge Road	10	2019	Jun 2022	Jun 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Italian Bar Road	12	2020	Jun 2022	Aug 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

TDA Slide Repair Settlement Curves

CalRecycle established survey points on the TDA projects by installing survey nail reference points into the repaired road surface. These nails represent survey points that can be relatively easy to find and measured over time, providing insights into the settlement occurring at these sites. In lightweight fill road repair methods, the TDA design involves incorporating layers of TDA within top and middle layers of traditional road fill material (two layers of TDA, typically a 5-foot and 10-foot layer separated by a 3-foot soil layer, resulting in a total TDA fill of 15 feet). GHD analyzed historical and recent survey data points overlaying the full TDA construction portions of the lightweight fill. Using the survey data from initial post construction and the most current survey event, GHD estimated the approximate total surface settlement associated with 15-foot TDA fills.

It was anticipated that in the lightweight fill method, there would be slightly more settlement on the outboard, or fill edge, of the roadways because the fill materials at the edge are unconfined. To determine the settlement over time, the data sets were normalized, and the time-dependent vertical strain was plotted against the post-construction time. Figures 5, 8 and 11 show the TDA settlement for the inner edge, outer edge, and centerline alignments of each site. For comparison, survey data from locations without TDA fill are also included in these figures. Generally, soil subgrade areas adjacent to the TDA fill experience lower settlement rates than areas with TDA fill. Although the outboard of the roadway settled more than the centerline for Geysers Road, this trend was not consistent for Marina Drive or Sonoma Mountain Road, making the settlement effect of roadway alignment and underlying TDA thickness inconclusive.

It is important to note that although this study did not investigate the exposure and frequency of vehicle loadings on the roadway, it has been postulated by Wartman et al. (2007) that time-dependent compression is independent of applied stress. Therefore, the effect of variable loads to degree of settlement was not included in this study.

When evaluating soldier pile walls, the top and center of the piles serve as survey reference points along with the road nail elevation data. These survey points can be relatively easy to locate and measure over time, providing insights into the settlement occurring at these sites. To date, the two survey event data points do not yet show clear signs of settlement. The piles and road nails should continue to be monitored and assessed over time.

The MSTDA design incorporates horizontal tie-back sheets layered within the TDA. This method transfers the horizontal forces holding the welded wire slope face to a vertical force within the subgrade fill. MSTDA projects have only been in place since around 2020, and the survey data does not yet show clear signs of settlement. They should continue to be monitored and assessed over time. Future survey information will be referenced back to the data gathered from the initial post-construction monitoring events to evaluate potential surface settlement.

Using the survey data from initial post construction, CalRecycle can continue to gather and evaluate data to approximate MSTDA project settlement.

The road surface elevations, design plans, and cross-section profiles for each site are provided in Appendix E. The settlement data results for the lightweight fill sites are described in the following sections.

Marina Drive

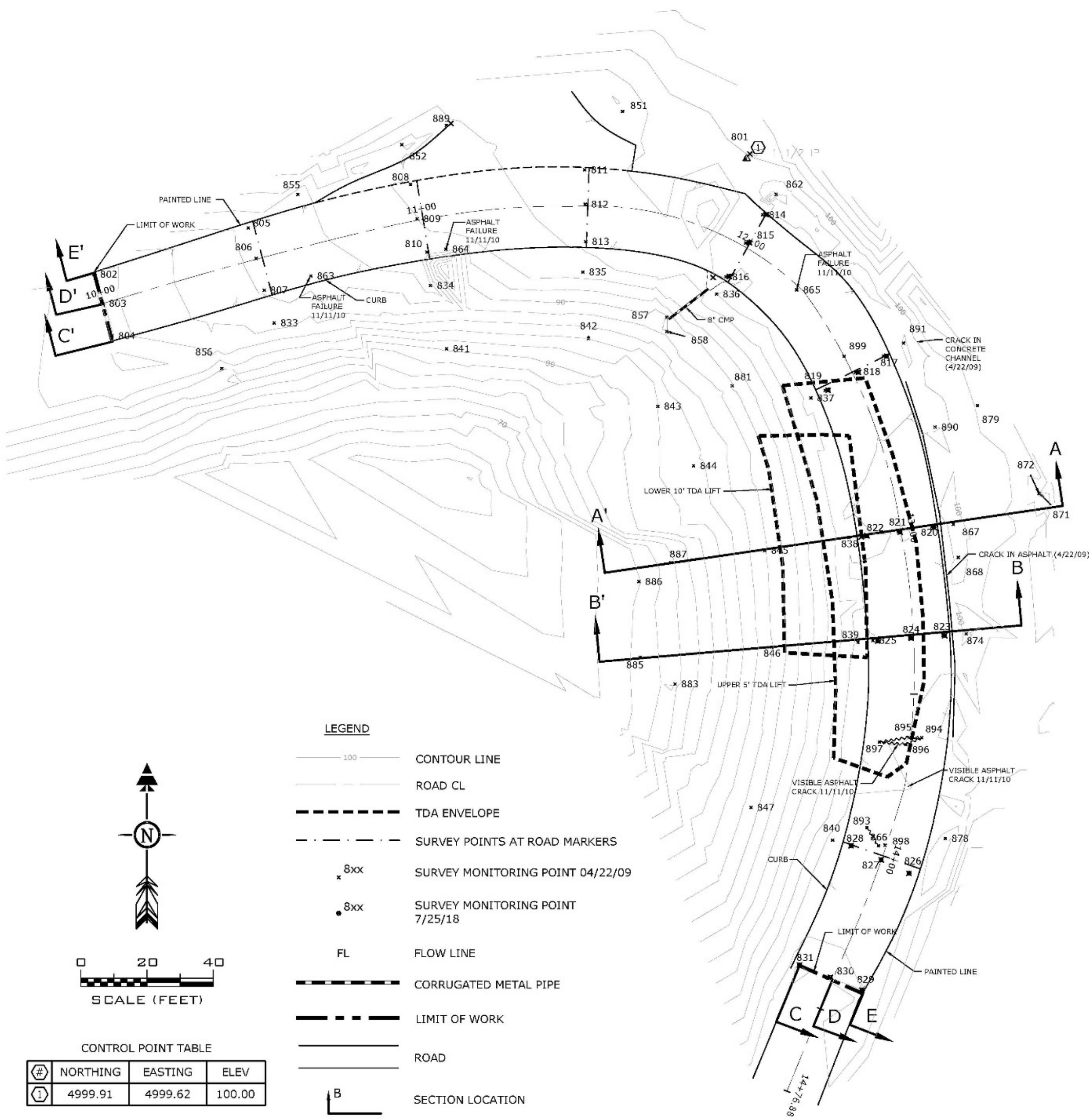


Figure 3. Detailed Drawings, Marina Drive

To date, the cross-sections A-A' and B-B' through the TDA fill portions of the Marina Drive repair (Points 820, 821, 822, 823, 824, 825) have shown an overall average settlement of 0.44 feet (5.28 inches) since the completion of construction in 2007. The approximate maximum settlement found was 0.63 feet (7.56 inches) at survey point 824, located along the centerline of the road (refer to Figure 3).

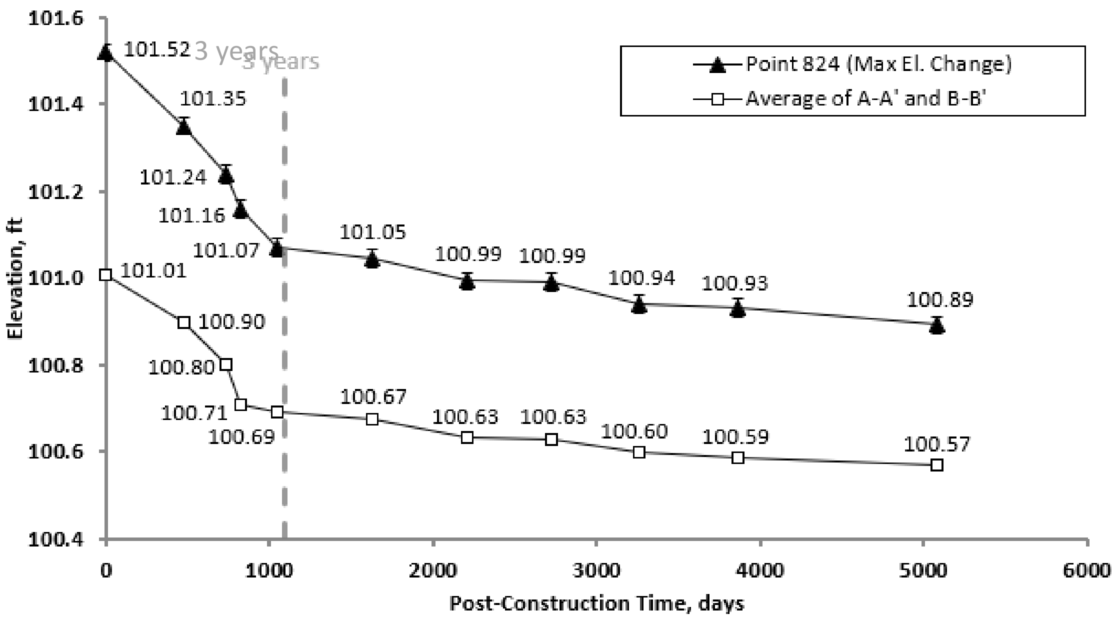


Figure 4. Average and Maximum Elevation Change vs. Time at Marina Drive

Since the November 2010 survey event, the survey data from the Marina Drive Project Site indicated that the settlement rates of the TDA-associated road repair have now reached levels below or close to the survey accuracy threshold for this site. The average elevations of the three most recent survey points (2016, 2018, 2022, respectively) fall within the sampling error range. It appears that the site has substantially stabilized approximately three years after the completion of construction and has remained stable for three consecutive survey events. Therefore, settlement is generally considered complete.

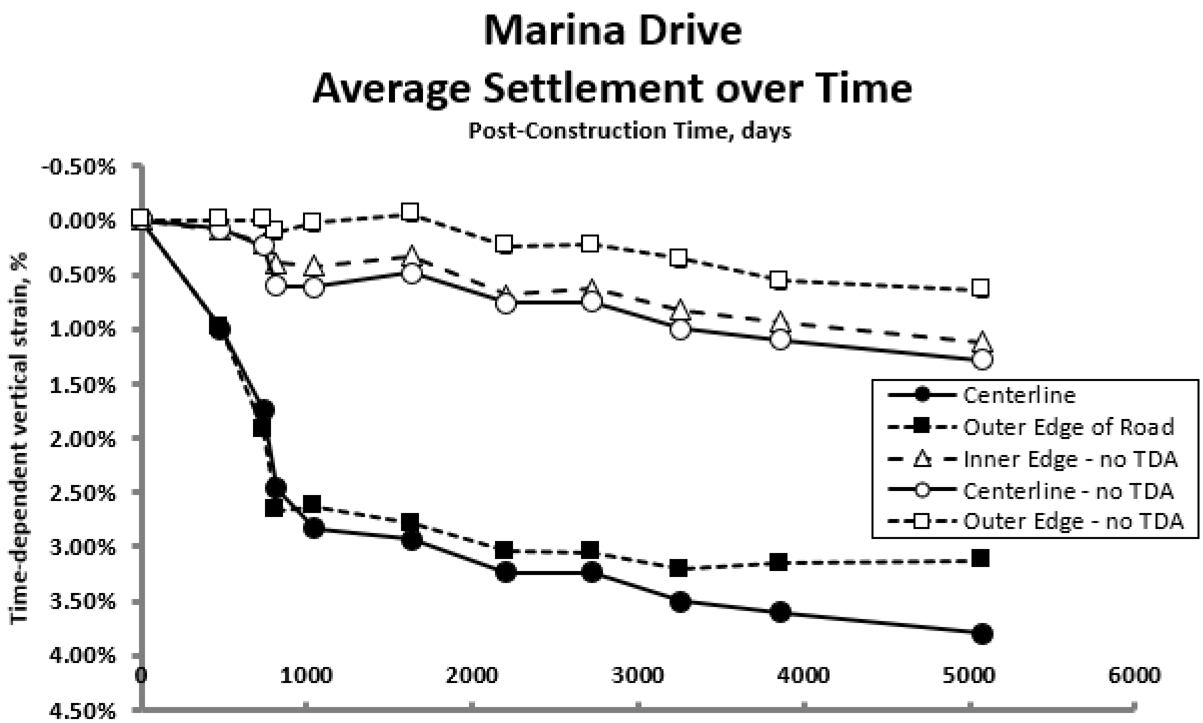


Figure 5 **Marina Drive: Time-dependent Settlement for the Inner Edge, Outer Edge, and Centerline Alignments**

Figure 5 depicts strain of approximately 3.7% was observed for the average centerline of the 15-foot TDA fill, corresponding to slightly over 6 inches of pavement settlement from the project completion in 2007 to the latest survey in 2022. While the average centerline data shows a continued increase in vertical strain, this trend is also reflected in the soil centerline data points, indicating that the increased strain may be uniform for the entire site.

Geysers Road

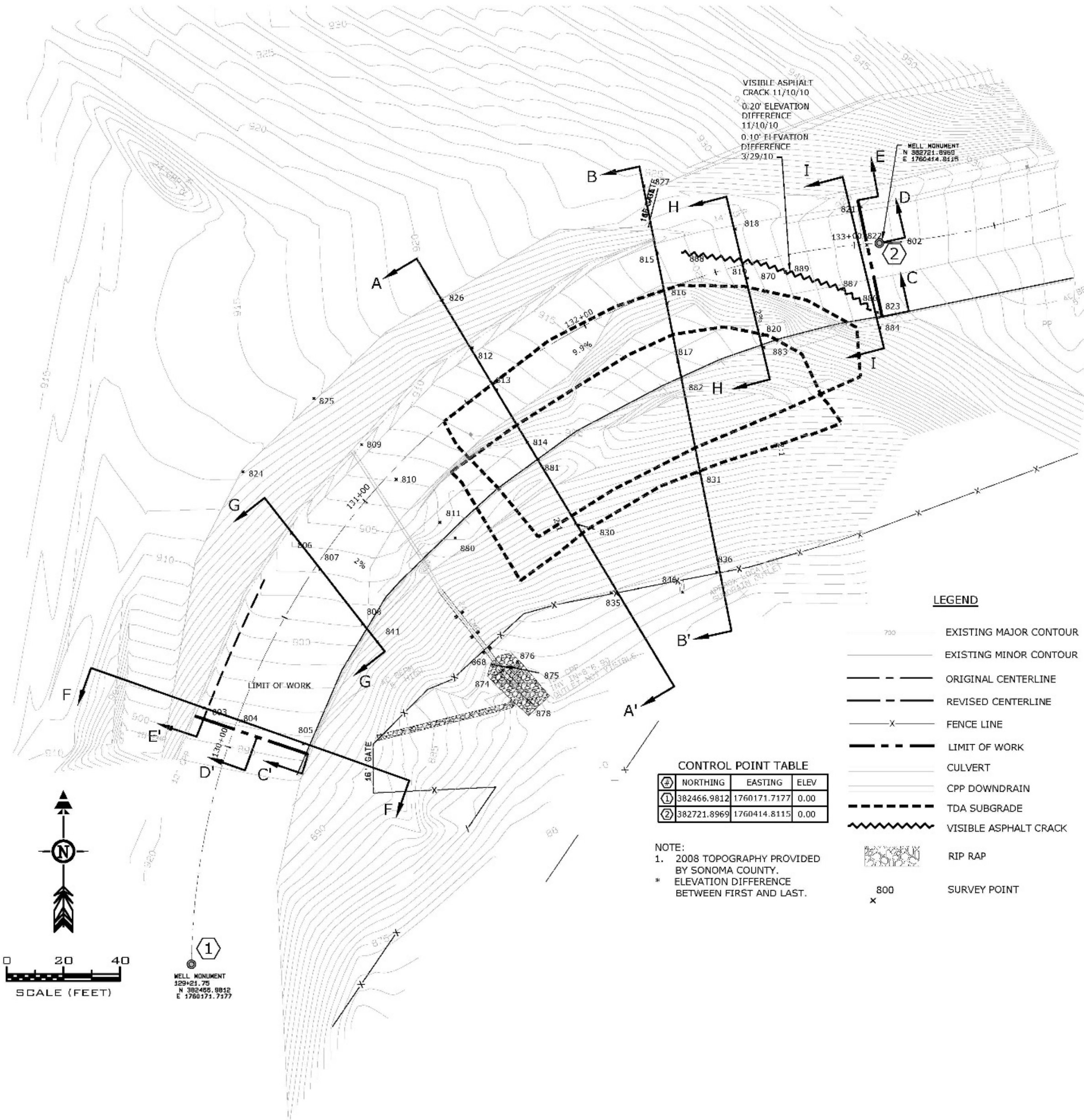


Figure 6. Detailed Drawings, Geysers Road

The cross-sections A-A’ and B-B’ through the TDA fill portions of the Geysers Road repair have an overall average settlement of 0.21 feet (2.52 inches) since the completion of construction. The approximate maximum settlement observed was 0.50 feet (6 inches) at survey point 817. (refer to Figure 6).

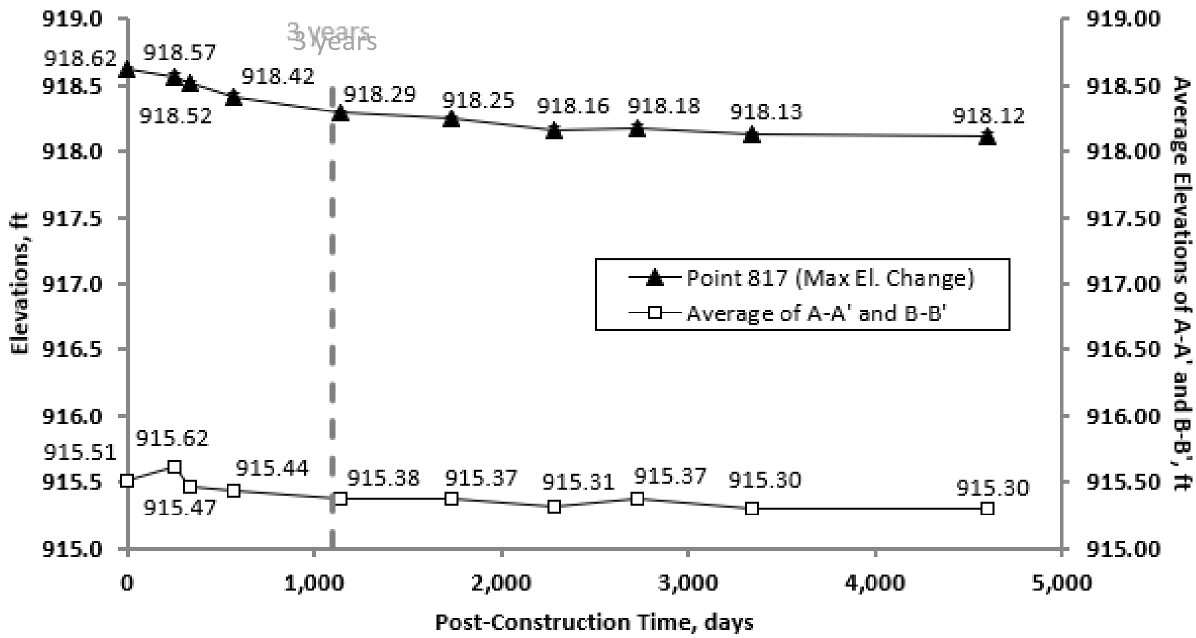


Figure 7. Average and Maximum Elevation Change vs. Time at Geysers Road

The general trend of the settlement curve for Geysers Road resembles that of Marina Drive, showing a high settlement rate for the first three years (steeper slope), followed by a slower settlement rate. The site appears to have substantially stabilized around three years after the completion of construction. The maximum elevation change point was Point 817, which remained stable for two consecutive survey events: June 19, 2018and November 30, 2021. The time-dependent settlement curve for Geysers Road (Figure 8) indicates that all survey elevations in 2018 matched those of the 2021 survey.

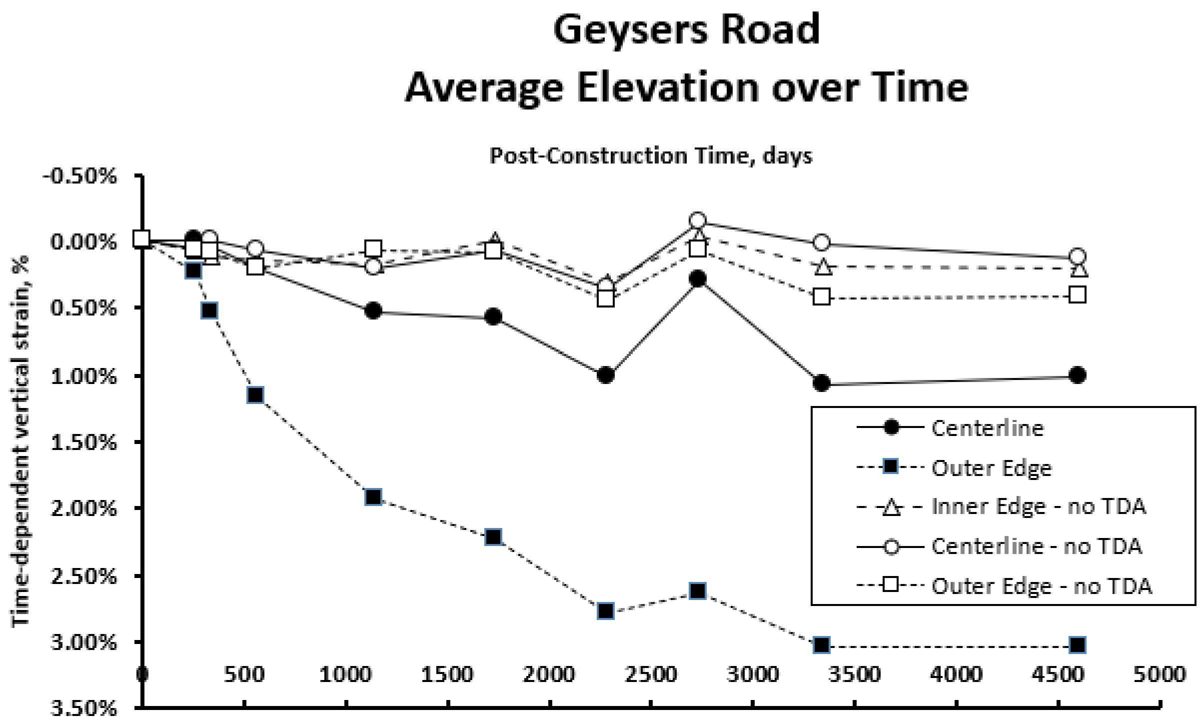


Figure 8. Geysers Road: Time-dependent Settlement for the Inner Edge, Outer Edge, and Centerline Alignments

A visible crack in the asphalt road surface on the eastern side of the Geysers Road TDA fill has been present since the 2012 survey (refer to the Photo Log in Appendix B). This crack aligns with the underlying differential between soil and TDA in the subgrade fill. During the construction phase, it was observed that the contractor (Sonoma County) excavated the eastern side of the repair differently from the construction drawings, resulting in a relatively abrupt transition between TDA and soil in the underlying subgrade fill. This could have influenced the visible crack in the road surface. However, the crack did not pose a driving hazard and has since been repaired. Average elevation data from 2018 to 2021 shows that the TDA fill volume under the road surface does not show signs of increased settlement.

Sonoma Mountain Road

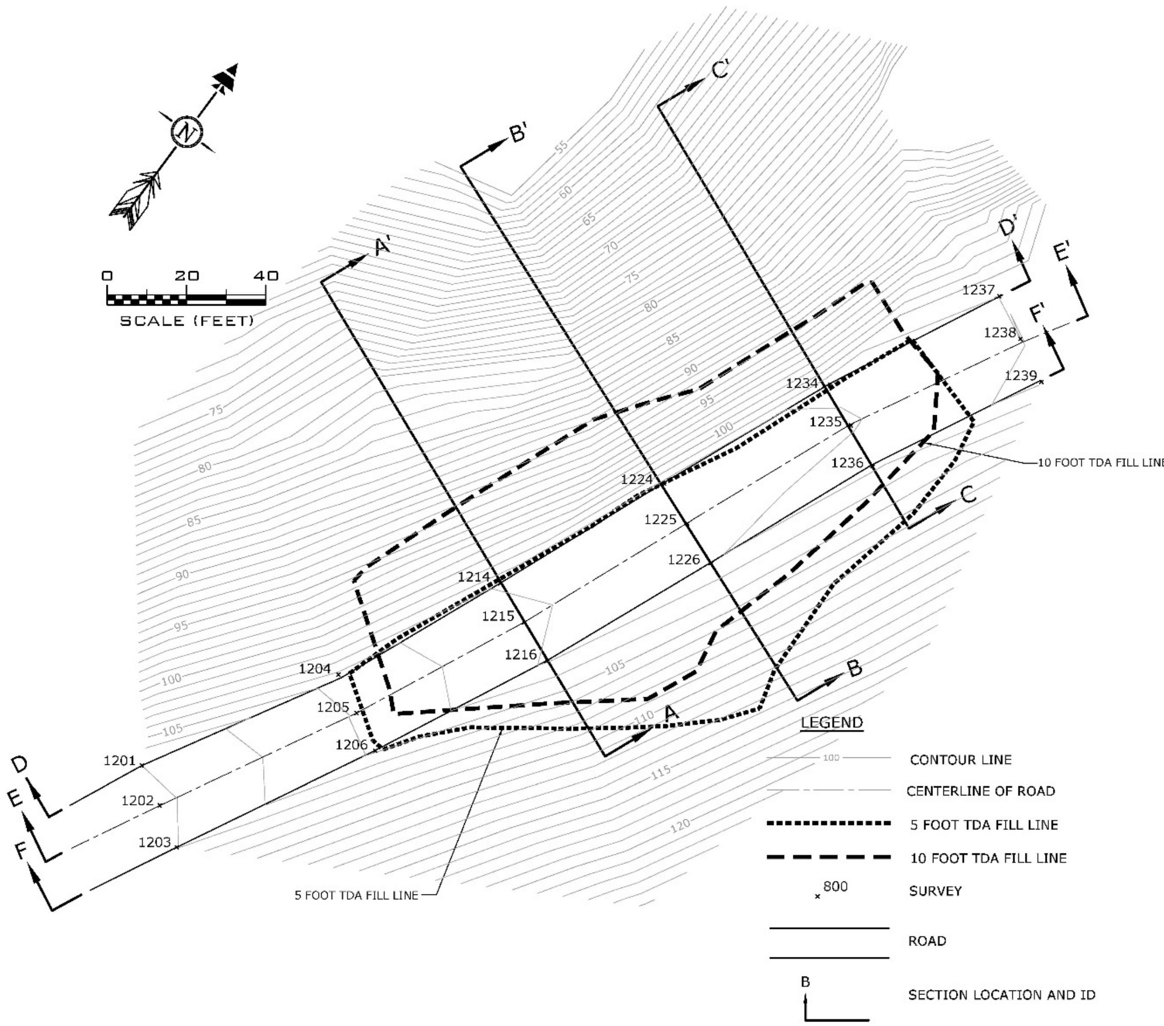


Figure 9. Detailed Drawings, Sonoma Mountain Road

The cross-sections A-A’, B-B’, and C-C’ through the TDA fill portions of the Sonoma Mountain Road repair indicate an overall average settlement of 0.44 feet (5.28 inches) since the completion of construction. The approximate maximum settlement observed was 0.69 feet (8.28 inches) at survey point 1204 (refer to Figure 9).

Analysis of the average settlement between 2018 and 2021 for this site reveals no settlement of the TDA fill, however, there is a slight increase in elevation at point 1204. This data point was derived from the asphalt surface and not from the previously installed survey nail, which could not be located. Consequently, this data point may potentially reflect the same value as the previously recorded 2018 elevation data.

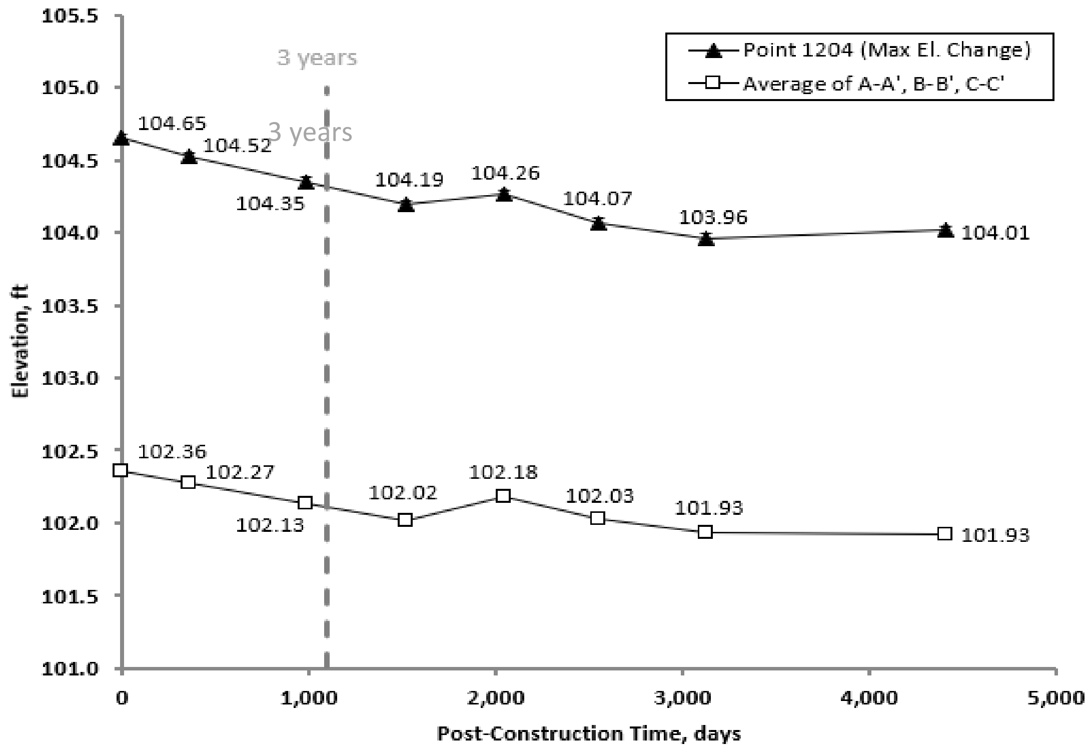


Figure 10. Average and Maximum Elevation Change vs. Time at Sonoma Mountain Road

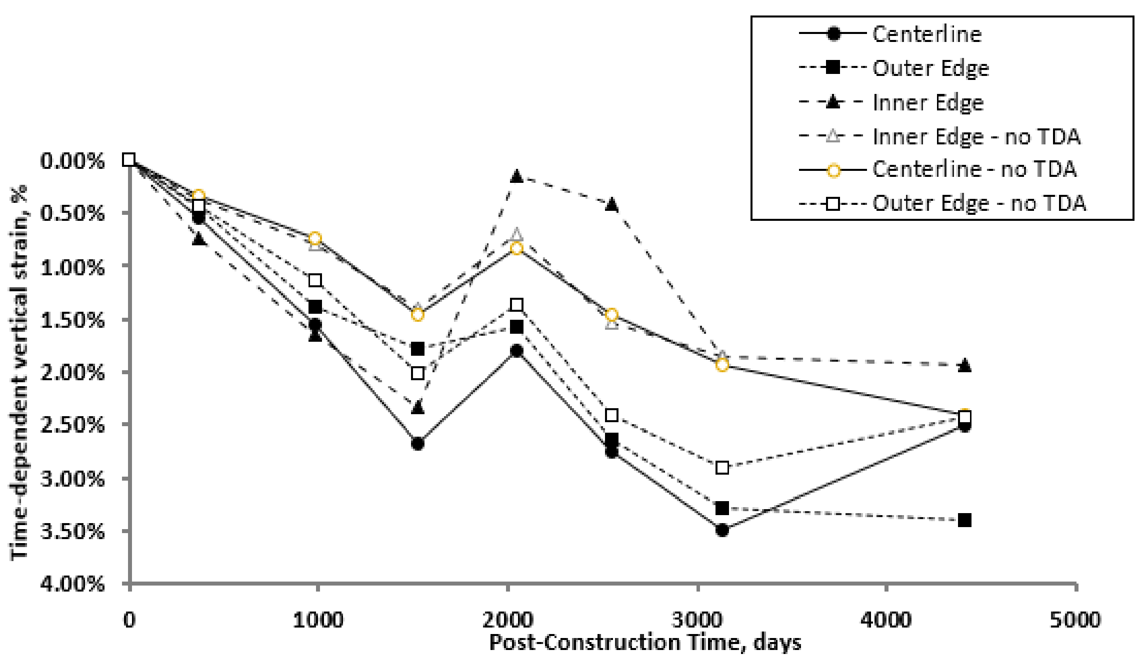


Figure 11. Sonoma Mountain Road: Time-dependent Settlement for the Inner Edge, Outer Edge, and Centerline Alignments

Palomino Road

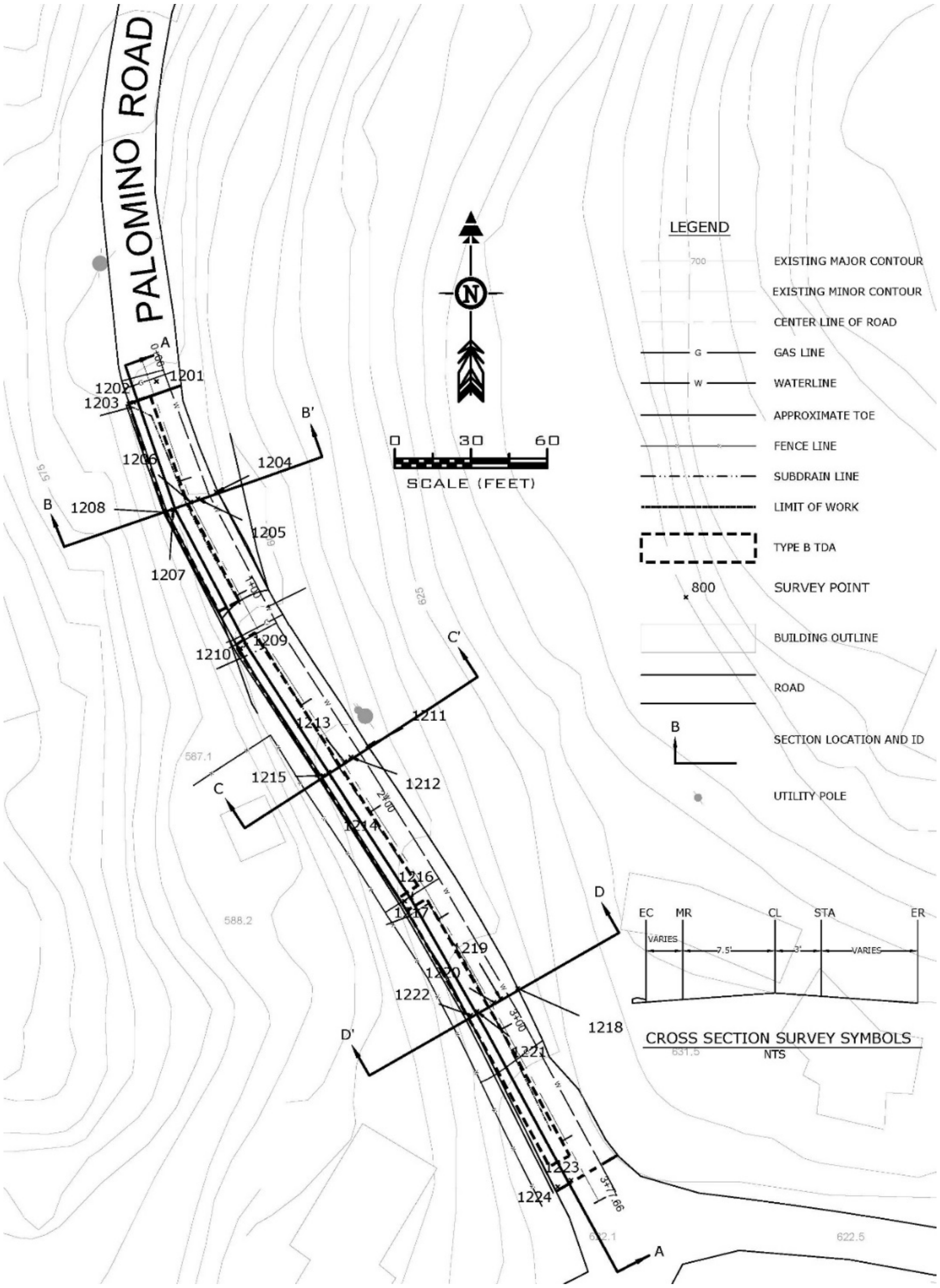


Figure 12. Plan View, Palomino Road

Palomino Road has a distinct construction design and function with respect to the previous three sites discussed. It involved a relatively long, thin, narrow, and shallowly placed TDA till portion in the road prism. Survey data from the TDA repaired section of the roadway indicates variable settlement over the 11-year project life. The maximum settlement of 0.69 feet (8.28 inches) was observed at point 1217 on the northern outside edge of the project. The average settlement over TDA cross sections is 0.33 feet or 3.96 inches.

This project used a 3-foot TDA fill under the engineered road section, and the global stability of the hill on which the road sits is known to be unstable. Additionally, various sections further north on the road have undergone repairs, including tiebacks and retaining walls, due to creep and global movement over the years. Given the uniqueness of this project, the settlement data was not incorporated with the data from the other three sites to develop the settlement curve for 5- to15-foot TDA fill volumes.

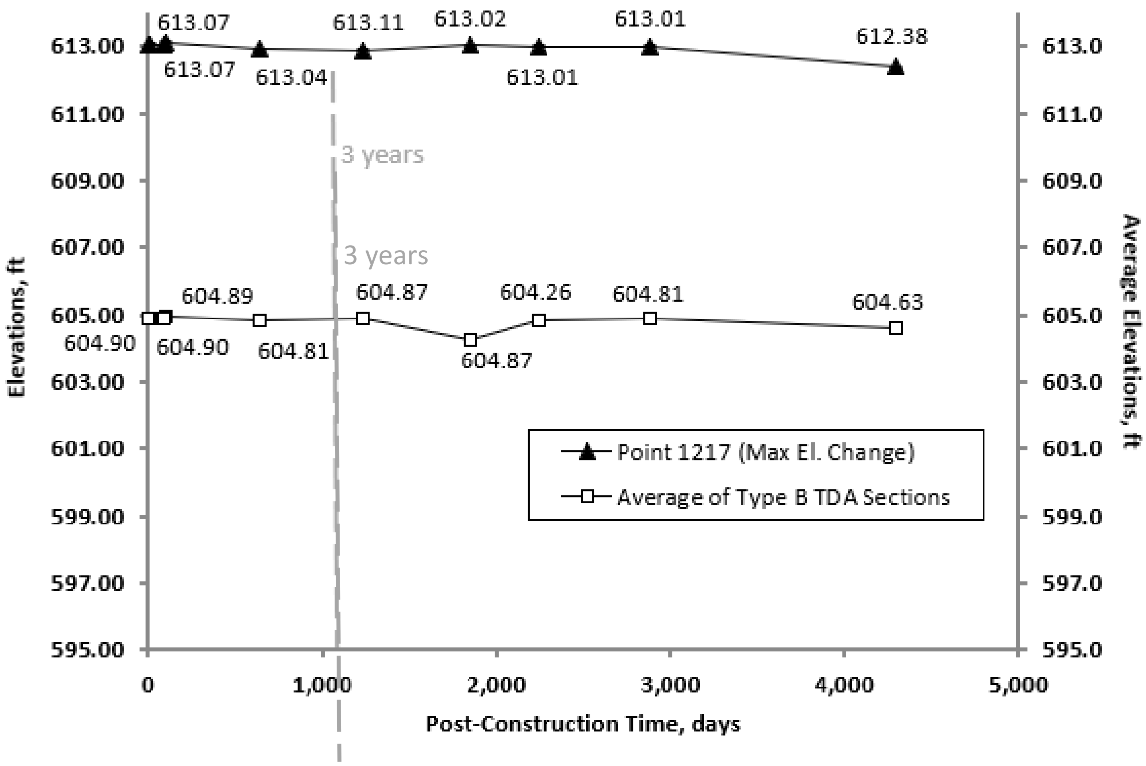


Figure 13. **Average and Maximum Elevation Change vs. Time at Palomino Road**

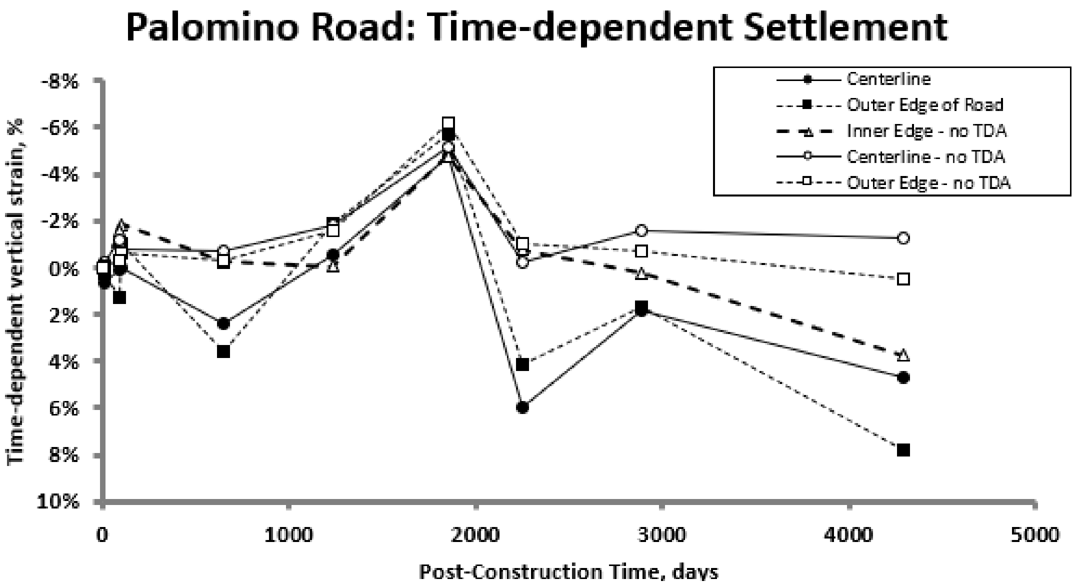


Figure 14. Palomino Road: Time-dependent Settlement for the Inner Edge, Outer Edge, and Centerline Alignments

Given the variable elevations observed in the survey data for Palomino Road during each monitoring event, it suggests that the overall constructed landslide road repair section is experiencing deformation. The observable vertical deformation is likely attributed to the pre-existing subsurface conditions of the site, particularly the presence of highly expansive and poorly consolidated native clay soils documented 32 feet below the ground surface at the Palomino Road repair site.

For reference, Appendix B, C, and D include photos, survey observations, and construction drawings of Palomino Road, respectively.

Time-dependent Settlement and Vertical Strain over Time

Based on the survey data depicted in Figures 5, 8, 11, and 14, no significant correlations were found between TDA roadway alignments and the time-dependent settlement rates of TDA. Consequently, the data sets from each project site were plotted together to determine the average Type B TDA settlement over time. All data points from previous surveys for Geysers Road, Marina Drive, and Sonoma Mountain Road were used to generate the graph. However, the settlement data from the Palomino Road site were not relevant or comparable to the other sites discussed in this report, therefore, they were excluded from the curve in Figure 15. The time-dependent vertical strain from each of the road embankment projects was plotted against the post-construction time (Figure 15).

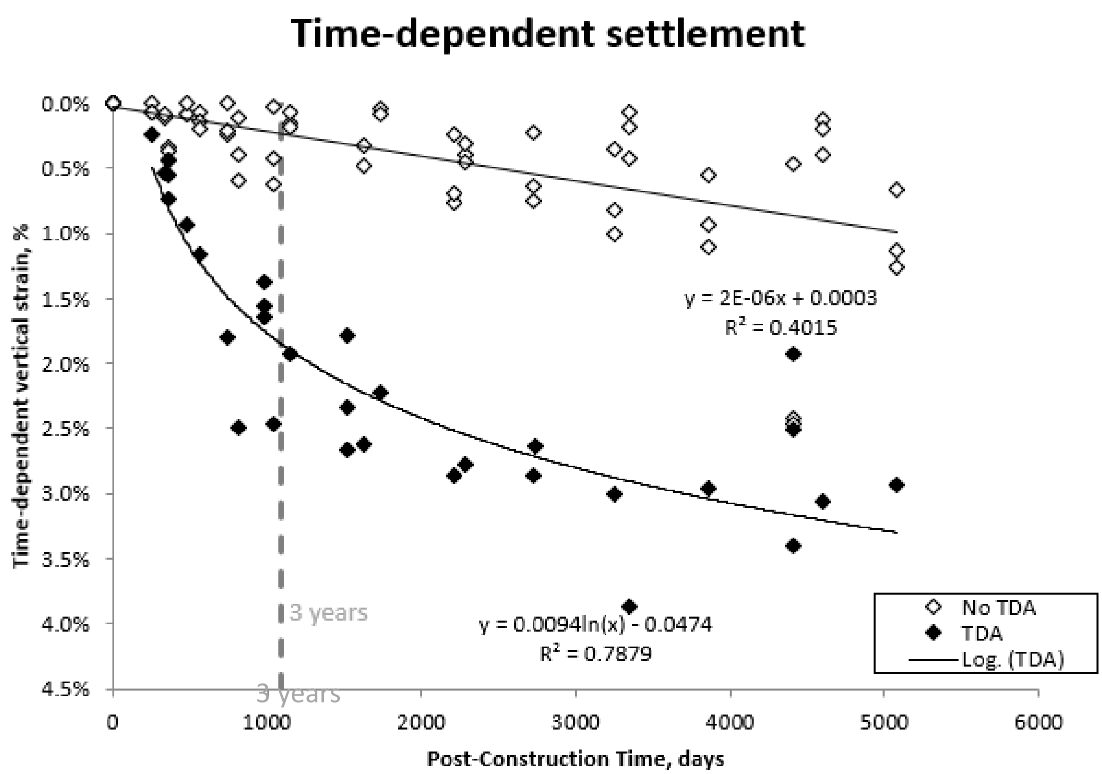


Figure 15. Time-dependent Settlement (combined data from Marina Drive, Geysers Road and Sonoma Mountain Road)

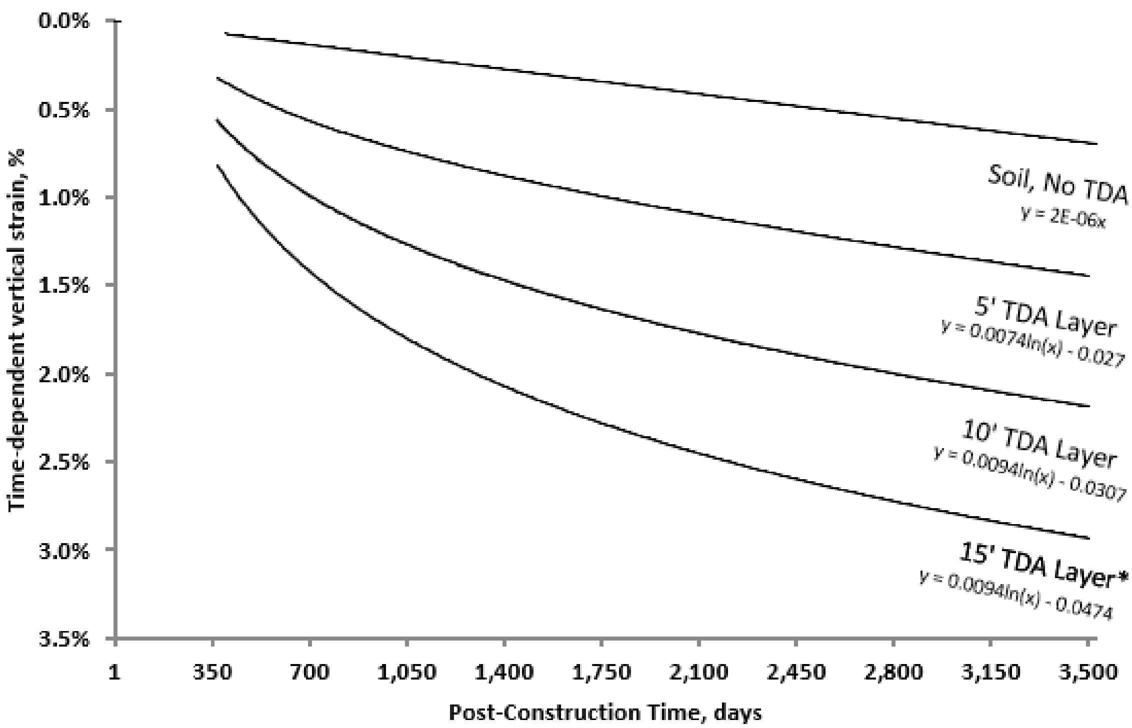
The curve relationship depicted in Figure 15 is based on empirical field data gathered from three different sites: Marina Drive, Geysers Road, and Sonoma Mountain Road, spanning over a period of 14+ years. As expected, areas without TDA installation exhibited lower settlement rates compared to those with TDA, displaying a relatively constant and linear slope over time.

The settlement rate over time for 15-foot TDA fills was best represented by a logarithmic relationship, yielding an R-squared value of 0.79. According to the TDA settlement curve, it is projected that after 3 years (1,095 days), approximately 2% strain (equivalent to 3.4 inches of settlement) can be anticipated from a 15-foot TDA fill.

TDA Layer Thickness and Settlement Over Time

In its laboratory investigations, Wartman et al. (2007) indicated that the time-dependent compression of TDA is primarily a function of TDA layer height, content, and time. Consequently, it was hypothesized that the extent of settlement would be dependent on the layer height of the TDA installed, with greater thickness yielding greater settlement.

Using survey data for both soil layers and 15-foot TDA layers from Figure 15, settlement rates for TDA layers of 5 feet and 10 feet were interpolated and plotted in Figure 16. This figure provides insights into the settlement behavior of TDA layers of varying thicknesses (5 feet, 10 feet, and 15 feet) over a 10-year period, offering valuable guidance for design and construction purposes as illustrated in Figure 12.



* Data Set Curve
(y = time-dependent vertical strain, %; x = time, days; and ln(x) = natural log of time in days)

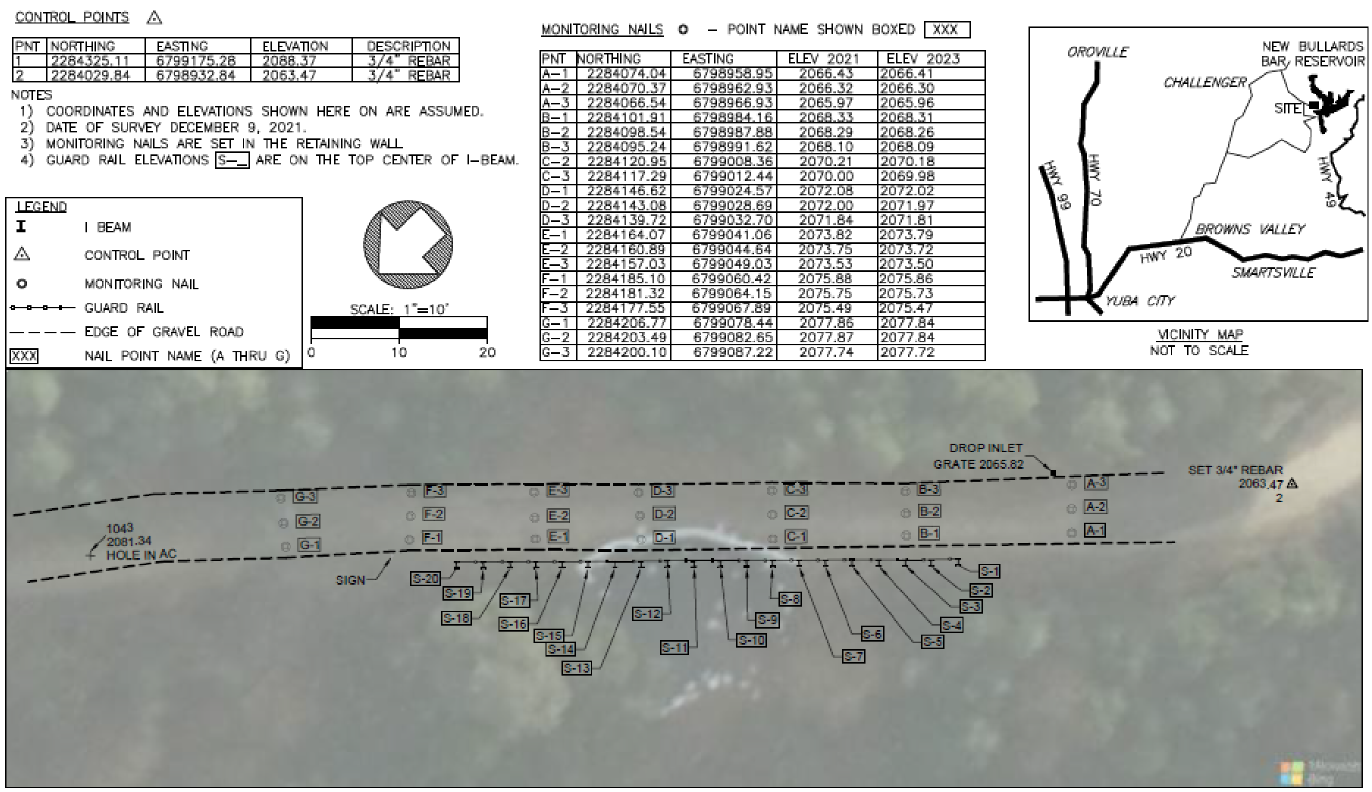
Figure 16. Estimated Settlement Rates by TDA Layer Thickness

TDA Mechanically Stabilized and Pile Wall Settlement

Moran Road

The Moran Road project implemented soldier piles with wood lagging and TDA backfill. Survey nails were strategically placed on the asphalt road surface, with three nails designated for each station: the outside edge, center, and inside edge. Stations A through G are labeled from southwest to northwest, with Stations A and G positioned on the existing road surface that does not contain embedded subgrade TDA fill. The repair site has 20 soldier piles, and the top of each pile is surveyed and numbered S-1 through S-20, arranged from northwest to southwest.

To date there have been two survey events conducted, and the data from these events is presented in Figure 17, the plan view site drawing. The differences observed between the reflected road surface and pile wall points fall within the survey accuracy/tolerance of 0.05 feet, thereby reflecting zero changes in elevation and northing and easting.



PNT	NORTHING	EASTING	ELEVATION	DESCRIPTION
1	2284325.11	6799175.28	2088.37	3/4" REBAR
2	2284029.84	6798932.84	2063.47	3/4" REBAR

PNT	NORTHING	EASTING	ELEV 2021	ELEV 2023
A—1	2284074.04	6798958.95	2066.43	2066.41
A—2	2284070.37	6798962.93	2066.32	2066.30
A—3	2284066.54	6798966.93	2065.97	2065.96
B—1	2284101.91	6798984.16	2068.33	2068.31
B—2	2284098.54	6798987.88	2068.29	2068.26
B—3	2284095.24	6798991.62	2068.10	2068.09
C—2	2284120.95	6799008.36	2070.21	2070.18
C—3	2284117.29	6799012.44	2070.00	2069.98
D—1	2284146.62	6799024.57	2072.08	2072.02
D—2	2284143.08	6799028.69	2072.00	2071.97
D—3	2284139.72	6799032.70	2071.84	2071.81
E—1	2284164.07	6799041.06	2073.82	2073.79
E—2	2284160.89	6799044.64	2073.75	2073.72
E—3	2284157.03	6799049.03	2073.53	2073.50
F—1	2284185.10	6799060.42	2075.88	2075.86
F—2	2284181.32	6799064.15	2075.75	2075.73
F—3	2284177.55	6799067.89	2075.49	2075.47
G—1	2284206.77	6799078.44	2077.86	2077.84
G—2	2284203.49	6799082.65	2077.87	2077.84
G—3	2284200.10	6799087.22	2077.74	2077.72

Figure 17. Moran Road Monitoring Points

Ortega Ridge Road

The Ortega Ridge Road project employed a mechanically stabilized system comprised of geogrid tiebacks, welded wire half baskets filled with decorative rock, and geotextile wrapped TDA backfill. Survey nails were strategically positioned on the asphalt road surface, with three nails designated for each station: the outside edge, center, and inside edge. Stations A through J are labeled from northwest to northeast, where Stations C through K are situated on the existing road surface above the embedded TDA subgrade fill.

The repair site features five layers of plastic geogrid reinforcement with three 3-foot lifts of TDA, topped with a soil layer, resulting in a total height of 12 feet. Additionally, two 2-foot sections of rebar were embedded in the lower welded wire wall for future surveys.

To date, there have been two survey events conducted, and the data from these events is presented in Figure 18, the plan view site drawing. The differences observed between the reflected road surface and welded wire wall rebar points fall within the survey accuracy/tolerance of 0.05 feet, thereby reflecting zero changes in elevation or northing or easting.

CONTROL POINTS △

PNT	NORTHING	EASTING	ELEVATION	DESCRIPTION
1	2217179.73	6649851.73	4000.00	REBAR
2	2217184.07	6649969.47	3994.51	IRON PIPE
3	2217216.55	6649724.89	4013.87	IRON PIPE

NOTES
1) COORDINATES AND ELEVATIONS SHOWN HERE ON ARE ASSUMED.
2) DATE OF SURVEY JUNE 22 AND JUNE 23.
3) MONITORING NAILS ARE SET IN THE RETAINING WALL
4) GAURD RAIL ELEVATIONS ARE ON THE TOP CENTER OF I-BEAM.

LEGEND
△ CONTROL POINT
XXX NAIL POINT NUMBER

SCALE: 1"=40'
0 40 80

MONITORING NAILS ○ – POINT NUMER SHOWN BOXED XXX

PNT	NORTHING	EASTING	ELEV 22	ELEV 23
A-1	1982732.90	6079379.56	442.13	
A-2	1982723.75	6079386.62	441.94	441.96
A-3	1982714.93	6079393.43	441.00	441.01
B-1	1982750.27	6079403.50	442.83	442.85
B-2	1982740.95	6079409.88	442.66	442.68
B-3	1982732.25	6079415.94	441.74	441.73
C-1	1982776.31	6079434.40	442.88	
C-2	1982762.03	6079442.88	443.14	443.15
C-3	1982752.80	6079448.43	442.82	442.82
D-1	1982791.68	6079461.97	443.17	443.21
D-2	1982776.51	6079469.74	443.40	443.38
D-3	1982766.81	6079474.49	443.08	443.08
E-1	1982805.53	6079490.53	443.36	
E-2	1982790.71	6079498.50	443.59	443.59
E-3	1982781.18	6079503.22	443.33	443.34
F-1	1982818.80	6079518.58	443.79	
F-2	1982803.67	6079525.77	444.04	444.03
F-3	1982793.65	6079530.30	443.78	443.79
G-1	1982832.02	6079547.38	444.47	
G-2	1982816.92	6079554.29	444.77	444.81
G-3	1982807.11	6079559.03	444.39	444.43
H-1	1982844.69	6079574.43	445.50	445.61
H-2	1982830.03	6079582.17	445.79	445.85
H-3	1982820.49	6079587.20	445.42	445.48
I-1	1982857.96	6079603.85	446.76	446.92
I-2	1982843.54	6079610.91	447.24	447.29
I-3	1982833.87	6079615.73	446.83	446.86
J-1	1982869.37	6079632.95	447.85	447.88
J-2	1982856.77	6079639.03	448.40	448.42
J-3	1982847.15	6079644.07	448.12	448.15
K-1	1982881.04	6079663.65	448.91	448.93
K-2	1982870.61	6079668.13	449.71	449.73
K-3	1982860.55	6079672.99	449.57	449.61
L-1	1982886.48	6079675.02	449.52	449.54
L-2	1982876.21	6079679.89	450.26	450.30
L-3	1982866.59	6079684.34	450.35	450.42
M-1	1982899.42	6079701.51	451.15	451.21
M-2	1982889.38	6079706.37	451.89	451.97
M-3	1982880.20	6079711.05	451.90	452.03

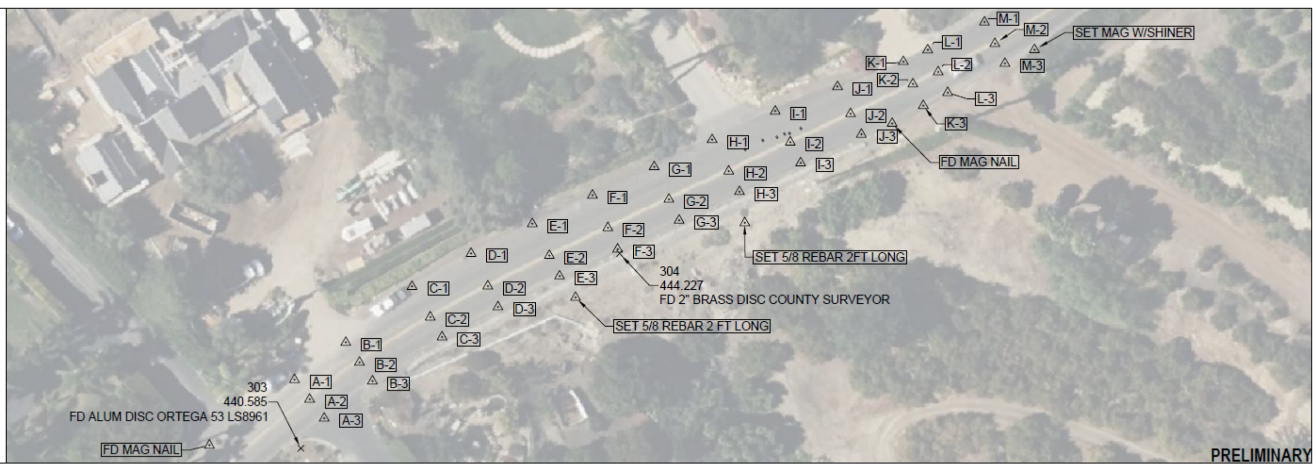


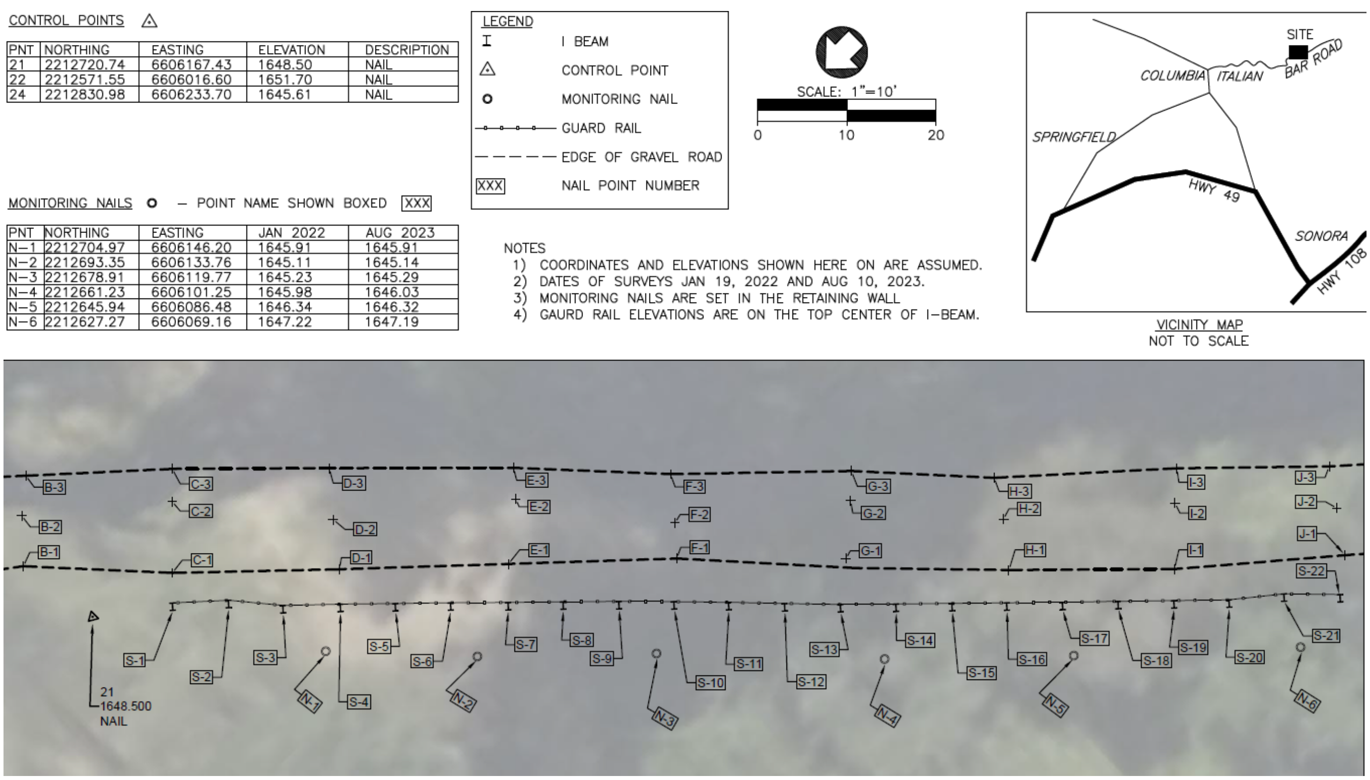
Figure 18. Ortega Ridge Road Monitoring Points

Italian Bar Road

The Italian Bar Road project utilized a mechanically stabilized system comprised of welded wire tiebacks, decorative rock facing, and geotextile wrapped TDA backfill. Survey nails were strategically placed on the gravel road surface, with three nails designated for each station: the outside edge, center, and inside edge. Stations A through J are labeled from northeast to northwest, where Stations C through J are located on the existing road surface above the embedded TDA subgrade fill.

The repair site consists of eight layers of galvanized welded wire reinforcement with 3-foot lifts of TDA, and a soil layer in the middle, resulting in a total height of 18 feet. Additionally, the top of each guardrail is surveyed and numbered S-1 through S-22 from northeast to northwest. Furthermore, six monitoring nails were attached to the welded wire face and numbered N-1 through N-6.

To date, there have been two survey events conducted, and the data from these events is presented on the plan view site drawing in Figure 19. Surface movement between the events is calculated in Table 3. The differences observed between the reflected road surface, guardrail I-beams, and welded wire wall points fall within the survey accuracy/tolerance of 0.05ft, thereby reflecting zero changes in elevation or northing or easting.



PNT	NORTHING	EASTING	ELEVATION	DESCRIPTION
21	2212720.74	6606167.43	1648.50	NAIL
22	2212571.55	6606016.60	1651.70	NAIL
24	2212830.98	6606233.70	1645.61	NAIL

PNT	NORTHING	EASTING	JAN 2022	AUG 2023
N–1	2212704.97	6606146.20	1645.91	1645.91
N–2	2212693.35	6606133.76	1645.11	1645.14
N–3	2212678.91	6606119.77	1645.23	1645.29
N–4	2212661.23	6606101.25	1645.98	1646.03
N–5	2212645.94	6606086.48	1646.34	1646.32
N–6	2212627.27	6606069.16	1647.22	1647.19

Figure 19. Italian Bar Road Monitoring Points

Discussion and Practical Implications

Results with Previous Studies

The analysis from Figure 15 reveals a notable trend: The TDA settlement rate depicted by the slope of the curve experiences a significant decrease after 3 years (1,095 days). Approximately 2% strain can be expected within this timeframe, which corresponds to 3.4 inches of settlement for an average 15-foot TDA fill. When compared to the Type A TDA settlement chart illustrated in Figure 2 (Tweedie et al., 1998), it becomes evident that Type B TDA settlement exhibits substantially lower rates than those observed in Type A TDA. However, both Type A and Type B TDA settlement curves exhibit a decline beginning at 2% vertical strain.

Moreover, if we consider the time-dependent settlement equation developed by Wartman et al. (2007), as discussed in the previous Lightweight Fill Section, it would have predicted a settlement depth (ΔH_t) of 11 inches. This prediction is three times greater than the observed average settlement of 3.4 inches obtained from this study.

Overall, these findings suggest a notable discrepancy between projected settlement depths based on existing models and the actual settlement observed in this study. Further examination is warranted to better understand the factors influencing this disparity and refine settlement prediction models accordingly.

Settlement Curve Discussion

While a general trend of decreasing TDA settlement rate over time is observed across all three project sites, notable differences in settlement curves exist. Specifically, at Marina Drive the settlement curves exhibit a logarithmic pattern, whereas those at Sonoma Mountain Road show a more linear trend. These differences may be attributed to variations in design, construction, or underlying geological factors.

The Marina Drive project was overseen by CalRecycle, with the design and construction methods adhering to CalRecycle's recommendations and ASTM D6270 guidelines. In contrast, the Geysers Road construction was not overseen by CalRecycle and deviated from the design drawings. Similarly, construction services for the Sonoma Mountain Road project were not provided by CalRecycle.

It is postulated that adherence to the recommendations of ASTM D6270 and CalRecycle in the design and construction of slide repair projects using TDA will result in settlement curves similar to those observed at Marina Drive. Figures 15 and 16 depict settlement data from Marina, Geysers, and Sonoma Mountain projects, providing insights into the variation in construction methods across the three projects. These figures can serve as a reference for estimating settlement rates for slide repair projects using 15-foot thickness or less of TDA fill. However, it is crucial to acknowledge that deviations from recommended standards in design and construction methods may lead to deviation from the settlement curve developed in this report.

Settlement Mitigation Strategies

Minimized settlement after the placement of a new pavement surface is crucial for any roadway project. When differential settlement exceeds 2 inches (50 mm to 100 mm) over a 100-foot (30-m) distance, it can lead to noticeable bumps and dips in the pavement surface (MDT Geotechnical Manual, 2008).

The settlement curve for TDA suggests that approximately 3.4 inches of settlement can be expected from a 15-foot TDA fill. To address road settlement from the use of TDA, the following subsections outline several settlement mitigation strategies.

Primary and Secondary Settlement

Per the Caltrans Geotechnical Manual (2022), settlement analyses must be conducted for all embankments, with total settlement encompassing primary consolidation settlement and secondary compression. As discussed in the introduction, primary settlement results from immediate compression and can be mitigated through overbuilding, as outlined in Appendix D, and surcharge loading. Following the completion of road section fill, the secondary (long-term) settlement phase begins. Design engineers can estimate the extent of secondary settlement based on the intended design life of the TDA roadway embankment, utilizing the settlement curves illustrated in Figure 16. The permissible levels of total and differential settlement during and after embankment construction should be evaluated using these resources.

Compaction

Proper compaction of TDA fill is critical to mitigate potential for differential settlement. According to ASTM D6270 guidelines, TDA should be placed in lifts no greater than 12 inches and compacted using either a tracked bulldozer, sheepsfoot roller, or smooth drum vibratory roller with a minimum operating weight of 10 tons, with a minimum of six passes. Additionally, surcharging the repair site with fill is recommended to minimize post-construction settlement (Mohamad, 2008).

Transition from existing soil to TDA Section

To address potential for differential settlement in TDA-filled areas and ensure a seamless transition between traditional fill areas and TDA sections, the installation of geogrids is recommended. Research by Weng and Wang (2011) has demonstrated that geogrid application can effectively prevent or mitigate pavement structure failures, while findings by Miao et al. (2014) suggest that geogrid reinforcement can reduce differential settlement by approximately 0.8 to 1.2 inches.

Additionally, it is essential to facilitate gradual transitions between different embankment materials, avoiding abrupt vertical changes. TDA fill sections should be sloped into the fill zones and securely keyed and benched into the adjacent fill materials.

Post-Construction Monitoring

It is advisable to collect settlement data for a period of years post-installation to assess any significant rates of settlement. This recommendation is based on the observed data from this study, which indicates that settlement rates are highest within the initial 3-year period.

Conclusions and Recommendations

This report documents the changes in surface grade elevation over time in seven landslide repair projects utilizing TDA fill in California, which aims to aid in the design of future landslide repairs employing TDA. The seven projects include the Marina Drive slide repair in Mendocino County, Geysers Road in Sonoma County, Sonoma Mountain Road in Sonoma County, Palomino Road in Santa Barbara County, Italian Bar Road in Tuolumne County, Moran Road in Yuba County, and Ortega Ridge Road in Santa Barbara County. The total thickness of TDA fill for all projects ranges from 3 to 15 feet.

As Palomino Drive implemented only a 3-foot layer of TDA fill, site photos and design drawings from that project were included, but empirical settlement curves were not derived from survey data.

Furthermore, survey data from newer projects, which feature mechanically stabilized and pile wall systems, were not used in the analysis to derive settlement curves. The MSTDA projects Ortega Ridge Road and Italian Bar Road #3, along with pile wall project Moran Road, were surveyed as part of the project monitoring effort. However, based on the behavior of previous TDA projects, the data is expected to become robust enough for analysis of potential settlement behavior and prediction for each road repair technique after four years of survey events.

Curves developed from surface elevation changes over time can help engineers predict and design TDA fill road repairs that ensure a long, safe lifespan without experiencing detrimental differential settlement.

Conclusions

Based on survey data and field observations collected thus far for Marina Drive, Geysers Road, and Sonoma Mountain Road, a time-dependent settlement curve has been developed. The curve suggests that the rate of TDA settlement typically follows a logarithmic trend, with significant decreases observed after three years (1,095 days). While primary settlement can be minimized by placing a surcharge amount (i.e., overbuild) following the procedure outlined in Appendix D, long-term, time-dependent settlement of Type B TDA can be estimated using the curve illustrated in Figure 16 or the following equations shown in Table 4.

Table 4. Settlement Curve Equations

TDA Layer Thickness	Settlement Curve Equation
No TDA	y = 2E-06x
5-foot TDA Layer	y = 0.0074ln(x) - 0.027
10-foot TDA Layer	y = 0.0094ln(x) - 0.0307
15-foot TDA Layer	y = 0.0094ln(x) - 0.0474

where y = time-dependent vertical strain, %
x = time, days
ln(x) = natural log of time

Multiplying the time-dependent vertical strain (y) by the depth of TDA yields an estimate for TDA settlement depth. After 3 years, approximately a 2% vertical strain, corresponding to approximately 3.4 inches of settlement for a 15-foot TDA fill, can be expected for TDA embankments.

To limit differential roadway settlement in TDA projects, design engineers should incorporate TDA settlement insights from this report and follow guidelines in ASTM D6270. During construction, the field engineer should assess the quality of the fill material delivered, verify construction overbuild values and compaction requirements, and ensure that construction activities comply with the technical specifications and design plans.

Recommendations

Based on the developed time-dependent settlement curves for lightweight fill TDA projects, the four historical sites have completed the expected settlement, and fluctuations resulting from TDA settlement are not anticipated in future surveys. However, continued observation and monitoring efforts should be conducted on an annual basis.

The more recently completed MSTDA and pile wall projects, which were funded in part by CalRecycle grants, should also undergo annual monitoring to understand settlement behavior for these new TDA road repair techniques. All major CalRecycle road repair projects should undergo settlement monitoring and performance assessment for at least three years to verify the predicted behavior.

GHD recommends annual survey monitoring of newer road repair applications using TDA. A proposal schedule for survey and site inspections is provided in Table 5.

The survey reference data presented in this report provides empirical data that was utilized to develop approximate settlement rates for a project site. As a broader array of sites undergo repair or construction using TDA fill material, it is recommended to expand the empirical dataset presented in this report. This expansion should include different repair designs, as well as various TDA fill depths and configurations.

Table 5. Survey and Site Inspection Schedule

County	TDA Site Location	Application	Construction Completed	Survey Recommended Monitoring Dates					
				2024	2025	2026	2027	2028	2029
Mendocino County	Location 1 Marina Drive	Landslide Repair	2007		✓		✓		✓
Sonoma County	Location 1 Geysers Road	Landslide Repair	2008		✓		✓		✓
Sonoma County	Location 2 Sonoma Mountain Road	Landslide Repair	2008		✓		✓		✓
Santa Barbabra County	Location 1 Palomino Road	Excavation and Fill	2010		✓		✓		✓
Santa Barbabra County	Location 2 Ortega Ridge Road	MSTDA	2019	✓	✓	✓	✓	✓	✓
Yuba County	Location 1 Moran Road	Soldier Pile Wall	2019	✓	✓	✓	✓	✓	✓
Tuolumne County	Location 3 Italian Bar Road West	Landslide Repair	2020	✓	✓	✓	✓	✓	✓

References

Ahn, Il-Sang, Lijuan Cheng, Patrick J. Fox, Joaquin Wright, Stacey Patenaude, and Bob Fujii. *Material Properties of Large-Size Tire Derived Aggregate for Civil Engineering Applications.* ASCE. 2014. DOI: 10.1061/(ASCE)MT.1943-5533.0001225.

CalRecycle and Humboldt State University. Properties of Tire Derived Aggregate for Civil Engineering Applications. 2013.

CalRecycle. *Tire Derived Aggregate (TDA)*. January 25, 2023. https://calrecycle.ca.gov/Tires/TDA/

CalRecycle. Usage Guide.

California Department of Transportation (Caltrans) Geotechnical Manual. December 2022. <http://www.dot.ca.gov/hq/esc/geotech/geo_manual/page/Embankments_Dec2014.pdf>

Humphrey, D. N. (2011). “Civil engineering applications Using Tire Derived Aggregate (TDA).” California integrated waste management board, California Environmental Protection Agency, Sacramento, CA. Publication # DRRR-2011-038

L. Miao, F. Wang, J. Han, and W. Lv. Benefits of geosynthetic reinforcement in widening of embankments subjected to foundation differential settlement. Geosynthetics International. 2014, 21:5, 321-332.

Mohamad, Ramli. Straits Consulting Engineers. Precompression of soft soils by surcharge preloading – some common pitfalls and misunderstood fundamentals. <http://www.straits-engineers.com/publications_pdf/publication_20.pdf>

Roadway Slopes and Embankments. Montana Department of Transportation Geotechnical Manual. July 2008. <https://www.mdt.mt.gov/other/materials/external/geotech_manual/chapter15.pdf>

Tweedie, J. J., Humphrey, D. N., and Sandford, T. C. _1998_. “Tire chips as light-weight backfill for retaining walls—Phase II.” A study for the New England Transportation Consortium, Dept. of Civil Engineering, Univ. of Maine, Orono, ME.

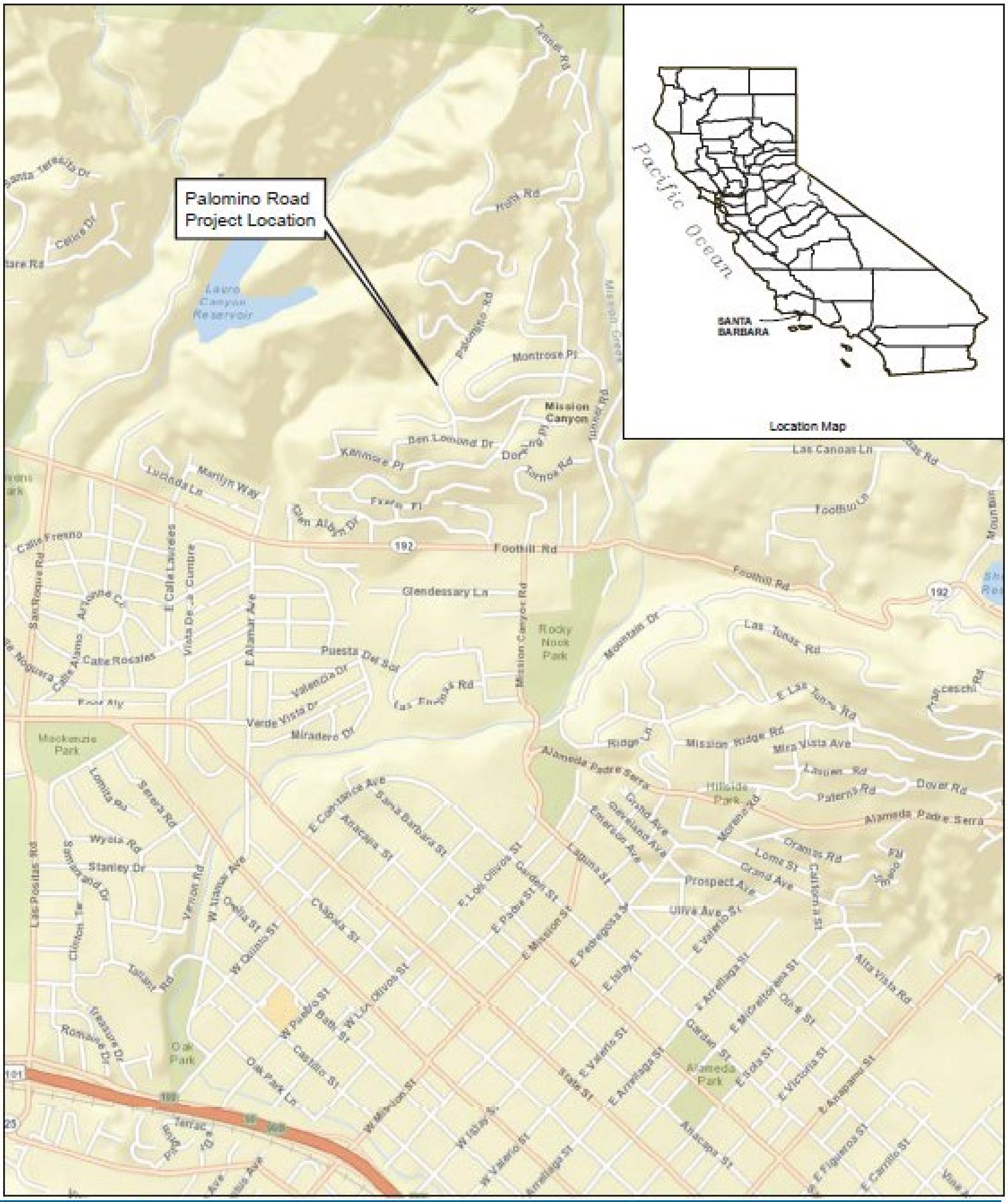
Wartman, J., Natale, M., and Strenk, P. (2007). “Immediate and Time-Dependent Compression of Tire Derived Aggregate.” J. Geotech. Geoenviron. Eng., 133(3), 245–256.

Weng, Xiaolin and Wei Wang. Influence of differential settlement on pavement structure of widened roads based on large-scale model test. Journal of Rock Mechanics and Geotechnical Engineering. 2011, 3 (1): 90-96.

WSDOT Pavement Policy. June 2011. <http://www.wsdot.wa.gov/NR/rdonlyres/D7971B81-5443-45B9-8B9B-BFC0D721F5A1/0/WSDOTPavementPolicyFinal71211.pdf

Appendices

Appendix A – Site Vicinity and Location Maps



Paper Size 8.5" x 11" (ANSI A)

0 0.25 0.5

Miles

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California V FIPS 0405 Feet

N

GHD

CalRecycle

CalRecycle
Palomino Road Repair Project

Project Location and Vicinity Map

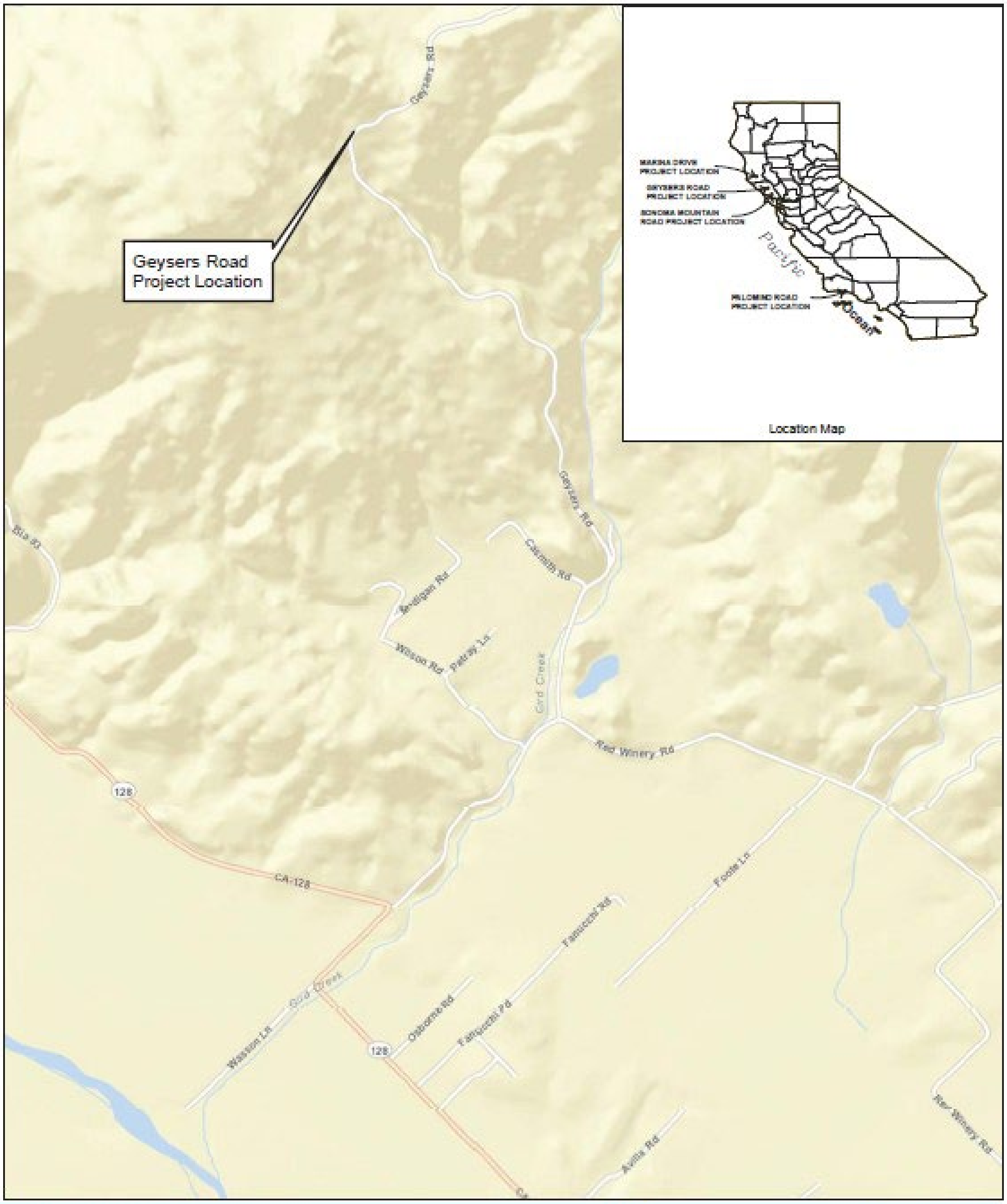
Job Number	12583-12002
Revision	A
Date	24 Sep 2012

Figure A-1

2235 Mercury Way Suite 150 Santa Rosa CA 95407 USA T 707 523 1010 F 707 527 8679 E santarosa@ghd.com W www.ghd.com

G:\12583 - CalRecycle\12583-12-002 Survey Slide Repair SURV 2\08-GIS\Maps\Figures\SB_Palomino_Vic Site Map.mxd

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:bnfev



Paper Size 8.5" x 11" (ANSI A)

0 0.25 0.5

Miles

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California II FIPS 0402 Feet

N

CalRecycle

CalRecycle
Geysers Road Repair Project

Project Location
and Vicinity Map

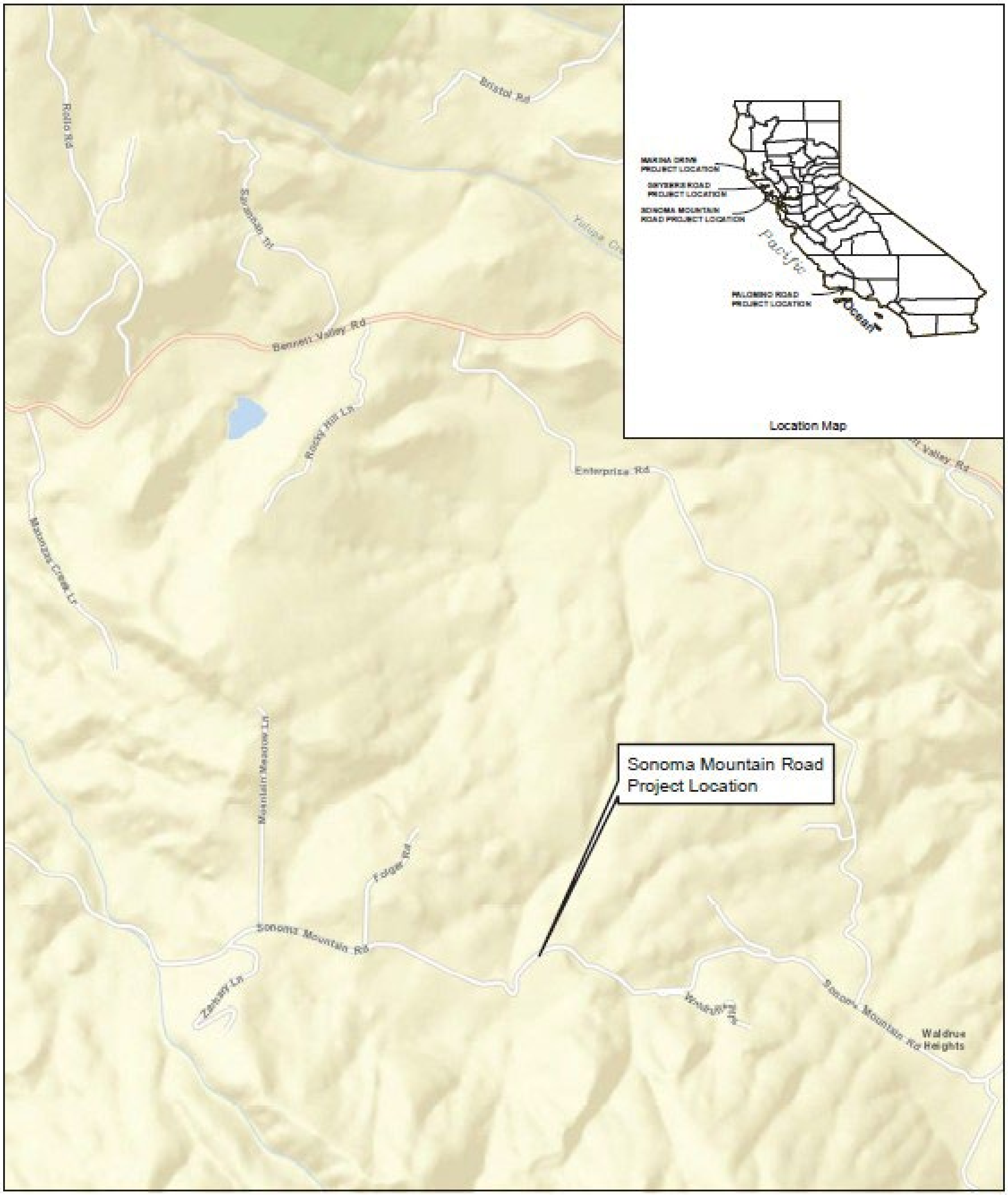
Job Number | 12583-12002
Revision | A
Date | 24 Sep 2012

Figure A-2

2235 Mercury Way Suite 150 Santa Rosa CA 95407 USA T 707 523 1010 F 707 527 8679 E santarosa@ghd.com W www.ghd.com

G:\12583 - CalRecycle\12583-12-002 Survey Slide Repair SURV 2108-GIS\Maps\Figures\HB_GeysersRd_Vic Site Map.mxd

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:jbriley



Paper Size 8.5" x 11" (ANSI A)

0 0.25 0.5

Miles

N

CalRecycle
Sonoma Mountain Road Repair Project

Project Location
and Vicinity Map

Job Number | 12583-12002
Revision | A
Date | 24 Sep 2012

Figure A-3

2235 Mercury Way Suite 150 Santa Rosa CA 95407 USA T 707 523 1010 F 707 527 8679 E santarosa@ghd.com W www.ghd.com

G:\12583 - CalRecycle\12583-12-002 Survey Slide Repair SURV 2\08-GIS\Maps\Figures\SR_SonomaMtn_Vic Site Map.mxd

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by jbriley

Paper Size 8.5" x 11" (ANSI A)
0 0.25 0.5
Miles
Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California II FIPS 0402 Feet

N

CalRecycle
Marina Drive Repair Project

Project Location
and Vicinity Map

Job Number	12583-12002
Revision	A
Date	24 Sep 2012

Figure A-4

2235 Mercury Way Suite 150 Santa Rosa CA 95407 USA T 707 523 1010 F 707 527 8679 E santarosa@ghd.com W www.ghd.com

G:\12583 - CalRecycle\12583-12-002 Survey Slide Repair SURV 2\08-GIS\Maps\Figures\UK_MarinaDrv_Vic Site Map.mxd

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by jbriley

CONTROL POINTS △

PNT	NORTHING	EASTING	ELEVATION	DESCRIPTION
1	2284325.11	6799175.28	2088.37	3/4" REBAR
2	2284029.84	6798932.84	2063.47	3/4" REBAR

NOTES
1) COORDINATES AND ELEVATIONS SHOWN HERE ON ARE ASSUMED.
2) DATE OF SURVEY DECEMBER 9, 2021.
3) MONITORING NAILS ARE SET IN THE RETAINING WALL
4) GUARD RAIL ELEVATIONS S–_ ARE ON THE TOP CENTER OF I–BEAM.

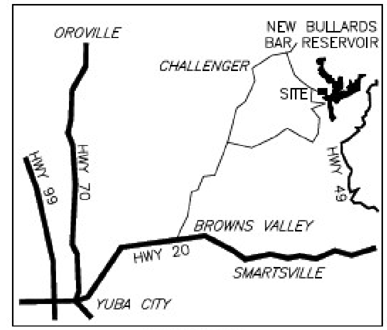
LEGEND

I	I BEAM
△	CONTROL POINT
O	MONITORING NAIL
o—•—•—o—	GUARD RAIL
— — — —	EDGE OF GRAVEL ROAD
XXX	NAIL POINT NAME (A THRU G)

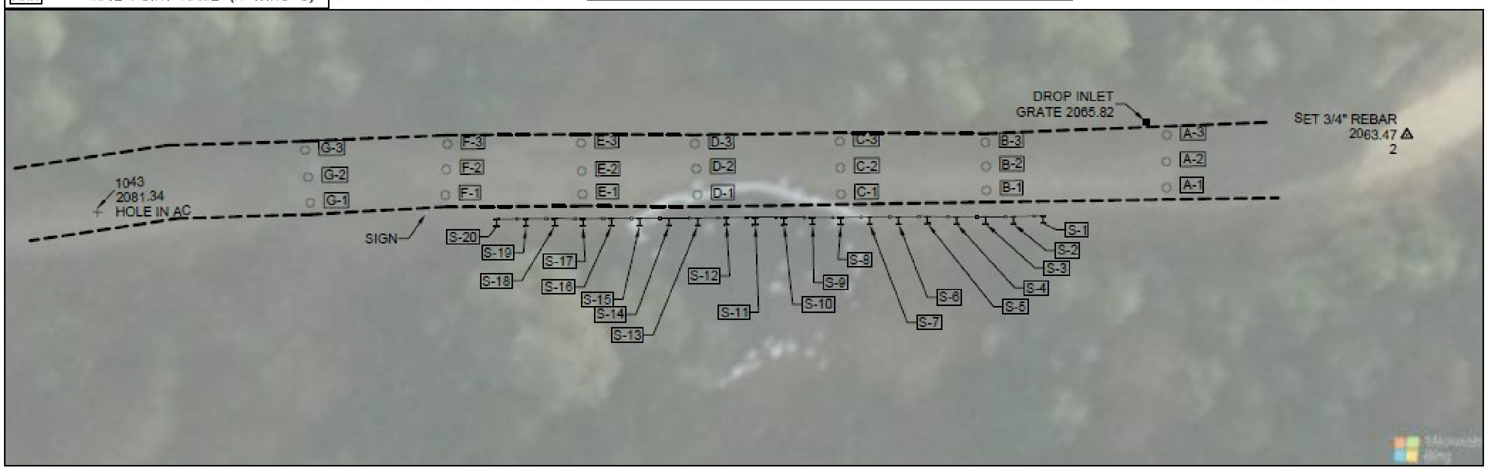
SCALE: 1"=10'
0 10 20

MONITORING NAILS O – POINT NAME SHOWN BOXED XXX

PNT	NORTHING	EASTING	ELEV 2021	ELEV 2023
A–1	2284074.04	6798958.95	2066.43	2066.41
A–2	2284070.37	6798962.93	2066.32	2066.30
A–3	2284066.54	6798966.93	2065.97	2065.96
B–1	2284101.91	6798984.16	2068.33	2068.31
B–2	2284098.54	6798987.88	2068.29	2068.26
B–3	2284095.24	6798991.62	2068.10	2068.09
C–2	2284120.95	6799008.36	2070.21	2070.18
C–3	2284117.29	6799012.44	2070.00	2069.98
D–1	2284146.62	6799024.57	2072.08	2072.02
D–2	2284143.08	6799028.69	2072.00	2071.97
D–3	2284139.72	6799032.70	2071.84	2071.81
E–1	2284164.07	6799041.06	2073.82	2073.79
E–2	2284160.89	6799044.64	2073.75	2073.72
E–3	2284157.03	6799049.03	2073.53	2073.50
F–1	2284185.10	6799060.42	2075.88	2075.86
F–2	2284181.32	6799064.15	2075.75	2075.73
F–3	2284177.55	6799067.89	2075.49	2075.47
G–1	2284206.77	6799078.44	2077.86	2077.84
G–2	2284203.49	6799082.65	2077.87	2077.84
G–3	2284200.10	6799087.22	2077.74	2077.72



VICINITY MAP
NOT TO SCALE



PRELIMINARY

GHD

CAL RECYCLE
MORAN ROAD 2023

MONITORING SURVEY

Project No. 12581260
Date May 2022

Appendix A-6

CONTROL POINTS △

PNT	NORTHING	EASTING	ELEVATION	DESCRIPTION
1	2217179.73	6649851.73	4000.00	REBAR
2	2217184.07	6649969.47	3994.51	IRON PIPE
3	2217216.55	6649724.89	4013.87	IRON PIPE

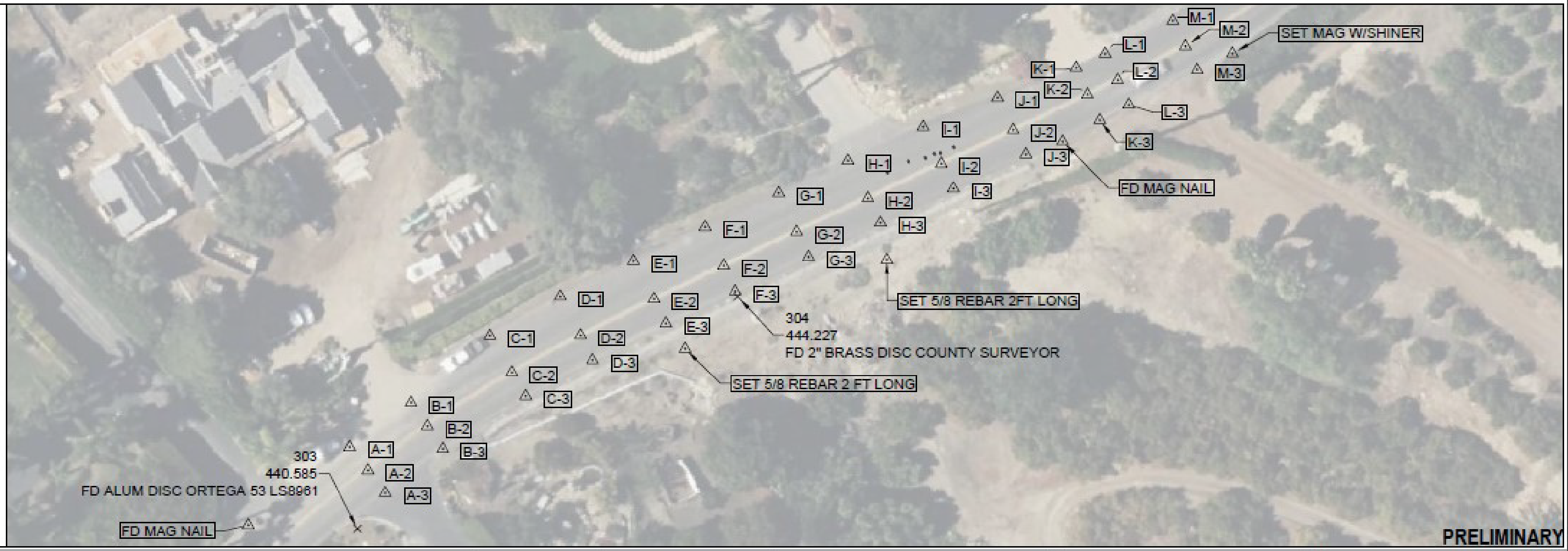
NOTES
1) COORDINATES AND ELEVATIONS SHOWN HERE ON ARE ASSUMED.
2) DATE OF SURVEY JUNE 22 AND JUNE 23.
3) MONITORING NAILS ARE SET IN THE RETAINING WALL
4) GAURD RAIL ELEVATIONS ARE ON THE TOP CENTER OF I-BEAM.

LEGEND
△ CONTROL POINT
XXX NAIL POINT NUMBER

SCALE: 1"=40'
0 40 80

MONITORING NAILS ⭘ – POINT NUMER SHOWN BOXED XXX

PNT	NORTHING	EASTING	ELEV 22	ELEV 23
A–1	1982732.90	6079379.56	442.13	
A–2	1982723.75	6079386.62	441.94	441.96
A–3	1982714.93	6079393.43	441.00	441.01
B–1	1982750.27	6079403.50	442.83	442.85
B–2	1982740.95	6079409.88	442.66	442.68
B–3	1982732.25	6079415.94	441.74	441.73
C–1	1982776.31	6079434.40	442.88	
C–2	1982762.03	6079442.88	443.14	443.15
C–3	1982752.80	6079448.43	442.82	442.82
D–1	1982791.68	6079461.97	443.17	443.21
D–2	1982776.51	6079469.74	443.40	443.38
D–3	1982766.81	6079474.49	443.08	443.08
E–1	1982805.53	6079490.53	443.36	
E–2	1982790.71	6079498.50	443.59	443.59
E–3	1982781.18	6079503.22	443.33	443.34
F–1	1982818.80	6079518.58	443.79	
F–2	1982803.67	6079525.77	444.04	444.03
F–3	1982793.65	6079530.30	443.78	443.79
G–1	1982832.02	6079547.38	444.47	
G–2	1982816.92	6079554.29	444.77	444.81
G–3	1982807.11	6079559.03	444.39	444.43
H–1	1982844.69	6079574.43	445.50	445.61
H–2	1982830.03	6079582.17	445.79	445.85
H–3	1982820.49	6079587.20	445.42	445.48
I–1	1982857.96	6079603.85	446.76	446.92
I–2	1982843.54	6079610.91	447.24	447.29
I–3	1982833.87	6079615.73	446.83	446.86
J–1	1982869.37	6079632.95	447.85	447.88
J–2	1982856.77	6079639.03	448.40	448.42
J–3	1982847.15	6079644.07	448.12	448.15
K–1	1982881.04	6079663.65	448.91	448.93
K–2	1982870.61	6079668.13	449.71	449.73
K–3	1982860.55	6079672.99	449.57	449.61
L–1	1982886.48	6079675.02	449.52	449.54
L–2	1982876.21	6079679.89	450.26	450.30
L–3	1982866.59	6079684.34	450.35	450.42
M–1	1982899.42	6079701.51	451.15	451.21
M–2	1982889.38	6079706.37	451.89	451.97
M–3	1982880.20	6079711.05	451.90	452.03



GHD
CAL RECYCLE
ORTEGA RIDGE ROAD
MONITORING SURVEY
Project No. 12581280
Date SEPT 2023
ANSI B

CONTROL POINTS △

PNT	NORTHING	EASTING	ELEVATION	DESCRIPTION
21	2212720.74	6606167.43	1648.50	NAIL
22	2212571.55	6606016.60	1651.70	NAIL
24	2212830.98	6606233.70	1645.61	NAIL

MONITORING NAILS ○ – POINT NAME SHOWN BOXED [XXX]

PNT	NORTHING	EASTING	JAN 2022	AUG 2023
N–1	2212704.97	6606146.20	1645.91	1645.91
N–2	2212693.35	6606133.76	1645.11	1645.14
N–3	2212678.91	6606119.77	1645.23	1645.29
N–4	2212661.23	6606101.25	1645.98	1646.03
N–5	2212645.94	6606086.48	1646.34	1646.32
N–6	2212627.27	6606069.16	1647.22	1647.19

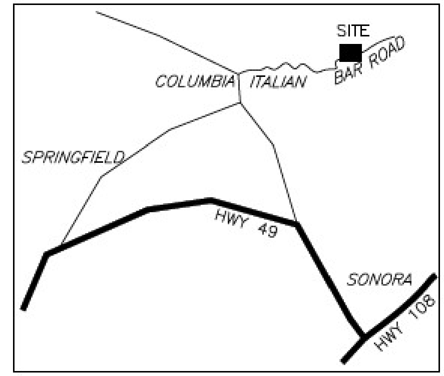
LEGEND

- I BEAM
- △ CONTROL POINT
- ○ MONITORING NAIL
- GUARD RAIL
- EDGE OF GRAVEL ROAD
- [XXX] NAIL POINT NUMBER

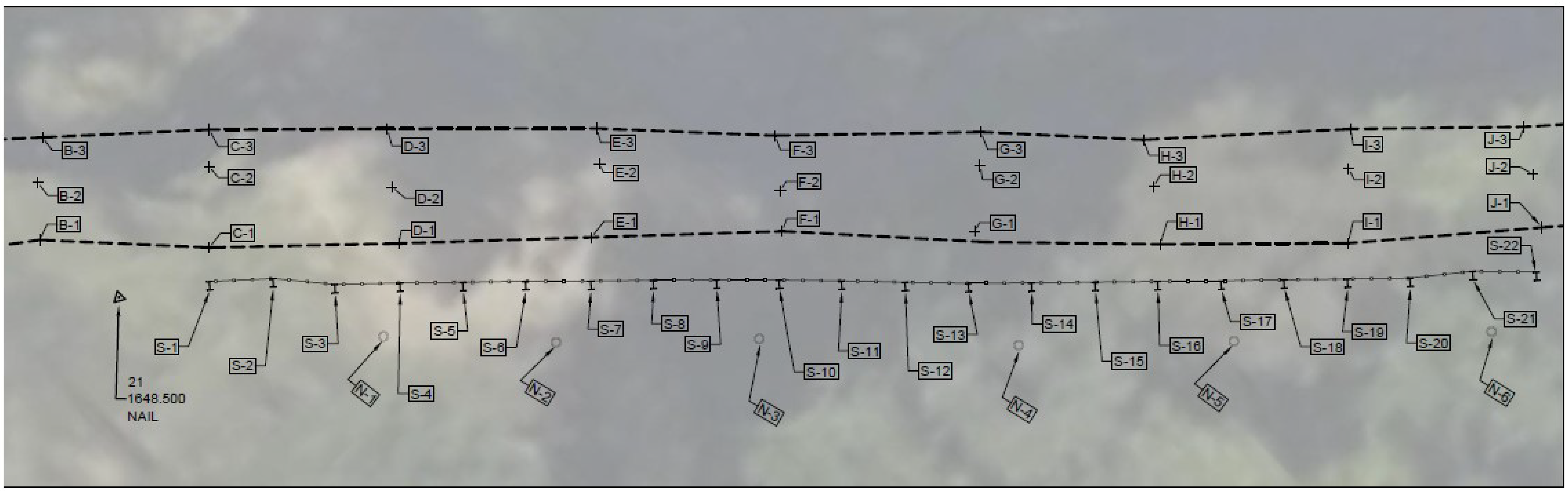
SCALE: 1"=10'

0 10 20

NOTES
1) COORDINATES AND ELEVATIONS SHOWN HERE ON ARE ASSUMED.
2) DATES OF SURVEYS JAN 19, 2022 AND AUG 10, 2023.
3) MONITORING NAILS ARE SET IN THE RETAINING WALL.
4) GAURD RAIL ELEVATIONS ARE ON THE TOP CENTER OF I-BEAM.



VICINITY MAP
NOT TO SCALE



PRELIMINAR

GHD Inc.

Client: CAL RECYCLE
Project: ITALIAN BAR ROAD 3
Title: MONITORING SURVEY
Project No. 12581260 | Date May 2022

Appendix B – Photo Log Summary

Marina Drive
Site and TDA Area

November 2021

January 2023

Geysers Road

Site and TDA Area

November 2021	January 2023
	
	

Sonoma Mountain Road
Site and TDA Area

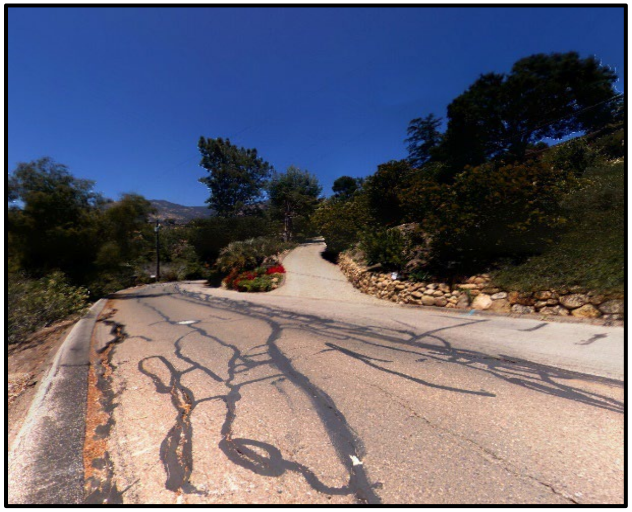
June 2018

December 2021

Palomino Road
Site and TDA Area

August 2018

June 2022



Moran Road
Site and TDA Area

October 2019

April 2023

Ortega Ridge Road
Site and TDA Area

January 2020

September 2023

Italian Bar Road
Site and TDA Area

June 2020

September 2023

Appendix C – Historical Survey Details

C1 Marina Drive

To date, 10 surveys have been completed at the Marina Drive project site, as summarized in Table C-1.

Table C1. Surveys Conducted at Marina Drive

Survey No.	Survey Date	Findings
1	April 22, 2009	This survey was conducted to establish a baseline of set surveying points. These points allow subsequent survey data to be compared to previous surveys, facilitating the assessment of any movement at the site. Survey data were collected at various locations, including the edges of pavement, centerline of pavement, and the toe of slope. Once complete, the datasets were compared to identify any movement at the site.
2	January 7, 2010	Prior to conducting the 2nd survey, a more refined survey method was developed to ensure more accurate data comparison. Permanent survey stakes were placed at designated locations, providing precise point data for all subsequent surveys. Survey measurements were taken at 50-foot intervals along the centerline of pavement and edge of pavement, spanning from the beginning to the end of the limit of work. Additional survey data were gathered on the slope and drainage features surrounding the TDA road improvement site. Given the variance in survey methodology compared to the 1st survey data, conducting a comparison of datasets after the 3rd survey in April 2010 proved beneficial.
3	March 29, 2010	The 3rd survey was the first survey that provided comparable data from the survey stakes set in January 2010. This survey was conducted to verify the baseline of set, staked surveying points established in the 2nd survey. The survey data showed no significant changes in location or elevation between the 2nd survey and the 3rd survey. However, some settlements were observed along the centerline of the road, along with the presence of two visible asphalt cracks. The first crack was noted near Station 12+19.13 of the centerline at survey point 766, while the second crack appeared near station 13+63.03 of the centerline, spanning from survey point 776 to 777.
4	November 11, 2010	This survey was conducted to collect data from the staked surveying points established in the 2nd survey. The survey data showed no significant changes in location or elevation between the 3rd survey

Survey No.	Survey Date	Findings
		and 4th survey. However, one area showed newly expanded asphalt cracking, along with a patch of alligator cracking. This area is located near Station 13+60, spanning from survey points 894 to 897.
5	June 18, 2012	The survey data showed no significant changes in location or elevation between this survey and the 4th survey. The elevation difference in the normalized average of all survey points was found to be less than the calculated survey precision of the survey instrument. However, the area of alligator cracking observed in November 2011 was noted to have increased in size, and the extent of asphalt cracking had also expanded.
6	January 15, 2014	Overall, this survey data indicated that the settlement at the site has stabilized. The average settlement rate (0.02 feet/year) of the survey points over entire TDA sections is less than the calculated survey precision of the survey instrument since the November 2010 survey event. There were no significant changes in location or elevation between this survey and the 5th survey. However, the extent of the asphalt cracking appears to have slightly increased.
7	June 19, 2015	This survey data confirmed that the settlement at the site has stabilized. There was no change in elevation between the 6th survey and this survey, and site conditions remained consistent with the previous survey.
8	November 29, 2016	The site appears to have substantially stabilized three years after completion of construction and has remained stable for three consecutive survey events; therefore, settlement is generally complete. However, there are several cracks along the edge of the roadway, and the alligator cracking near the southern edge of the TDA area has increased.
9	July 25, 2018	The survey of the site confirmed substantially stabilized settlement. However, there are several cracks along the edge of the roadway and the alligator cracking near the southern edge of the TDA area has increased. MCDOT is in the process of repaving the road. Photos from this survey event are provided in Appendix B.
10	November 24, 2021	The survey reveals the site has been repaved since the last survey. However, there is still some alligator cracking and settling along the cliff's edge. Photos from this survey event are provided in Appendix B.

C2 Geysers Road

To date, 10 surveys have been completed at the Geysers Road project site, as summarized in Table C-2.

Table C2. Surveys Conducted at Geysers Road

Survey No.	Survey Date	Findings
1	April 22, 2009	The survey was conducted to establish a baseline of set surveying points, facilitating comparison with subsequent surveys. Survey data were collected at various locations, including but not limited to the edges of pavement, centerline of pavement, the toe of slope, drainage outlet elevations, and above-ground pipe locations.
2	January 5, 2010	Prior to conducting the 2nd survey, a more refined survey method was developed to ensure more accurate data comparison. Permanent survey stakes were placed at designated locations, providing precise point data for all subsequent surveys. The survey was conducted to establish a baseline of set staked surveying points. Survey data were taken at various locations, including the edges of pavement, centerline of pavement, and the toe of slope.
3	March 29, 2010	This 3rd survey was the first survey that provided comparable data from the survey stakes set in January 2010. The survey was conducted to verify the baseline of set, staked surveying points established in the 2nd survey. The survey data showed no significant changes in location or elevation between the 2nd and 3rd surveys. However, compared to the 1st survey, some noticeable changes were observed. At Cross Section A-A', settlement was observed along the shoulder of the southern edge of Geysers Road. This settlement was also visible in Section C-C', depicting the profile of Geysers Road along the south edge of the pavement. The settlement appears to be between Stations 131+00 and 132+00, with the maximum settlement at Station 131+39 (Section A-A'). Additionally, a visible asphalt crack was observed near Station 132+63, with a measured elevation difference of 0.10 feet that extended for approximately 40 linear feet. The location of the crack was adjacent to the edge of TDA, as surveyed during construction. During this survey, three survey control points were established outside the limit of work to be used for all subsequent surveys: Well Monument #1 located on the road centerline near Station 129+20, Well Monument #2 located on the road centerline near Station 133+00, and Survey Monument 10100, located on the inside shoulder of Geysers Road approximately 20 feet outside of the limit of work.

Survey No.	Survey Date	Findings
4	November 10, 2010	The survey was conducted to collect data from the staked surveying points established in the 2nd survey. The data showed no major changes in elevation between the 3rd survey and the 4th survey. Again, an asphalt crack was observed near Station 132+63 measuring a difference in elevation of 0.10 feet that extended for approximately 40 linear feet. The location of the crack was adjacent to the edge of TDA, as surveyed during construction.
5	May 7, 2012	This site survey was conducted to assess settlement over the 18 months since the 4th survey. Continued gradual settlement was measured. It was observed that Sonoma County had applied asphalt emulsion sealant to the existing cracks noted in earlier surveys. Additionally, it was noted that the existing HDPE culvert located below the TDA fill area at centerline station 131+00 had separated at the pipe joints above and between the pipe anchors, potentially leading to erosion damage at the fill slope. When reduced to 2 significant figures, the settlement rate remained at or below the survey precision from day one.
6	January 22, 2014	The survey was conducted to assess settlement over the previous 20 months since the 5th survey event. Continued gradual settlement was measured since the previous survey event. It was observed that the county had placed an additional layer of asphalt over the existing cracks noted in earlier surveys. The previously noted existing HDPE culvert, located below the TDA fill area at centerline station 131+00, had further separated at the pipe joints above and between the pipe anchors.
7	July 22, 2015	Results from this survey documented the continued gradual settlement at this site. Asphalt separation persisted, resulting in cracks along the roadway and curb.
8	October 13, 2016	This survey showed that pavement elevations had increased compared to the previous survey, with no significant changes in terms of pavement cracks.
9	June 19, 2018	This survey showed minimal settlement compared to the 2016 survey. Asphalt separation and cracks were observed along the roadway and curbside, consistent with previous surveys. Photos from this survey event are provided in Appendix B.
10	December 10, 2021	This survey showed minimal settlement compared to the 2018 survey. Asphalt separation and cracks were observed along the roadway and curbside, consistent with previous surveys. Photos from this survey event are provided in Appendix B.

C3 Sonoma Mountain Road

To date, eight (8) surveys have been completed at the Sonoma Mountain Road project site, as summarized in Table C3.

Table C3. Surveys Conducted at Sonoma Mountain Road

Survey No.	Survey Date	Findings
1	November 12, 2009	Similarly to the April 2009 TDA Surveys at Marina Drive and Geysers Road, the initial survey of Sonoma Mountain Road was conducted to establish a baseline collection of points. A baseline of surveying points allows subsequent survey data to be compared to previous surveys, enabling the detection of any movement through dataset comparison.
2	November 10, 2010	This survey was conducted to collect data from the previously staked surveying points. The survey data showed that there were no significant changes in elevation. However, it was noted there was an area adjacent to and east of the TDA area on the road shoulder that appeared to be lower in elevation than expected, resulting in a puddle with no apparent drainage outlet. This observation was also made immediately after construction had been completed. Since the low spot is not situated directly over the TDA fill, it is not represented in the TDA fill area drawings.
3	July 22, 2012	The 3rd survey showed no significant changes in elevation at the repair site. While this survey only provided two data points for assessing the rate of settlement, the repair project appeared to be settling at a constant rate. Some minor cracking was noted, which was subsequently sealed by Sonoma County. Additionally, a circular depression with slumping features was observed on the downhill side of the road near the north end. Although, the depression was not observed to be directly connected to the drainage piping locations, its shape suggested a potential association with piping or slumping of undetermined causes.
4	January 9, 2014	This survey measured and quantified settlement over the previous 18 months, and indicated continued settlement over the site. Yet, there were no significant changes in elevation. With this survey now providing three data points for assessing the rate of settlement, the repair project appeared to be settling consistently overall. The minor cracking noted in the previous 2012 survey, which was sealed by Sonoma County, has continued to widen up to 1 inch. Additionally, the circular depression with slumping features observed on the downhill side of the road near the north end in the previous survey did not show any significant changes.

Survey No.	Survey Date	Findings
5	June 15, 2015	The 5th survey was conducted to monitor the degree of settlement at this site. Between November 2009 and January 2014, settlement at this site occurred at a constant rate. However, results from this survey indicated a rise in elevation for all points at this site. Roadway cracking was sealed by the County.
6	November 1, 2016	This survey revealed that pavement elevations were lower than the June 2015 survey. However, several data points showed elevations above those recorded in the 2014 survey, suggesting possible subsurface movement. The asphalt separation, previously sealed by the county, has continued to widen and is now over 2 inches wide.
7	June 8, 2018	This survey showed minimal settlement compared to the 2016 survey. Asphalt separations were like previous surveys. Photos from this survey event are provided in Appendix B.
8	June 24, 2022	The survey of this site showed minimal settlement compared to the 2018 survey. Asphalt separations were like previous surveys. Photos from this survey event are provided in Appendix B.

C4 Palomino Road

To date, ten (10) field surveys have been completed at the Palomino Road project site, as summarized in Table C4.

Table C4. Surveys Conducted at Palomino Road

Survey No.	Survey Date	Findings
1	September 8 and September 22, 2010	The early September survey was conducted to establish a baseline of semi-permanent surveying points. Survey reference point nails were installed in the road surface prior to this initial survey, positioned at the east edge of road, centerline, center of TDA fill, and edge of pavement along stations 0+59.46, 1+78.49, and 2+90.00. Additionally, survey reference point nails were installed only in the center of TDA fill, hammered into place along stations 1+19.15, 2+38.14, and at the limits of work. Survey data were collected at various locations, including the edges of pavement, centerline of new pavement, and centerline of adjacent existing asphalt, serving as points for comparison. The late September survey was conducted to establish a 2nd set of data from the survey reference point nails. The edge of road, station marker, centerline, middle of TDA fill, and inside edge of the asphalt berm were surveyed along stations 0+59.46, 1+78.49, and 2+90.00. Additionally, the middle of TDA fill and edge of berm were surveyed along Station 1+19.15, 2+38.14, and at the limits of work. No obvious changes to the newly rebuilt road section were observed.
2	October 8, 2010	This survey was conducted to establish a 3rd set of data from the survey nail points. The edge of road, station marker, centerline, middle of TDA fill, and inside edge of the asphalt berm were shot along stations 0+59.46, 1+78.49, and 2+90.00. Additionally, the middle of TDA fill and edge of berm were shot along stations 1+19.15, 2+38.14, and at the limits of work. No obvious changes to the newly rebuilt road section were observed.
3	December 27, 2010	The survey was conducted to establish a 4th set of data from the survey nail points. The edge of road, station marker, centerline, middle of TDA fill, and inside edge of the asphalt berm were shot along stations 0+59.46, 1+78.49, and 2+90.00. The middle of TDA fill and edge of berm were shot along stations 1+19.15, 2+38.14, and at the limits of work. No obvious changes to the newly rebuilt road section were observed.

Survey No.	Survey Date	Findings
4	January 2, 2011	This survey was conducted to establish a 5th set of data from the survey nail points. The edge of road, station marker, centerline, middle of TDA fill, and inside edge of the asphalt berm were shot along Station 0+59.46, 1+78.49, and 2+90.00. The middle of TDA fill and edge of berm were shot along Station 1+19.15, 2+38.14, and at the limits of work. However, a visible crack was noted in the asphalt road surface on the western side of the Palomino Road TDA fill area.
5	June 28, 2012	The June survey conducted to establish a sixth set of data from the survey reference point nails. The edge of road, station marker, centerline, middle of TDA fill, and inside edge of the asphalt berm were shot along stations 0+59.46, 1+78.49, and 2+90.00. Additionally, the middle of TDA fill and edge of berm were surveyed along Station 1+19.15, 2+38.14, and at the limits of work. No obvious changes to the newly rebuilt road section were observed. However, cracking and horizontal movement were observed in a concrete wall and paver entry to the private driveways adjacent to the north end of the road repair. This may be caused by some earthwork observed to be in progress immediately downslope of the entry.
6	February 7, 2014	The February 2014 survey was conducted to establish a seventh set of data from the survey reference point nails. As conducted previously, the edge of road, station marker, centerline, middle of TDA fill, and inside edge of the asphalt berm were surveyed along stations 0+59.46, 1+78.49, and 2+90.00. Additionally, the middle of TDA fill and edge of berm were surveyed along Station 1+19.15, 2+38.14, and at the limits of work. No obvious changes to the newly rebuilt road section were observed.
7	October, 2015	The survey was conducted to determine whether there were additional changes to the repair site. Pavement cracking along the road and adjacent driveways, as documented in previous surveys, was observed. No significant changes were noted.
8	November 16, 2016	The survey showed that the pavement cracking along the road and driveways remained like that observed in previous surveys. No significant changes were observed in the newly rebuilt road section.
9	August 15, 2018	The survey revealed that several data points exhibited elevations higher than those recorded in the 2016 survey, indicating potential subsurface movement consistent with previous findings. Photos from this survey event are provided in Appendix B.

Survey No.	Survey Date	Findings
10	June 24, 2022	The survey indicated that the average site grades decreased by 1.8 inch compared to the 2018 survey, confirming total site subsurface movement consistent with the previous survey. Photos from this survey event are provided in Appendix B.

Additional Comments Regarding Palomino Road:

Based on the 2014 findings, the TDA repaired section of the roadway is currently functioning as a single block, in contrast to the road section prior to repair and the current northbound side of the road, which has developed a series of cracks in response to tensile stress. Cracking of the asphalt surface is expected after repairs of this nature as the surface and subsurface materials adjust to the new configuration. The Santa Barbara County Department of Public Works noted cracking at Palomino Road on October 24, 2011 (See Appendix B for Photo Log Summary).

Cracking of the paved surface at the Palomino Road repair has been observed since the repair was completed and was documented in October 2011. The cracks extend along the roadway in both the new paving and the older paving which was unaffected by the road repair. Prior to the February 2014 survey event, during an October 2013 site visit, it was noted that road cracks were consistent with the orientation of the cracks observed historically. The main difference observed between the historical cracks and those currently present is their location. Most of the current road deformation is concentrated in the center of the roadway at the seam connecting the TDA-repaired section (southbound lane) to the original road section (northbound lane). Additionally, the prominent crack through the center of the road, which extends west to the curb for approximately 30 feet before transversing back to the center, occurred in the approximate location historically documented.

These observations suggest that the previously documented poor subsurface conditions of the site persist. Consequently, CalRecycle and the County of Santa Barbara installed slope inclinometers in February 2014 to initiate a separate phase of subsurface investigation for site slope stability and monitoring. Given the extent of cracking over both TDA fill and non-TDA fill areas, it is assumed that the crack results from a deep-seated geologic movement. Further surveys and investigations will be recommended and reported under separate cover.

C5 Moran Road

To date, two (2) surveys have been completed at the Moran Road project site, as summarized in Table C5.

Table C5. Surveys Conducted at Moran Road

Survey No.	Survey Date	Findings
1	June, 2022	Newly constructed pile wall and asphalt road surveyed to establish a baseline of semi-permanent surveying points. Survey reference point nails were installed in the road surface prior to this initial survey, reference points established on top of piles.
2	April, 2023	Site condition looks like previous year observations, no obvious changes to the newly rebuilt road section were observed.

C6 Ortega Ridge Road

To date, two (2) surveys have been completed at the Ortega Ridge Road project site, as summarized in Table C6.

Table C6. Surveys Conducted at Ortega Ridge Road

Survey No.	Survey Date	Findings
1	June, 2022	Newly constructed MSTDA wall project and asphalt road top surveyed to establish a baseline of semi-permanent surveying points. Survey reference point nails were installed in the road surface prior to this initial survey, reference points established on gabion wall face.
2	September, 2023	Site condition looks similar to previous observations, no obvious changes to the newly rebuilt road section were observed.

C7 Italian Bar Road

To date, two (2) field surveys have been completed at the Italian Bar Road project sites, as summarized in Table C7.

Table C7. Surveys Conducted at Italian Bar Road

Survey No.	Survey Date	Findings
1	June, 2022	Newly constructed MSTDA wall project and gravel road top surveyed to establish a baseline of semi-permanent surveying points. Survey reference point nails were installed in the road surface prior to this initial survey, reference points established on top of rock gabion wall face.

Survey No.	Survey Date	Findings
2	September, 2023	Site condition looks similar to previous observations, no obvious changes to the newly rebuilt road section were observed.

Appendix D – Calculation of Overbuild

Tire shreds experience immediate compression under an applied load, such as the weight of an overlying soil cover. The top elevation of the tire shred layer(s) should be overbuilt to compensate for this compression. The amount of overbuild is determined using the procedure given below with the aid of a design chart (Figure D-1). Figure D-1 is applicable to Type B tire shreds (12-in. maximum size) that have been placed and compacted in 12-inch layers. To use this procedure with smaller Type A shreds (3-in. maximum size), increase the calculated overbuild by 30 percent.

Single TDA Layer

The amount of overbuild for a single tire shred layer is determined directly from Figure D-1. First, calculate the vertical stress that will be applied to the top of the tire shred layer as the sum of the unit weights times the thicknesses of the overlying layers. Second, enter Figure D-1 with the calculated vertical stress and the final compressed thickness of the tire shred layer to find the amount of overbuild. Consider the following example:

9 in (0.75 ft) pavement at 160 pcf

2 ft aggregate base at 125 pcf

2 ft low permeability soil cover at 120 pcf

10 ft thick tire shred layer

The vertical stress applied to the top of the tire shred layer would be:

(0.75 ft x 160 pcf) + (2 ft x 125 pcf) + (2 ft x 120 pcf) = 610 psf

Enter Figure D-1 with 610 psf. Using the line for a tire shred layer thickness of 10 feet results in an overbuild of 0.68 feet. Round to the nearest 0.1 feet; thus, use an overbuild of 0.7 feet.

Bottom TDA Layer of Two-Layer Cross Section

The amount of overbuild for the bottom tire-derived aggregate layer of a two-layer cross section is also determined directly from Figure D-1. The procedure is the same as described above for a single tire shred layer. Consider the following example:

9 in (0.75 ft) pavement at 160 pcf

2 ft aggregate base at 125 pcf

2 ft low-permeability soil cover at 120 pcf

10 ft upper tire shred layer at 50 pcf

3 ft soil separation layer at 120 pcf

10 ft thick lower tire shred layer

The vertical stress applied to the top of the lower tire shred layer would be:

(0.75 ft x 160 pcf) + (2 ft x 125 pcf) + (2 ft x 120 pcf) + (10 ft x 50 pcf) + (3 ft x 120 pcf) = 1470 psf

Enter Figure D-1 with 1470 psf and using the line for a tire shred layer thickness of 10 feet results in an overbuild of 1.13 feet. Round to the nearest 0.1 foot; thus, use an overbuild of 1.1 feet for the lower tire shred layer.

Upper TDA Layer of Two-Layer Cross Section

The overbuild of the top elevation for the upper tire shred layer for a two-layer cross section must include both the compression of the upper tire shred layer when the pavement, base, and soil cover is placed, and the compression of the lower tire shred layer that will still occur under the weight of these layers. In other words, the lower tire shred layer has not yet compressed to its final thickness. This will only occur once the embankment reaches final grade. To determine how much compression of the lower tire shred layer will occur due to placing the pavement, base and soil cover, consider the two-layer example used above:

9 in (0.75 ft) pavement at 160 pcf

2 ft aggregate base at 125 pcf

2 ft low permeability soil cover at 120 pcf

10 ft upper tire shred layer at 50 pcf

3 ft soil separation layer @120 pcf

10 ft thick lower tire shred layer

Step 1. The final vertical stress applied to the top of the upper tire shred layer would be: (0.75 ft x 160 pcf) + (2 ft x 125 pcf) + (2 ft x 120 pcf) = 610 psf. Enter Figure D-1 with 610 psf. Using the line for a tire shred layer thickness of 10 feet results in a compression of 0.68 feet.

Step 2. Once the upper tire shred layer is in place, the vertical stress applied to the top of the lower tire shred layer would be: (10 ft x 50 pcf) + (3 x 120 pcf) = 860 psf. To determine the compression of the lower tire shred layer that has occurred up to this point, enter Figure D-1 with 860 psf. Using the line for a tire shred layer thickness of 10 feet results in a compression of 0.84 feet.

Step 3. Once the embankment reaches its final grade, the vertical stress applied to the top of the lower tire shred layer would be: (0.75 ft x

160 pet) + (2 ft x 125 pet) + (2 ft x 120 pcf) + (10 ft x 50 pcf) + (3 ft x 120 pcf) = 1470 psf. Enter Figure D-1 with 1470 psf. Using the line for a tire shred layer thickness of 10 feet results in an overbuild of 1.13 feet. (Note: Rounding to 1.1 feet would give the overbuild of the lower tire shred layer).

Step 4. Subtract the result from Step 2 from Step 3 to obtain the compression of the lower tire shred layer that will occur when the pavement, base, and soil cover is placed: 1.13 ft - 0.84 ft = 0.29 ft.

Step 5. Sum the results from Steps 1 and 4 to obtain the amount the top elevation of the upper tire shred layer should be overbuilt: 0.68 ft + 0.29 ft = 0.97 ft. Round to the nearest 0.1 feet. Thus, the elevation of the top of the upper tire shred layer should be overbuilt by 1.0 feet.

Final result: Overbuild the top elevation of the lower tire shred layer by 1.1 feet and the upper tire shred layer by 1.0 feet.

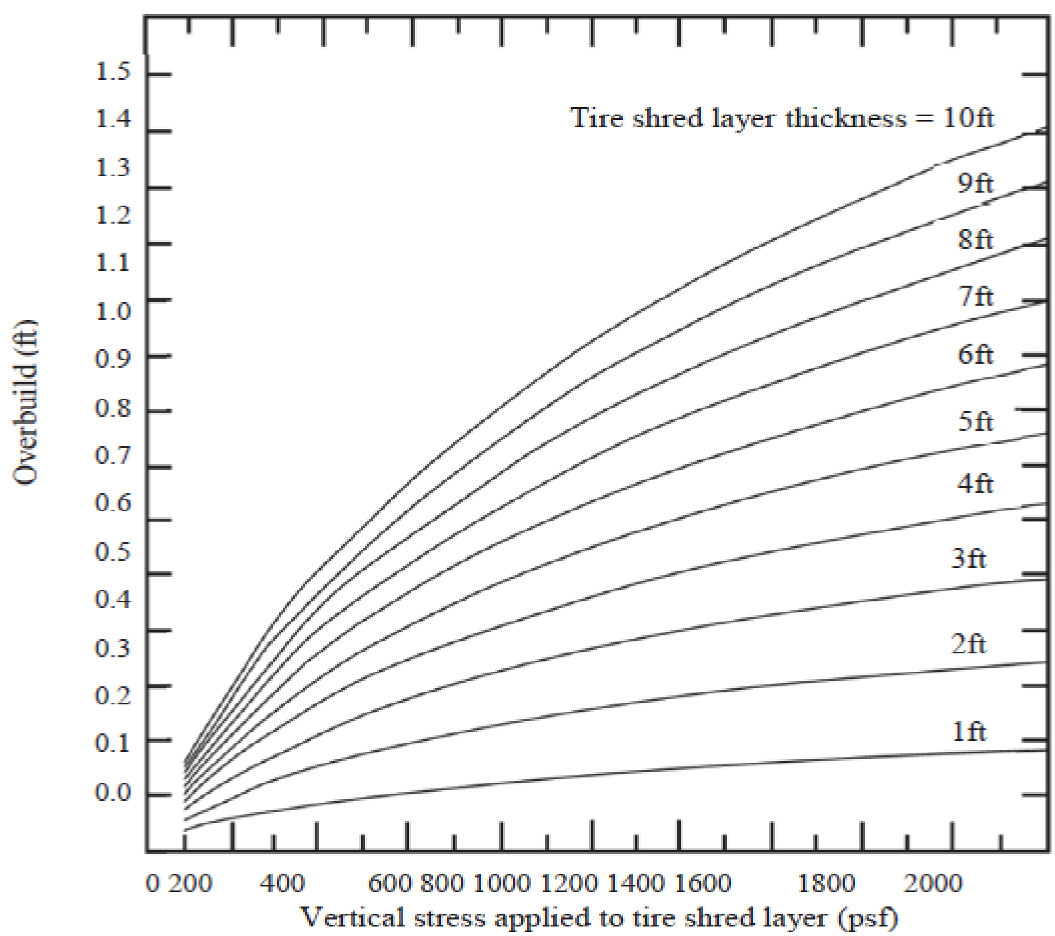
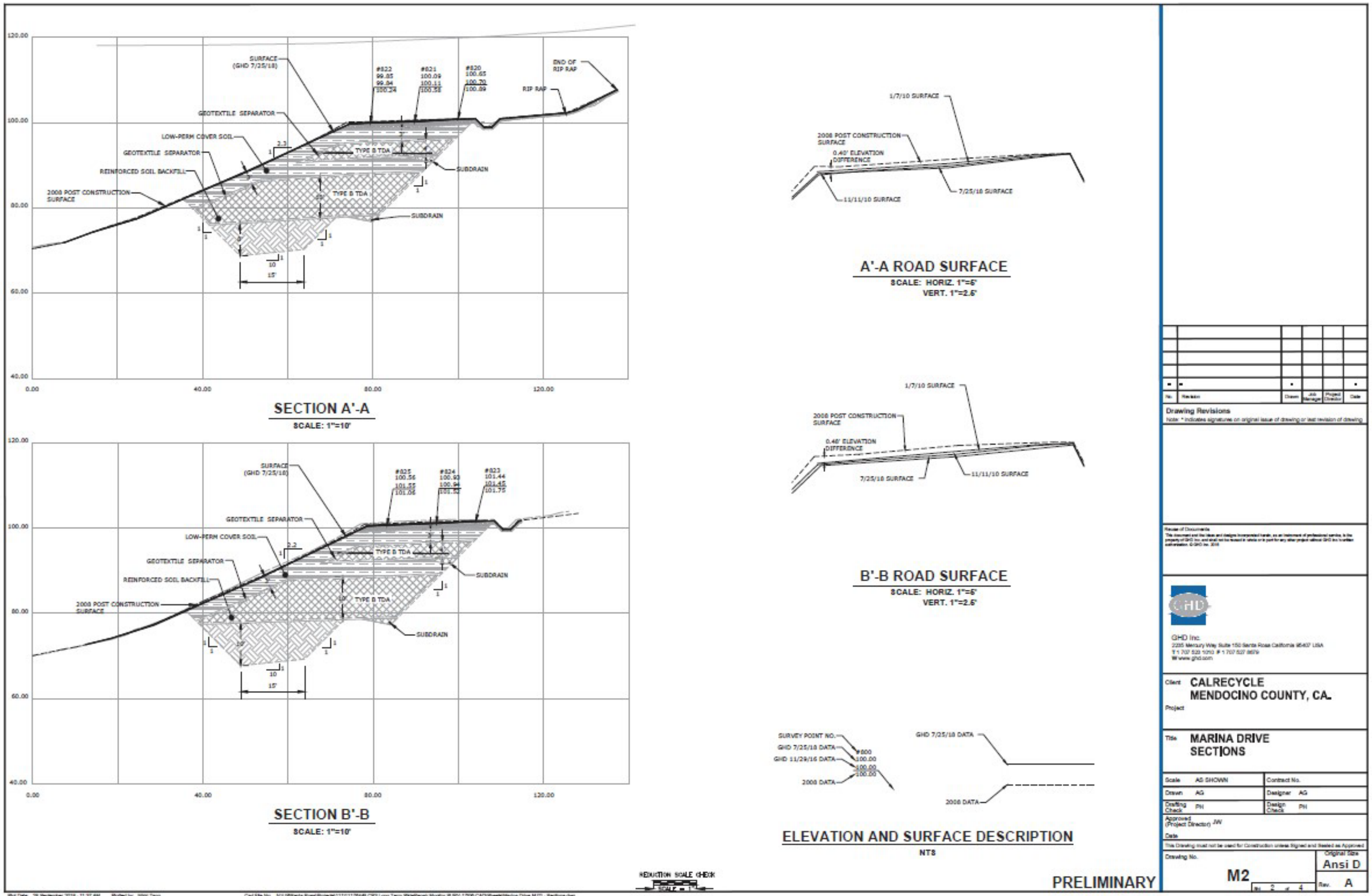
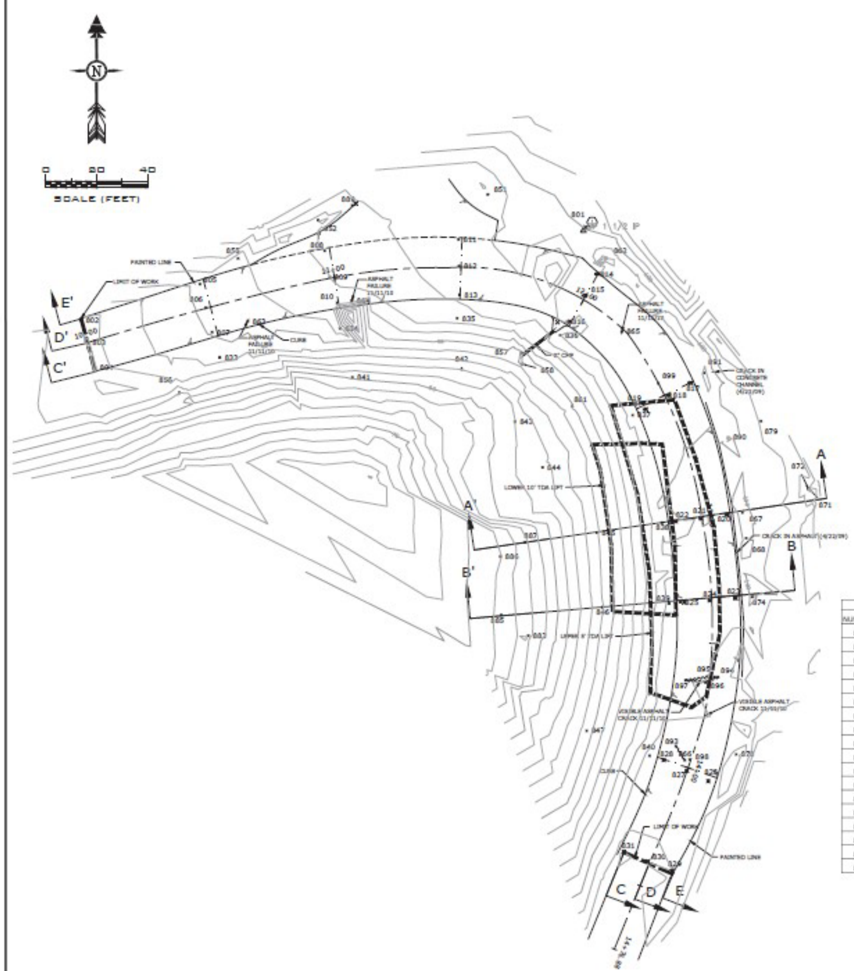


Figure D-1: Overbuild Design Chart for Type B

Appendix E - Drawings


SECTION A'-A
SCALE: 1"=10'
SECTION B'-B
SCALE: 1"=10'
A'-A ROAD SURFACE
SCALE: HORIZ. 1"=6'
VERT. 1"=2.6'
B'-B ROAD SURFACE
SCALE: HORIZ. 1"=6'
VERT. 1"=2.6'
ELEVATION AND SURFACE DESCRIPTION
NTS
SURFACE (GHD 7/25/18)
GEOTEXTILE SEPARATOR
LOW-PERM COVER SOIL
REINFORCED SOIL BACKFILL
2008 POST CONSTRUCTION SURFACE
TYPE B TDA
SUBDRAIN
END OF RIP RAP
RIP RAP
1/7/10 SURFACE
0.40' ELEVATION DIFFERENCE
11/11/10 SURFACE
7/25/18 SURFACE
SURVEY POINT NO.
GHD 7/25/18 DATA
GHD 11/29/16 DATA
2008 DATA
PRELIMINARY
CALRECYCLE
MENDOCINO COUNTY, CA.
MARINA DRIVE
SECTIONS
Drawing Revisions
Scale AS SHOWN
Drawn AG
Designer AG
Drawing No. M2
Original Size Ansi D
Rev. A



LEGEND

(line)	CONTOUR LINE
(line)	ROAD CL
(line)	TDA ENVELOPE
(line)	SURVEY POINTS AT ROAD MARKERS
8xx	SURVEY MONITORING POINT 04/22/09
8xx	SURVEY MONITORING POINT 7/25/18
FL	FLOW LINE
(line)	CORRUGATED METAL PIPE
(line)	LIMIT OF WORK
(line)	ROAD
B	SECTION LOCATION

CONTROL POINT TABLE

#	NORTHING	EASTING	ELEV
1	4999.91	4999.62	100.00

SURVEY DATA TABLE

NUMBER	11/24/21	7/25/18	11/29/16	6/19/15	1/15/14	6/18/12	11/11/10	3/29/10	1/7/10	4/22/09	1/1/08	DIFF. IN ELEV.
814	98.918	98.92	98.92	98.96	98.93	98.96	98.96	98.95	98.96	98.97	98.98	-0.06
815	98.55	98.57	98.58	98.61	98.60	98.62	98.62	98.59	98.67	98.67	98.67	-0.12
816	98.046	98.06	98.09	98.12	98.12	98.13	98.14	98.11	98.16	98.16	98.16	-0.11
817	99.716	99.74	99.78	99.80	99.79	99.82	99.82	99.82	99.86	99.86	99.86	-0.14
818	99.088	99.14	99.18	99.24	99.24	99.28	99.29	99.32	99.46	99.55	99.60	-0.51
819	98.923	98.92	98.92	98.96	98.95	98.96	98.96	98.95	99.08	99.14	99.24	-0.32
820	100.64	100.65	100.70	100.71	100.71	100.75	100.76	100.78	100.85	100.87	100.89	-0.25
821	100.074	100.09	100.11	100.14	100.14	100.17	100.18	100.20	100.34	100.45	100.58	-0.51
822	99.887	99.85	99.84	99.86	99.86	99.88	99.90	99.89	100.02	100.12	100.24	-0.37
823	101.39	101.44	101.45	101.49	101.50	101.57	101.57	101.58	101.63	101.70	101.75	-0.36
824	100.892	100.93	100.94	100.99	100.99	101.05	101.07	101.16	101.24	101.35	101.52	-0.63
825	100.549	100.56	100.55	100.58	100.58	100.63	100.66	100.66	100.74	100.90	101.06	-0.51
826	103.266	103.29	103.27	103.30	103.29	103.35	103.31	103.31	103.31	103.31	103.31	-0.04
827	103.056	103.04	103.04	103.07	103.08	103.13	103.09	103.11	103.10	103.10	103.10	-0.08
828	102.741	102.78	102.82	102.83	102.84	102.89	102.88	102.88	102.88	102.88	102.88	-0.14
829	103.863	103.93	103.94	103.98	103.96	104.06	104.01	104.04	104.01	104.02	104.02	-0.16
830	104.294	104.31	104.31	104.35	104.34	104.40	104.35	104.34	104.35	104.35	104.35	-0.06
831	104.317	104.31	104.33	104.35	104.34	104.41	104.37	104.36	104.36	104.36	104.36	-0.04

NOTES:
1. CONTOURS ARE RELATIVE TO CP 1 1/2 IP AT 100.00' ELEVATION.
* ELEVATION DIFFERENCE BETWEEN FIRST (2008) AND LAST (2018).

REDUCTION SCALE CHECK

PRELIMINARY

Drawing Revisions

GHD Inc.

Client CALRECYCLE MENDOCINO COUNTY, CA.

Title MARINA DRIVE SURVEY

Scale AS SHOWN

Drawn AG | Designer AG

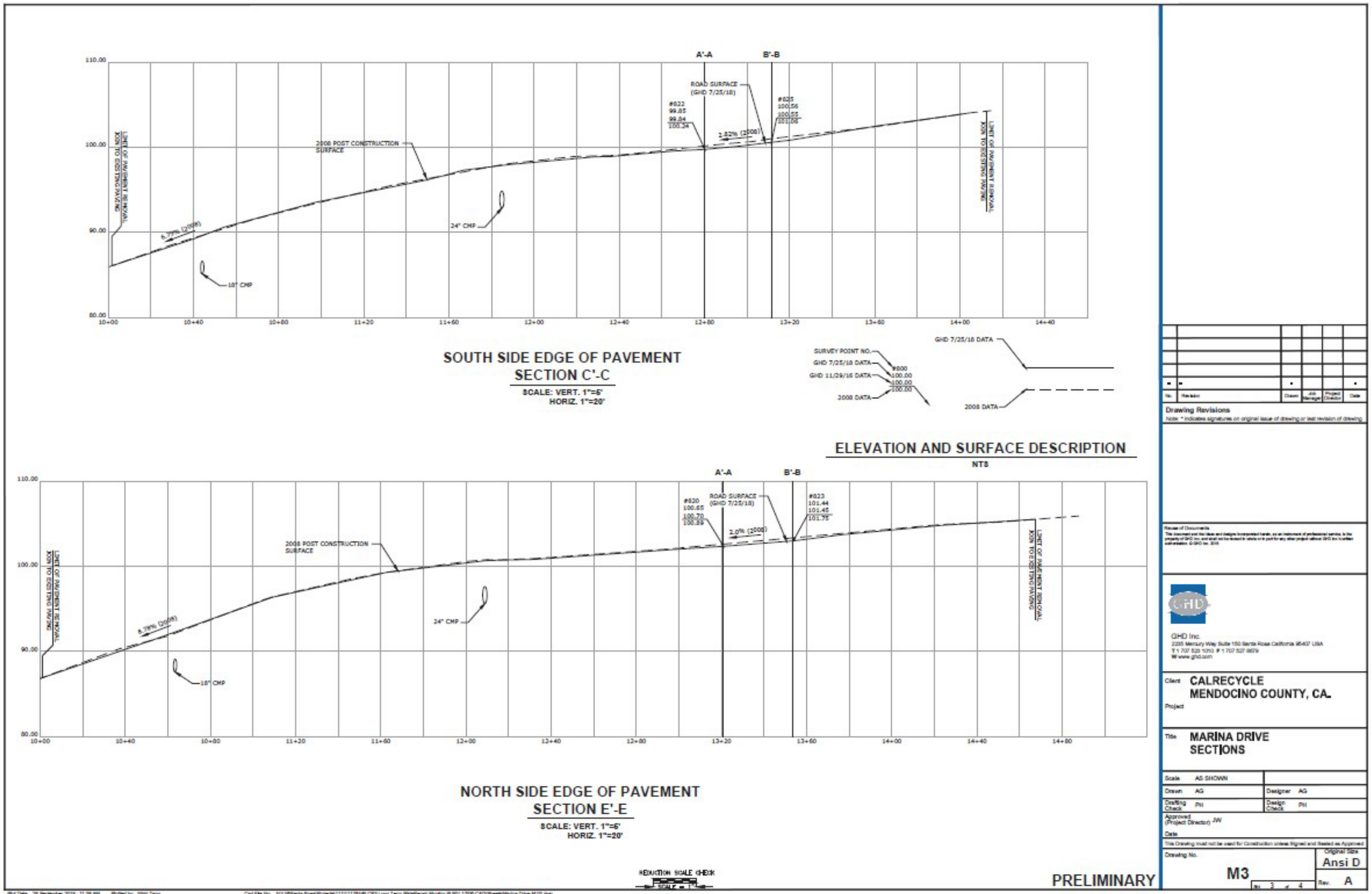
Drafting Check PH | Design Check PH

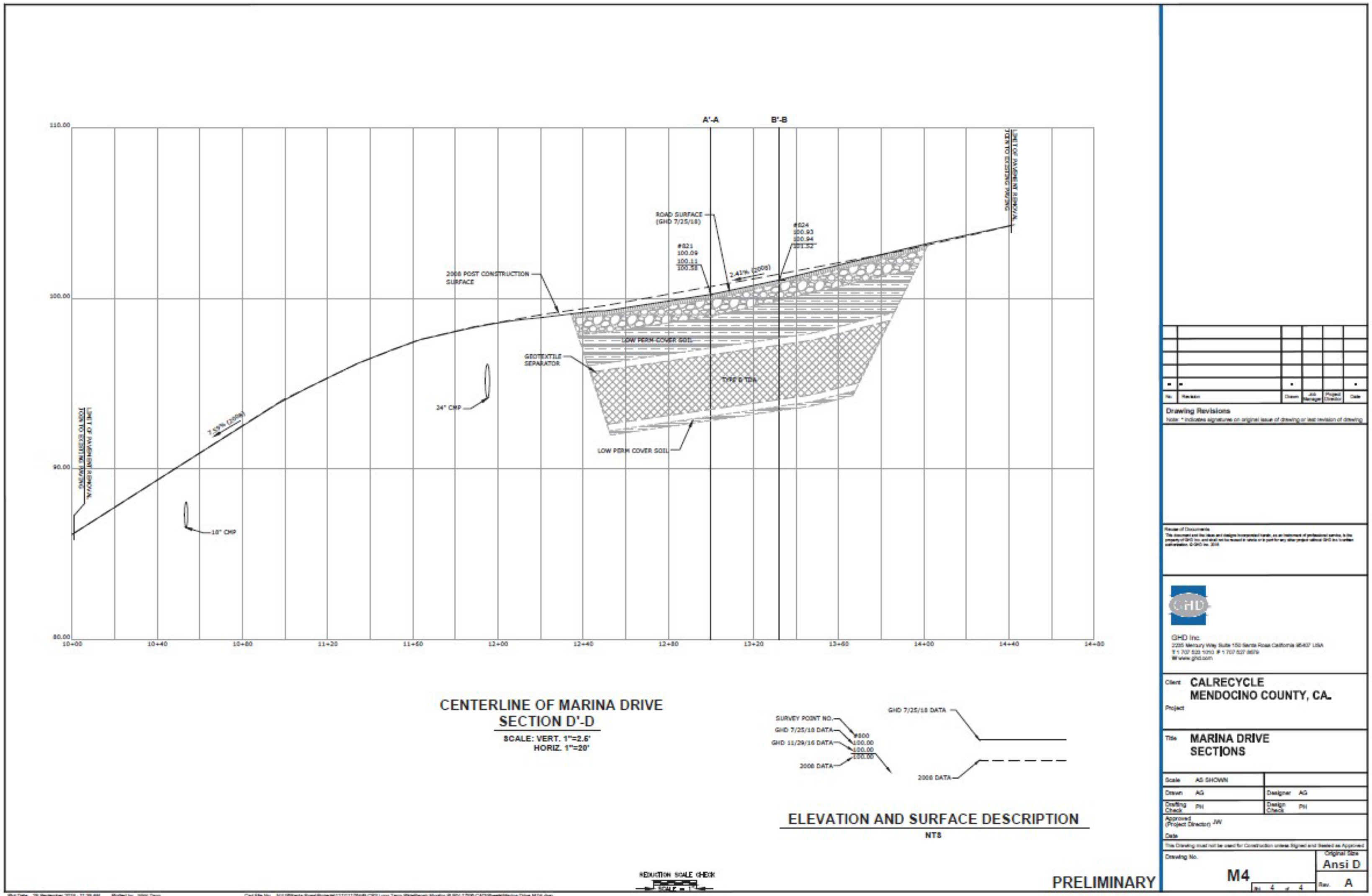
Approved (Project Director) JW

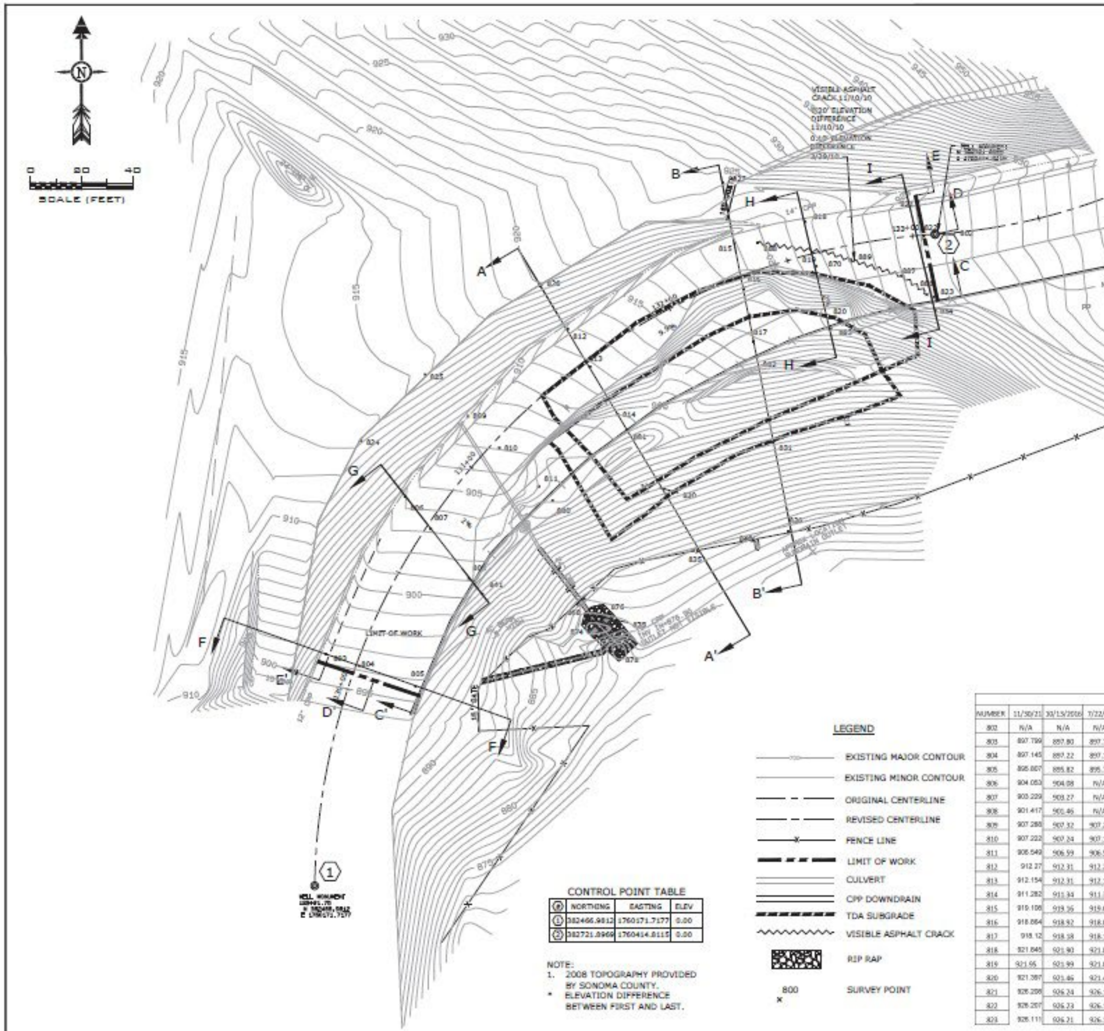
Drawing No. M1

Original Size Ansi D

Rev. A


A'-A
B'-B
ROAD SURFACE (GHD 7/25/18)
2008 POST CONSTRUCTION SURFACE
24" CMP
18" CMP
LIMIT OF PAVEMENT REMOVAL JOIN TO EXISTING PAVING
SOUTH SIDE EDGE OF PAVEMENT
SECTION C'-C
SCALE: VERT. 1"=5'
HORIZ. 1"=20'
SURVEY POINT NO.
GHD 7/25/18 DATA
GHD 11/29/16 DATA
2008 DATA
ELEVATION AND SURFACE DESCRIPTION
NTS
NORTH SIDE EDGE OF PAVEMENT
SECTION E'-E
SCALE: VERT. 1"=5'
HORIZ. 1"=20'
REDUCTION SCALE CHECK
PRELIMINARY
Drawing Revisions
GHD Inc.
Client CALRECYCLE
MENDOCINO COUNTY, CA.
Title MARINA DRIVE
SECTIONS
Scale AS SHOWN
Drawn AG
Designer AG
Drafting Check PH
Design Check PH
Approved (Project Director) JW
Original Size Ansi D
Drawing No. M3
Rev. A


A'-A
B'-B
110.00
100.00
90.00
80.00
10+00
10+40
10+80
11+20
11+60
12+00
12+40
12+80
13+20
13+60
14+00
14+40
14+80
ROAD SURFACE
(GHD 7/25/18)
#824
100.93
100.94
101.52
#821
100.09
100.11
100.58
2.41% (2008)
2008 POST CONSTRUCTION
SURFACE
LOW PERM COVER SOIL
GEOTEXTILE
SEPARATOR
24" CMP
LOW PERM COVER SOIL
7.55% (2008)
18" CMP
CENTERLINE OF MARINA DRIVE
SECTION D'-D
SCALE: VERT. 1"=2.5'
HORIZ. 1"=20'
SURVEY POINT NO.
GHD 7/25/18 DATA
GHD 11/29/16 DATA
2008 DATA
#800
100.00
100.00
100.00
GHD 7/25/18 DATA
2008 DATA
ELEVATION AND SURFACE DESCRIPTION
NTS
REDUCTION SCALE CHECK
PRELIMINARY
Drawing Revisions
GHD Inc.
Client CALRECYCLE
MENDOCINO COUNTY, CA.
Project
Title MARINA DRIVE
SECTIONS
Scale AS SHOWN
Drawn AG
Designer AG
Drafting Check PH
Design Check PH
Approved (Project Director) JW
Date
Drawing No.
M4
Original Size
Ansi D
Rev. A



CONTROL POINT TABLE

#	NORTHING	EASTING	ELEV
1	382466.9812	1760171.7177	0.00
2	382721.0969	1760414.8115	0.00

NOTE:
1. 2008 TOPOGRAPHY PROVIDED BY SONOMA COUNTY.
* ELEVATION DIFFERENCE BETWEEN FIRST AND LAST.

SURVEY DATA TABLE

NUMBER	11/30/21	10/15/2016	7/22/15	1/22/14	6/7/12	11/11/10	3/29/10	1/5/10	4/22/08	DIFF. IN ELEV.
802	N/A	N/A	N/A	N/A	N/A	926.65	926.65	926.65	926.65	#VALUE!
803	897.799	897.80	897.78	897.81	897.79	897.80	897.81	897.79	897.83	-0.03
804	897.145	897.22	897.16	897.20	897.20	897.21	897.21	897.22	897.22	-0.08
805	895.807	895.82	895.78	895.82	895.83	895.81	895.82	895.82	895.82	-0.01
806	904.053	904.08	N/A	904.07	904.05	904.05	904.03	904.03	904.05	0.00
807	903.229	903.27	N/A	903.25	903.22	903.25	903.18	903.22	903.25	-0.02
808	901.417	901.46	N/A	901.44	901.42	901.41	901.41	901.41	901.41	0.01
809	907.288	907.32	907.26	907.31	907.28	907.21	907.28	907.27	907.28	0.01
810	907.222	907.24	907.19	907.24	907.22	907.22	907.17	907.22	907.22	0.00
811	906.549	906.59	906.55	906.60	906.60	906.55	906.57	906.60	906.63	-0.08
812	912.27	912.31	912.27	912.32	912.29	912.32	912.28	912.37	912.34	-0.07
813	912.154	912.31	912.13	912.20	912.21	912.26	912.26	912.27	912.27	-0.12
814	911.282	911.34	911.30	911.38	911.42	911.52	911.55	944.60	911.62	-0.34
815	919.108	919.16	919.08	919.15	919.11	919.13	919.13	919.12	919.15	-0.04
816	918.864	918.92	918.88	918.95	918.95	919.00	919.05	919.05	919.05	-0.19
817	918.12	918.18	918.16	918.25	918.29	918.42	918.52	918.57	918.62	-0.50
818	921.845	921.90	921.84	921.90	921.86	921.88	921.88	921.87	921.88	-0.03
819	921.95	921.99	921.80	921.86	921.85	921.88	921.91	921.92	921.92	0.03
820	921.397	921.46	921.43	921.52	921.56	921.66	921.75	921.79	921.81	-0.41
821	926.208	926.24	926.18	926.26	926.21	926.23	926.22	926.22	926.22	-0.01
822	926.207	926.23	926.18	926.26	926.22	926.23	925.67	926.22	926.22	-0.01
823	926.111	926.21	926.11	926.19	926.19	926.20	926.22	926.20	926.20	-0.09

PRELIMINARY

Drawing Revisions
Note: * indicates signatures on original issue of drawing or last revision of drawing

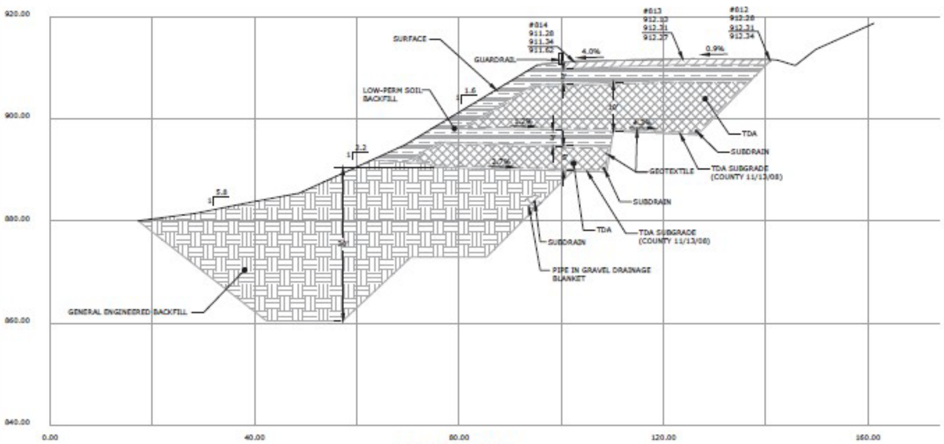
GHD Inc.
2235 Mercury Way Suite 150 Santa Rosa California 95407 USA
T 1 707 523 1010 F 1 707 527 8679
W www.ghd.com

Client: CALRECYCLE SONOMA COUNTY, CA.
Project
Title: GEYSERS ROAD SURVEY

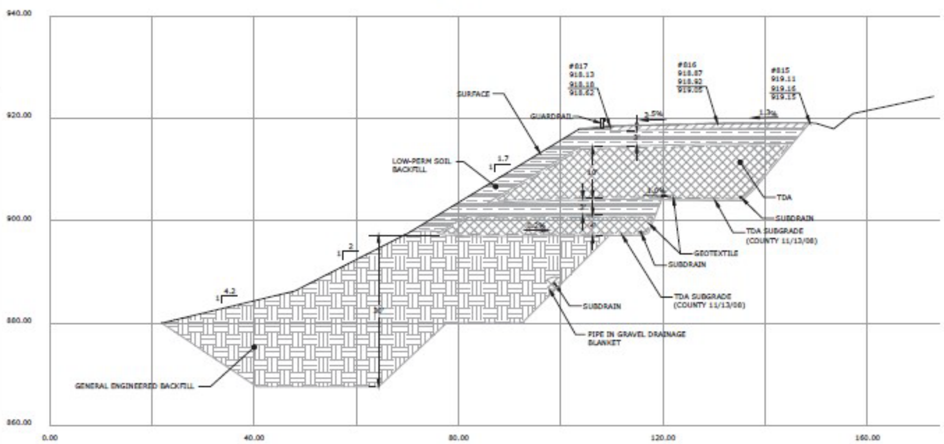
Scale: AS SHOWN	
Drawn: CB	Designer: CB
Drafting Check: JR	Design Check: JR
Approved (Project Director): JW	
Date	

This Drawing must not be used for Construction unless Signed and Sealed as Approved

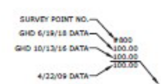
Drawing No. G1 — Sht 1 of 4
Original Size: Ansi D
Rev. A



SECTION A'-A
SCALE: 1"=10'



SECTION B'-B
SCALE: 1"=10'



ELEVATION DESCRIPTION
NTS

PRELIMINARY

No.	Revision	Drawn	Job Manager	Project Director	Date

Drawing Revisions
Note: * indicates signatures on original issue of drawing or last revision of drawing

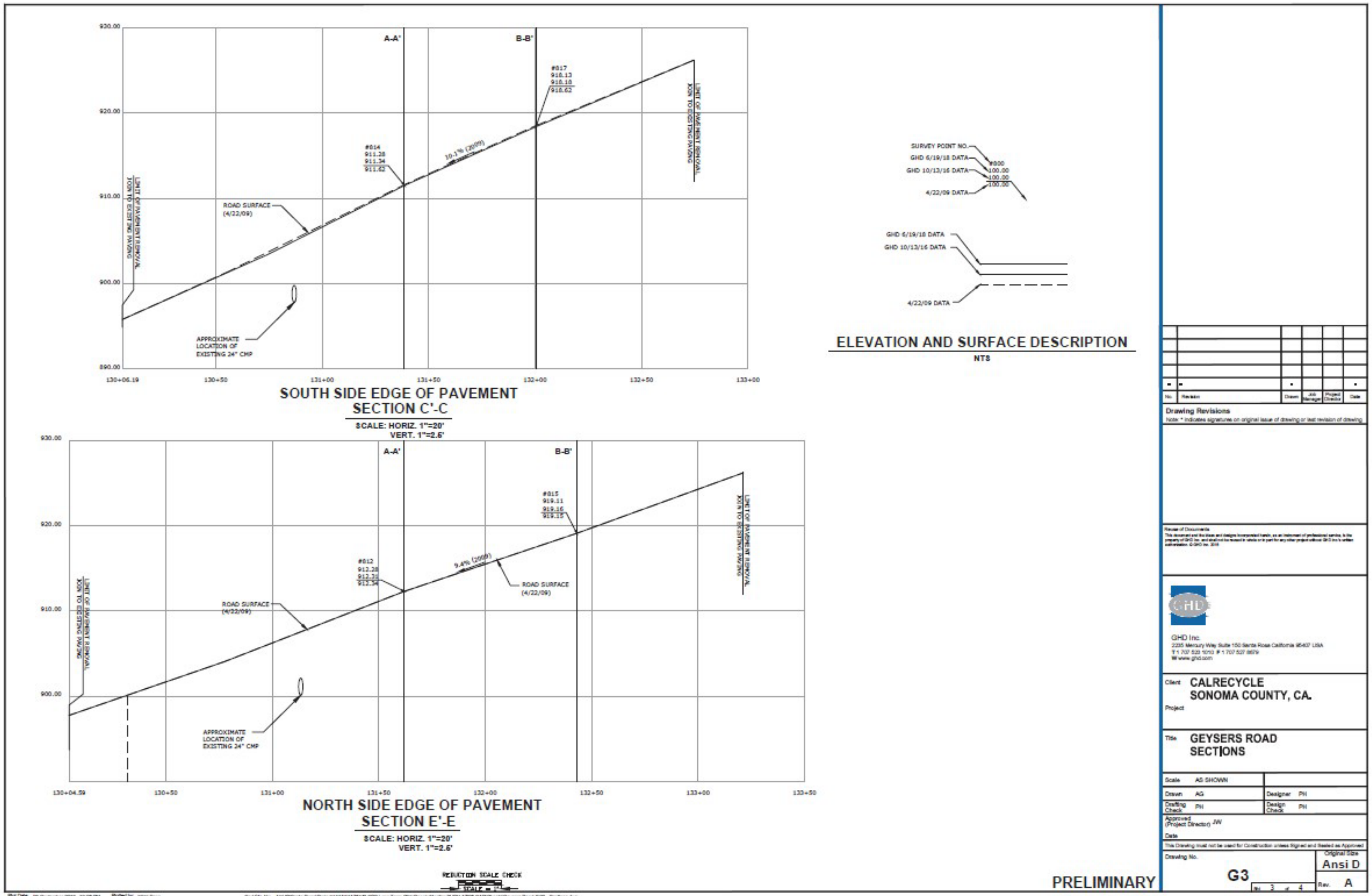
GHD Inc.
2235 Mercury Way Suite 150 Santa Rosa California 95407 USA
T 1 707 523 1010 F 1 707 527 8679
W www.ghd.com

Client **CALRECYCLE SONOMA COUNTY, CA.**
Project
Title **GEYSERS ROAD SECTIONS**

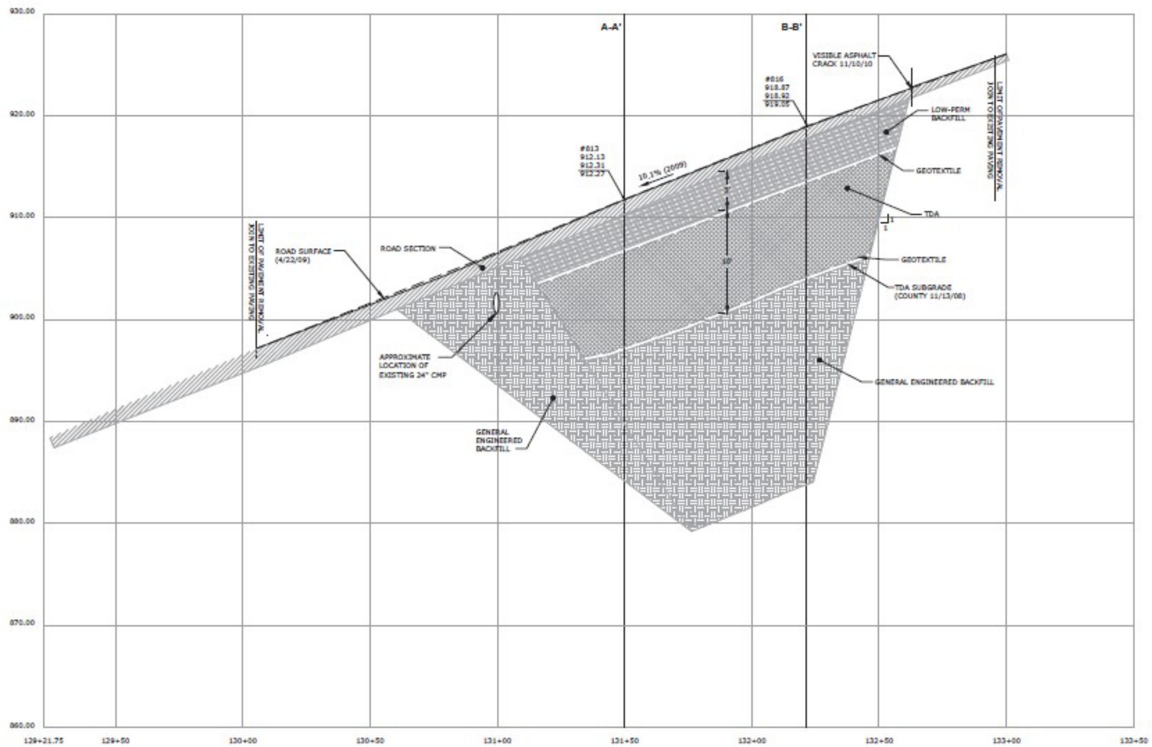
Scale	AS SHOWN		
Drawn	AG	Designer	PH
Drafting Check	PH	Design Check	PH
Approved (Project Director)	JW		
Date			

This Drawing must not be used for Construction unless Signed and Sealed as Approved

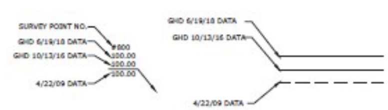
Drawing No. **G2** Sht 2 of 4 — Original Size Ansi D — Rev. A



A-A'
B-B'
#817
918.13
918.18
918.62
#814
911.28
911.34
911.62
10.1% (2009)
ROAD SURFACE (4/22/09)
LIMIT OF PAVEMENT REMOVAL JOIN TO EXISTING PAVING
APPROXIMATE LOCATION OF EXISTING 24" CMP
930.00
920.00
910.00
900.00
890.00
130+06.19
130+50
131+00
131+50
132+00
132+50
133+00
SOUTH SIDE EDGE OF PAVEMENT
SECTION C'-C
SCALE: HORIZ. 1"=20'
VERT. 1"=2.5'
#815
919.11
919.16
919.15
#812
912.28
9.4% (2009)
130+04.59
133+50
NORTH SIDE EDGE OF PAVEMENT
SECTION E'-E
SCALE: HORIZ. 1"=20'
VERT. 1"=2.5'
SURVEY POINT NO.
GHD 6/19/18 DATA
GHD 10/13/16 DATA
4/22/09 DATA
#800
100.00
100.00
100.00
ELEVATION AND SURFACE DESCRIPTION
NTS
REDUCTION SCALE CHECK
PRELIMINARY
Drawing Revisions
GHD Inc.
Client CALRECYCLE
SONOMA COUNTY, CA.
Title GEYSERS ROAD
SECTIONS
Scale AS SHOWN
Drawn AG
Designer PH
Drafting Check PH
Design Check PH
Approved (Project Director) JW
Drawing No.
G3
Original Size
Ansi D
Rev. A



CENTERLINE OF GEYSERS ROAD
SECTION D'-D
SCALE: HORIZ. 1"=20'
VERT. 1"=2.5'



ELEVATION AND SURFACE DESCRIPTION
NTS

REDUCTION SCALE CHECK

PRELIMINARY

Drawing Revisions

GHD Inc.

Client	CALRECYCLE SONOMA COUNTY, CA.
Project	
Title	GEYSERS ROAD SECTIONS
Scale	AS SHOWN
Drawn	AG
Designer	PH
Drafting Check	PH
Design Check	PH
Approved (Project Director)	JW
Date	
Drawing No.	G4
Original Size	Ansi D
Rev.	A

This Drawing must not be used for Construction unless Signed and Sealed as Approved

LEGEND

CONTOUR LINE

CENTERLINE OF ROAD

5 FOOT TDA FILL LINE

10 FOOT TDA FILL LINE

SURVEY

ROAD

SECTION LOCATION AND ID

SURVEY DATA TABLE

SURVEY DATA TABLE									
NUMBER	12/8/21	6/8/18	11/1/16	6/15/15	1/9/14	7/22/12	11/10/10	11/12/09	DIFF. IN ELEV.
1201	107.526	107.44	107.48	107.60	107.48	107.58	107.62	107.62	-0.09
1202	107.517	107.71	107.77	107.85	107.75	107.83	107.85	107.84	-0.32
1203	107.786	107.41	107.46	107.56	107.45	107.51	107.56	107.56	0.22
1204	104.014	103.96	104.07	104.26	104.19	104.35	104.52	104.65	-0.64
1205	104.498	104.45	104.53	104.64	104.55	104.69	104.79	104.90	-0.40
1206	104.506	104.46	104.51	104.66	104.56	104.68	104.76	104.87	-0.36
1214	102.453	102.42	102.50	102.65	102.56	102.68	102.82	102.90	-0.45
1215	102.65	102.63	102.72	102.86	102.78	102.89	103.03	103.13	-0.48
1216	102.435	102.42	102.51	102.64	102.58	102.66	102.78	102.89	-0.45
1224	101.739	101.79	101.89	102.05	101.98	102.09	102.24	102.29	-0.55
1225	101.801	101.82	101.94	102.08	102.00	102.13	102.30	102.38	-0.58
1226	101.853	101.85	N/A	102.12	101.63	101.76	101.91	102.03	-0.18
1234	101.366	101.40	101.51	101.68	101.75	101.70	101.83	101.90	-0.53
1235	102	101.56	101.68	101.83	101.60	101.86	102.00	102.07	-0.53
1236	101.478	101.47	101.59	101.75	101.34	101.42	101.56	101.66	-0.18
1237	101.772	101.76	101.79	101.90	101.74	101.74	101.70	N/A	0.07
1238	101.912	101.91	101.96	102.04	101.87	101.85	101.75	N/A	0.16
1239	101.448	101.44	101.42	101.49	101.39	101.45	101.46	N/A	-0.01

NOTES:
1. TOPOGRAPHIC IMAGE 7/23/08 PROVIDED BY SONOMA COUNTY.
2. SURVEY DATA AS OF 6/8/2018.

*ELEVATION DIFFERENCE BETWEEN FIRST (2009) AND LAST (2018).

REDUCTION SCALE CHECK

No.	Revision	Drawn	Job Manager	Project Director	Date

Drawing Revisions

Note: * indicates signatures on original issue of drawing or last revision of drawing

Reuse of Documents

PRELIMINARY

GHD Inc.

Client CALRECYCLE
SONOMA COUNTY, CA.

Project

Title SONOMA MOUNTAIN ROAD SURVEY

Scale AS SHOWN

Drawn AG | Designer AG

Drafting Check PN | Design Check PN

Approved (Project Director) JW

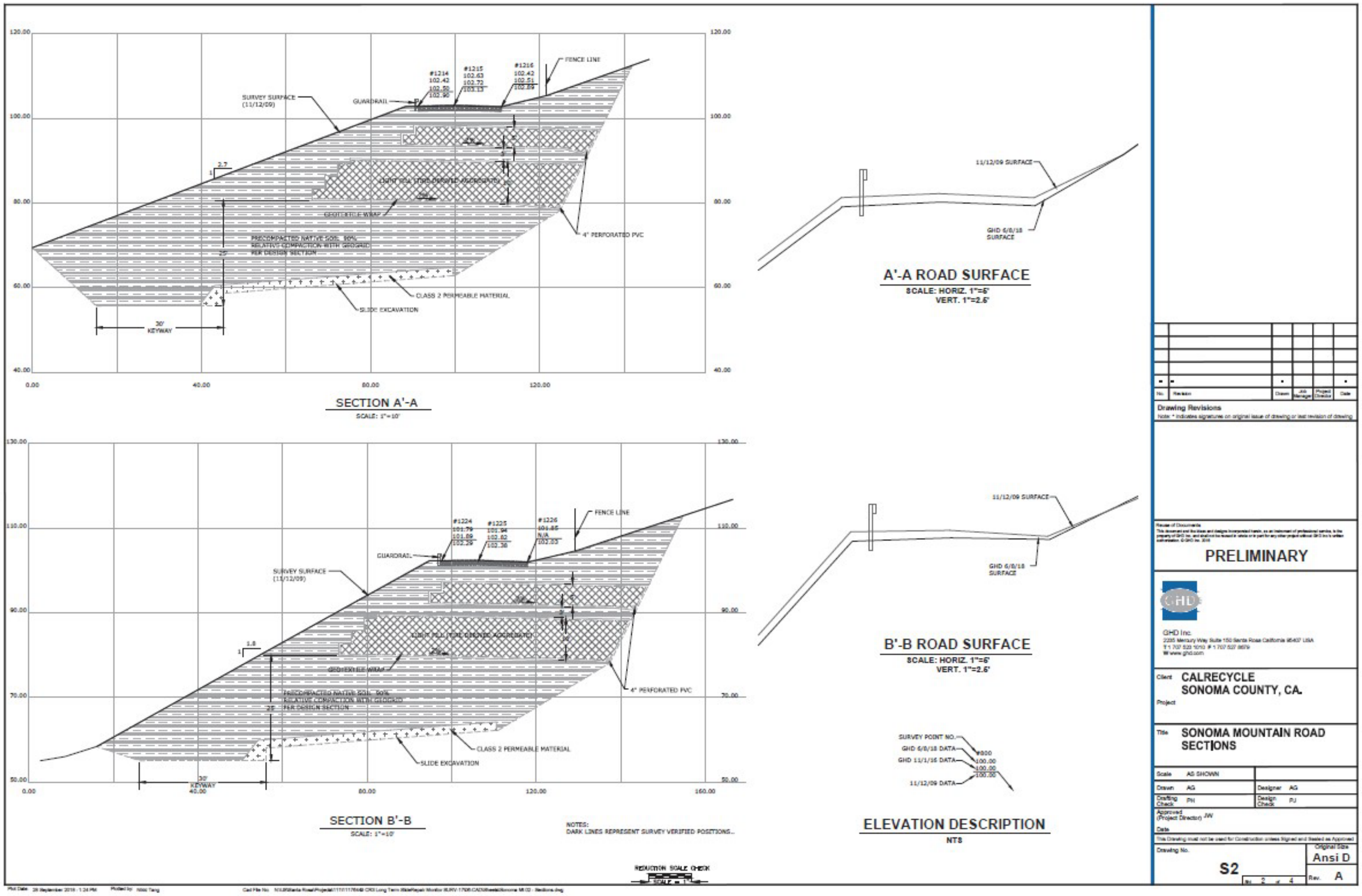
Date

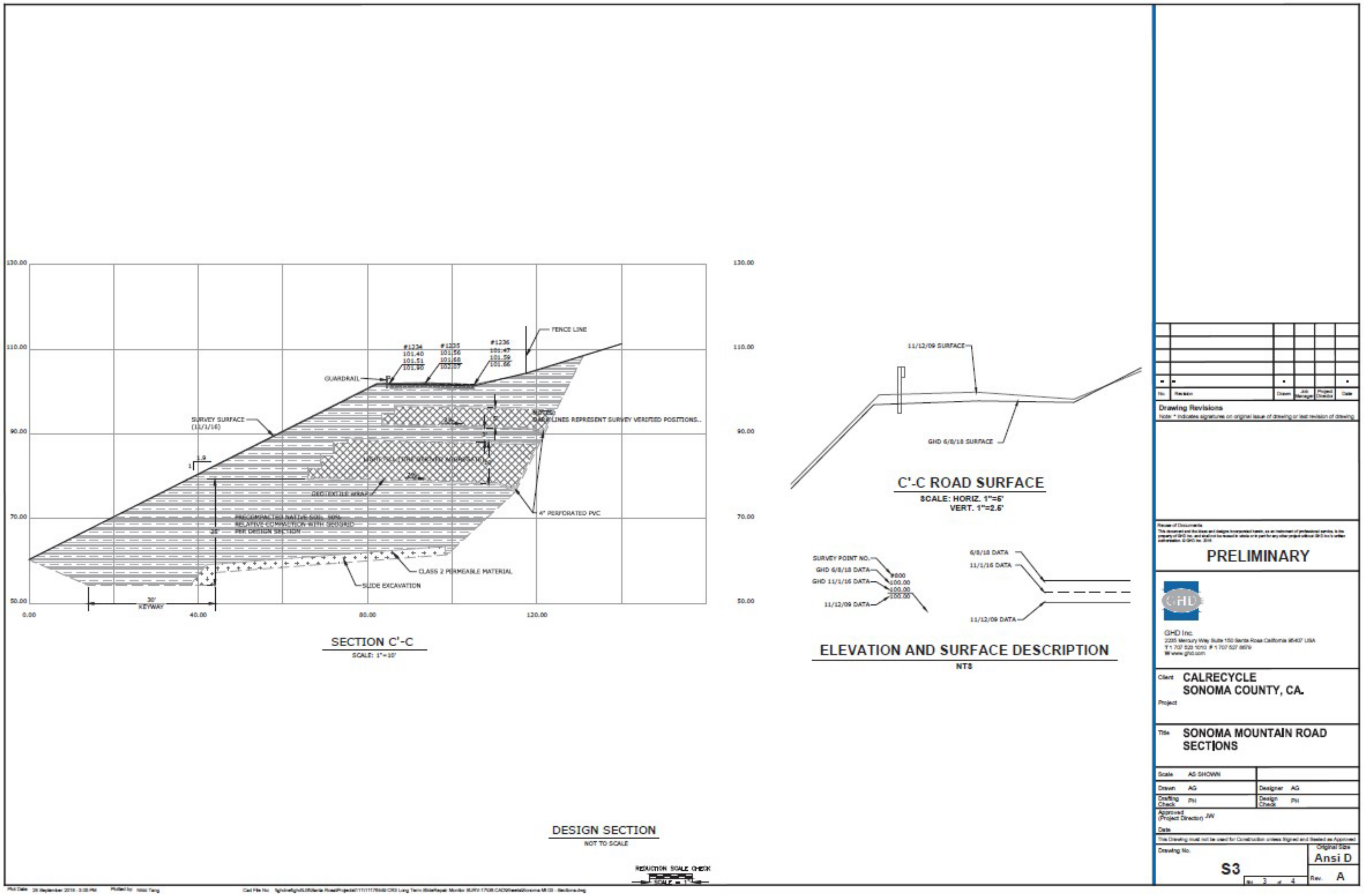
This Drawing must not be used for Construction unless Signed and Sealed as Approved

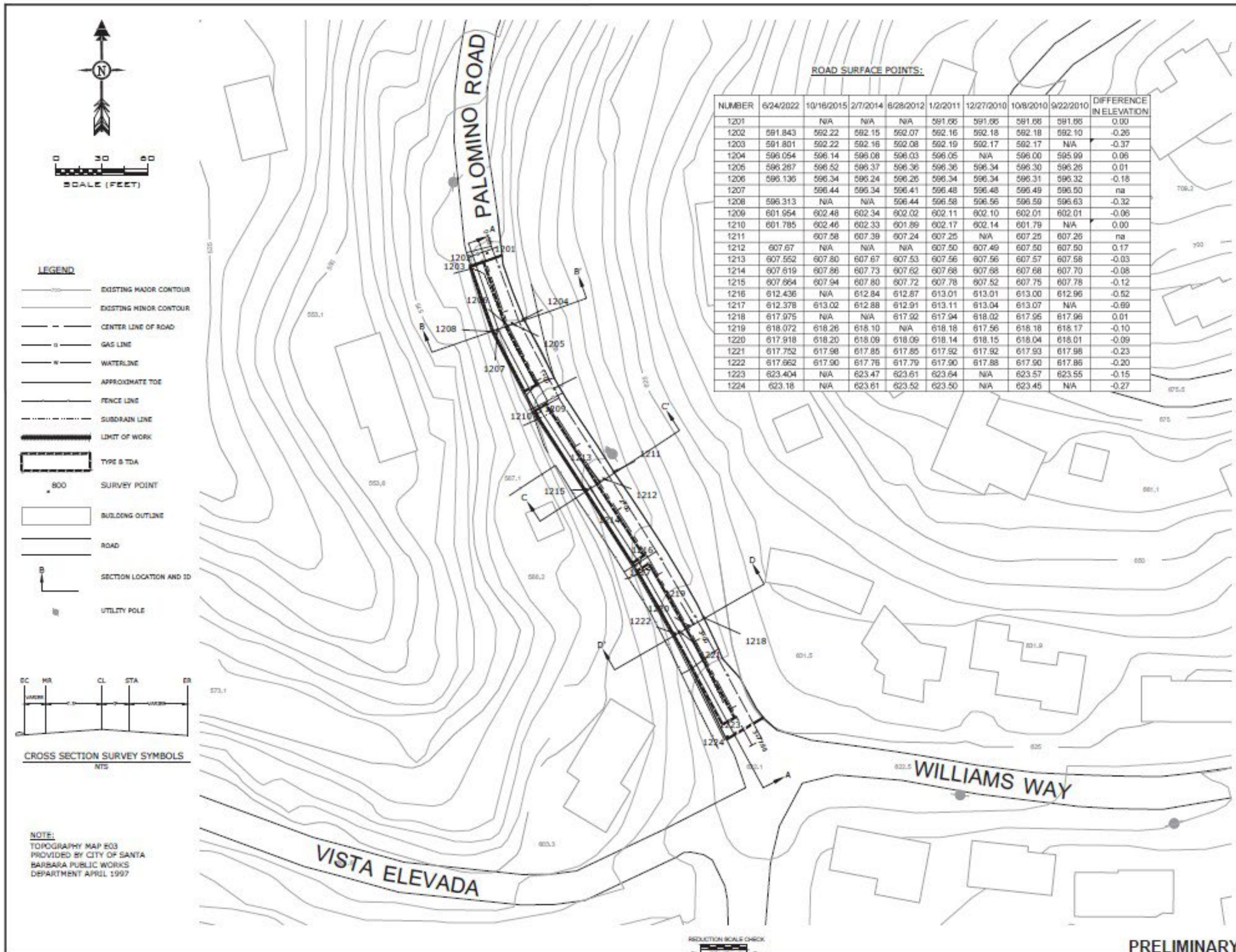
Drawing No. S1 | Original Size Ansi D | Rev. A

Sht 1 of 4

Plot Date: 8 March 2023 - 10:25 AM Plotted by: Richard Maddock


SECTION A'-A
SCALE: 1"=10'
SURVEY SURFACE (11/12/09)
GUARDRAIL
FENCE LINE
#1214
#1215
#1216
LIGHT FILL (TIRE DERIVED AGGREGATE)
GEOTEXTILE WRAP
PRECOMPACTED NATIVE SOIL 90% RELATIVE COMPACTION WITH GEOGRID PER DESIGN SECTION
4" PERFORATED PVC
CLASS 2 PERMEABLE MATERIAL
SLIDE EXCAVATION
30' KEYWAY
SECTION B'-B
SCALE: 1"=10'
#1224
#1225
#1226
A'-A ROAD SURFACE
SCALE: HORIZ. 1"=6'
VERT. 1"=2.6'
11/12/09 SURFACE
GHD 6/8/18 SURFACE
B'-B ROAD SURFACE
SCALE: HORIZ. 1"=6'
VERT. 1"=2.6'
SURVEY POINT NO.
GHD 6/8/18 DATA
GHD 11/1/16 DATA
11/12/09 DATA
ELEVATION DESCRIPTION
NTS
NOTES:
DARK LINES REPRESENT SURVEY VERIFIED POSITIONS.
REDUCTION SCALE CHECK
Drawing Revisions
PRELIMINARY
GHD Inc.
Client CALRECYCLE
SONOMA COUNTY, CA.
Project
Title SONOMA MOUNTAIN ROAD SECTIONS
Scale AS SHOWN
Drawn AG
Designer AG
Drafting Check PH
Design Check PJ
Approved (Project Director) JW
Drawing No. S2
Original Size Ansi D
Rev. A


FENCE LINE
GUARDRAIL
SURVEY SURFACE (11/1/16)
DASH LINES REPRESENT SURVEY VERIFIED POSITIONS.
GEOTEXTILE WRAP
4" PERFORATED PVC
CLASS 2 PERMEABLE MATERIAL
SLIDE EXCAVATION
30' KEYWAY
SECTION C'-C
SCALE: 1"=10'
11/12/09 SURFACE
GHD 6/8/18 SURFACE
C'-C ROAD SURFACE
SCALE: HORIZ. 1"=5'
VERT. 1"=2.5'
SURVEY POINT NO.
GHD 6/8/18 DATA
GHD 11/1/16 DATA
11/12/09 DATA
6/8/18 DATA
11/1/16 DATA
ELEVATION AND SURFACE DESCRIPTION
NTS
DESIGN SECTION
NOT TO SCALE
Drawing Revisions
PRELIMINARY
GHD
CALRECYCLE
SONOMA COUNTY, CA.
SONOMA MOUNTAIN ROAD
SECTIONS
Scale AS SHOWN
Drawn AG
Designer AG
Drafting Check PH
Design Check PH
Approved (Project Director) JW
Drawing No.
S3
Original Size
Ansi D
Rev. A



ROAD SURFACE POINTS:

NUMBER	6/24/2022	10/16/2015	2/7/2014	6/28/2012	1/2/2011	12/27/2010	10/8/2010	9/22/2010	DIFFERENCE IN ELEVATION
1201		N/A	N/A	N/A	591.66	591.66	591.66	591.66	0.00
1202	591.843	592.22	592.15	592.07	592.16	592.18	592.18	592.10	-0.26
1203	591.801	592.22	592.16	592.08	592.19	592.17	592.17	N/A	-0.37
1204	596.054	596.14	596.08	596.03	596.05	N/A	596.00	595.99	0.06
1205	596.267	596.52	596.37	596.36	596.36	596.34	596.30	596.26	0.01
1206	596.136	596.34	596.24	596.26	596.34	596.34	596.31	596.32	-0.18
1207		596.44	596.34	596.41	596.48	596.48	596.49	596.50	na
1208	596.313	N/A	N/A	596.44	596.58	596.56	596.59	596.63	-0.32
1209	601.954	602.48	602.34	602.02	602.11	602.10	602.01	602.01	-0.06
1210	601.785	602.46	602.33	601.89	602.17	602.14	601.79	N/A	0.00
1211		607.58	607.39	607.24	607.25	N/A	607.25	607.26	na
1212	607.67	N/A	N/A	N/A	607.50	607.49	607.50	607.50	0.17
1213	607.552	607.80	607.67	607.53	607.56	607.56	607.57	607.58	-0.03
1214	607.619	607.86	607.73	607.62	607.68	607.68	607.68	607.70	-0.08
1215	607.664	607.94	607.80	607.72	607.78	607.52	607.75	607.78	-0.12
1216	612.436	N/A	612.84	612.87	613.01	613.01	613.00	612.96	-0.52
1217	612.378	613.02	612.88	612.91	613.11	613.04	613.07	N/A	-0.69
1218	617.975	N/A	N/A	617.92	617.94	618.02	617.95	617.96	0.01
1219	618.072	618.26	618.10	N/A	618.18	617.56	618.18	618.17	-0.10
1220	617.918	618.20	618.09	618.09	618.14	618.15	618.04	618.01	-0.09
1221	617.752	617.98	617.85	617.85	617.92	617.92	617.93	617.98	-0.23
1222	617.662	617.90	617.76	617.79	617.90	617.88	617.90	617.86	-0.20
1223	623.404	N/A	623.47	623.61	623.64	N/A	623.57	623.55	-0.15
1224	623.18	N/A	623.61	623.52	623.50	N/A	623.45	N/A	-0.27

Drawing Revisions

Note: * indicates signatures on original issue of drawing or last revision of drawing

GHD Inc.
718 Third Street Eureka California 95501 USA
T 1 707 443 8326 F 1 707 444 8330
W www.ghd.com

Client: **CALRECYCLE SANTA BARBARA COUNTY, CA.**

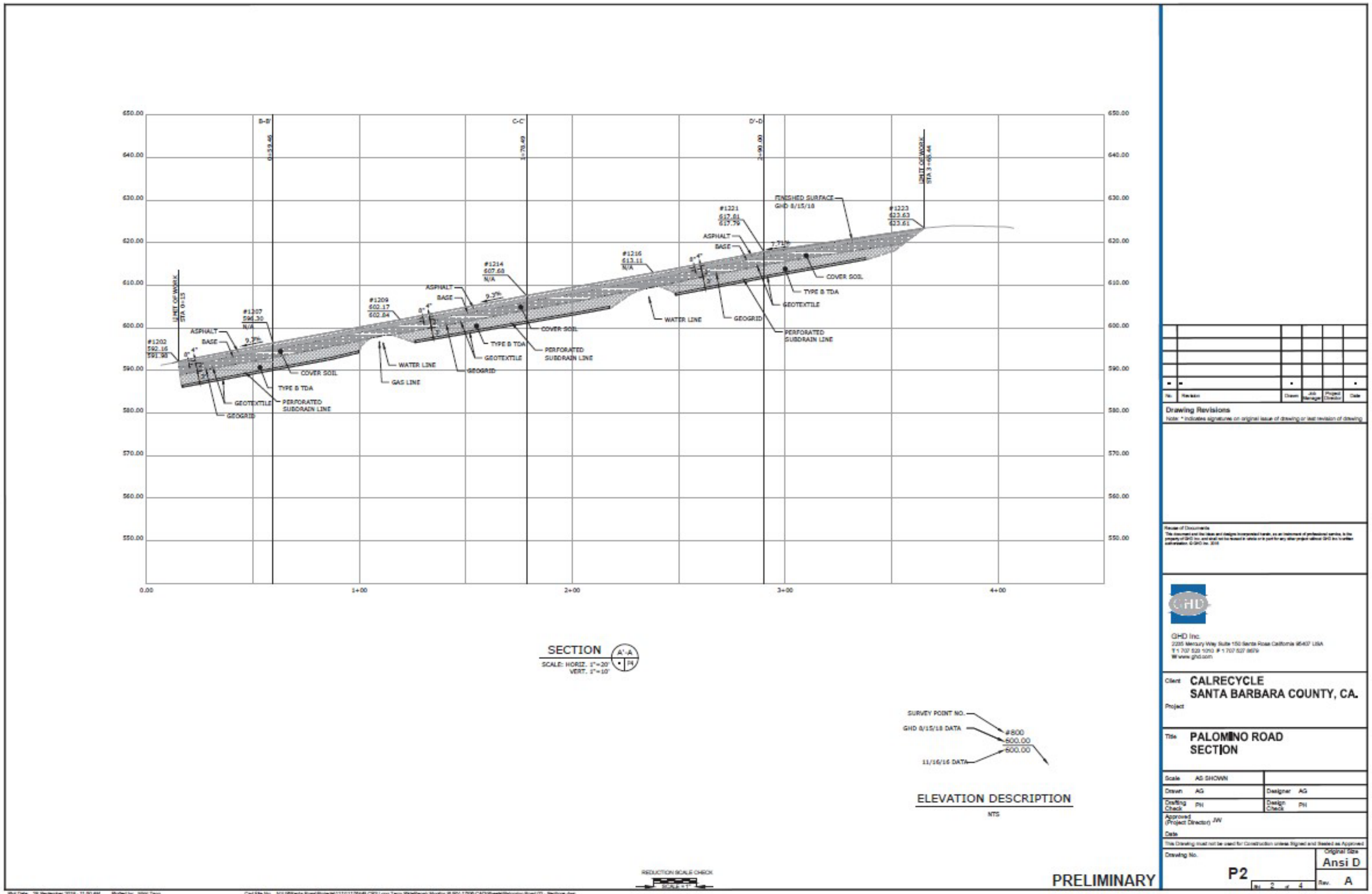
Project

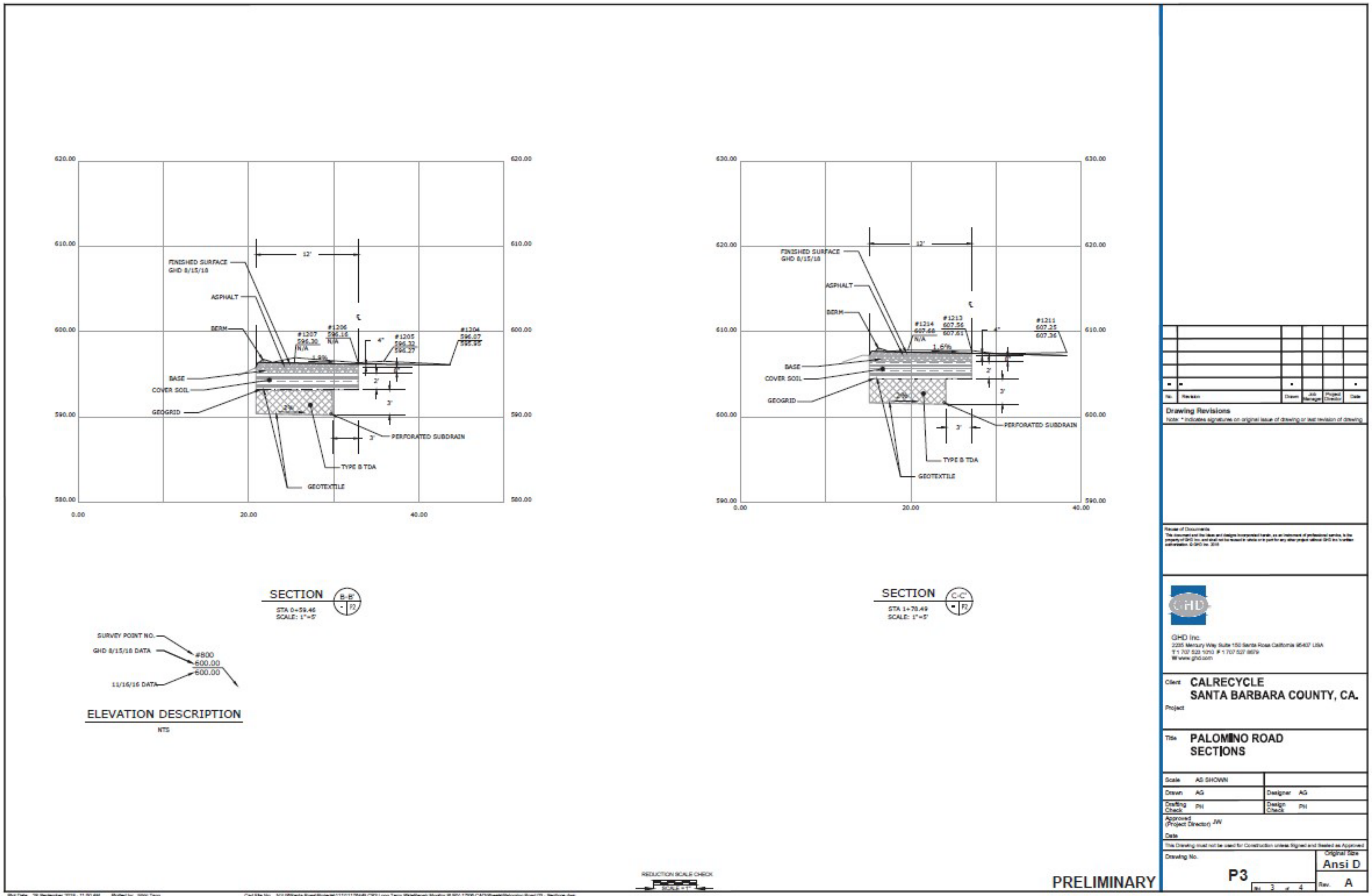
Title: **PALOMINO ROAD SURVEY**

Scale: AS SHOWN	
Drawn: CB	Designer: CB
Drafting Check: JR	Design Check: JR
Approved (Project Director): JW	
Date	

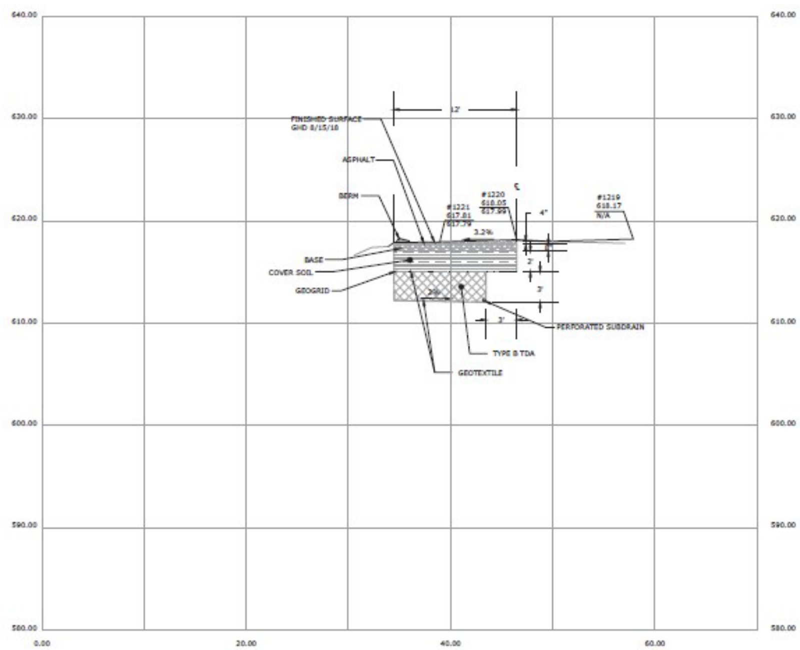
This Drawing must not be used for Construction unless Signed and Sealed as Approved

Drawing No. **P1** — Original Size: Ansi D — Rev. A


SECTION A'-A P4
SCALE: HORIZ. 1"=20' VERT. 1"=10'
ELEVATION DESCRIPTION
NTS
SURVEY POINT NO.
GHD 8/15/18 DATA
11/16/16 DATA
FINISHED SURFACE GHD 8/15/18
LIMIT OF WORK
COVER SOIL
TYPE B TDA
GEOTEXTILE
GEOGRID
PERFORATED SUBDRAIN LINE
ASPHALT
BASE
WATER LINE
GAS LINE
Drawing Revisions
GHD Inc.
CALRECYCLE
SANTA BARBARA COUNTY, CA.
PALOMINO ROAD
SECTION
Scale AS SHOWN
Drawn AG
Designer AG
Drafting Check PH
Design Check PH
Approved (Project Director) JW
Drawing No. P2
Original Size Ansi D
Rev. A
PRELIMINARY
REDUCTION SCALE CHECK



FINISHED SURFACE
GHD 8/15/18
ASPHALT
BERM
BASE
COVER SOIL
GEOGRID
PERFORATED SUBDRAIN
TYPE B TDA
GEOTEXTILE
SECTION B-B'
SECTION C-C'
SURVEY POINT NO.
GHD 8/15/18 DATA
11/16/16 DATA
#800
600.00
600.00
ELEVATION DESCRIPTION
NTS
Drawing Revisions
GHD Inc.
Client CALRECYCLE
SANTA BARBARA COUNTY, CA.
Project
Title PALOMINO ROAD
SECTIONS
Scale AS SHOWN
Drawn AG
Designer AG
Drafting Check PH
Design Check PH
Approved (Project Director) JW
Date
Drawing No.
P3
Original Size
Ansi D
Rev. A
PRELIMINARY



SECTION
STA 2+90
SCALE: 1"=5'

SURVEY POINT NO.
GHD 8/15/18 DATA
11/16/16 DATA
#800
600.00
600.00

ELEVATION DESCRIPTION
NTS

PRELIMINARY

Drawing Revisions

GHD Inc.
2235 Mercury Way Suite 150 Santa Rosa California 95407 USA
T 1 707 523 1010 F 1 707 527 8679
W www.ghd.com

Client CALRECYCLE
SANTA BARBARA COUNTY, CA.

Project

Title PALOMINO ROAD
SECTION

Scale	AS SHOWN		
Drawn	AG	Designer	AG
Drafting Check	PH	Design Check	PH
Approved (Project Director)	JW		
Date			

This Drawing must not be used for Construction unless Signed and Sealed as Approved

Drawing No. P4 Sht 4 of 4
Original Size Ansi D
Rev. A

CONTROL POINTS △

PNT	NORTHING	EASTING	ELEVATION	DESCRIPTION
1	2284325.11	6799175.28	2088.37	3/4" REBAR
2	2284029.84	6798932.84	2063.47	3/4" REBAR

NOTES
1) COORDINATES AND ELEVATIONS SHOWN HERE ON ARE ASSUMED.
2) DATE OF SURVEY DECEMBER 9, 2021.
3) MONITORING NAILS ARE SET IN THE RETAINING WALL
4) GUARD RAIL ELEVATIONS [S-_] ARE ON THE TOP CENTER OF I-BEAM.

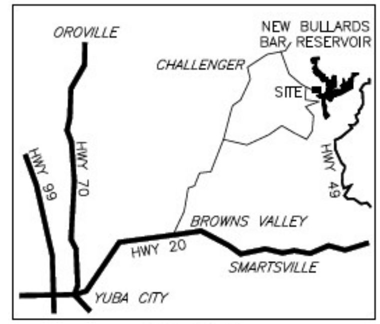
LEGEND

I	I BEAM
△	CONTROL POINT
o	MONITORING NAIL
—•—•—	GUARD RAIL
— — — —	EDGE OF GRAVEL ROAD
[XXX]	NAIL POINT NAME (A THRU G)

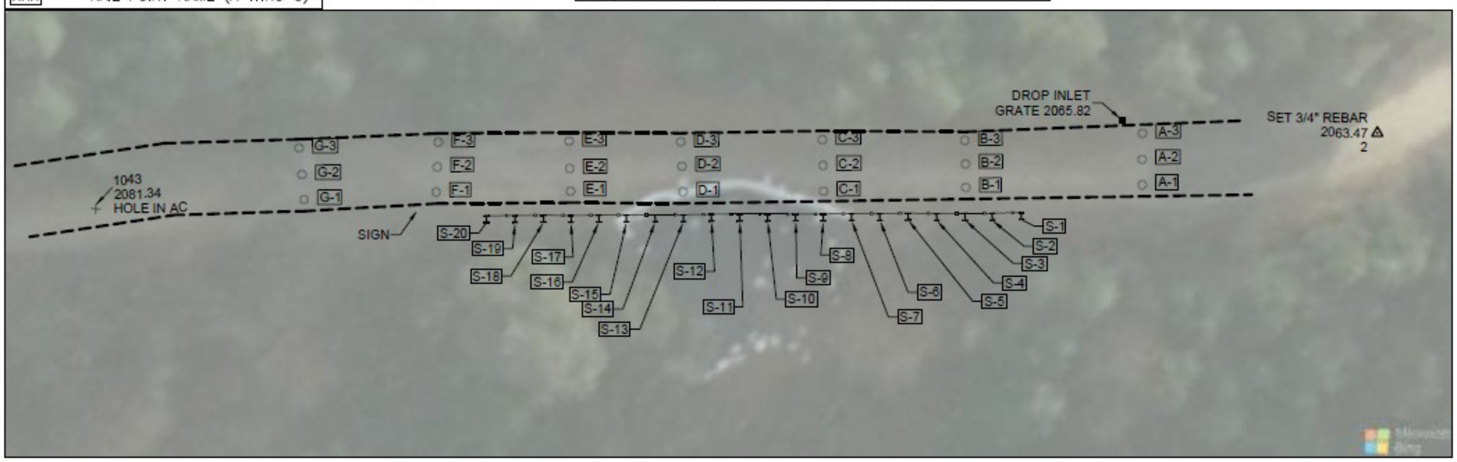
SCALE: 1"=10'
0 10 20

MONITORING NAILS o - POINT NAME SHOWN BOXED [XXX]

PNT	NORTHING	EASTING	ELEV 2021	ELEV 2023
A-1	2284074.04	6798958.95	2066.43	2066.41
A-2	2284070.37	6798962.93	2066.32	2066.30
A-3	2284066.54	6798966.93	2065.97	2065.96
B-1	2284101.91	6798984.16	2068.33	2068.31
B-2	2284098.54	6798987.88	2068.29	2068.26
B-3	2284095.24	6798991.62	2068.10	2068.09
C-2	2284120.95	6799008.36	2070.21	2070.18
C-3	2284117.29	6799012.44	2070.00	2069.98
D-1	2284146.62	6799024.57	2072.08	2072.02
D-2	2284143.08	6799028.69	2072.00	2071.97
D-3	2284139.72	6799032.70	2071.84	2071.81
E-1	2284164.07	6799041.06	2073.82	2073.79
E-2	2284160.89	6799044.64	2073.75	2073.72
E-3	2284157.03	6799049.03	2073.53	2073.50
F-1	2284185.10	6799060.42	2075.88	2075.86
F-2	2284181.32	6799064.15	2075.75	2075.73
F-3	2284177.55	6799067.89	2075.49	2075.47
G-1	2284206.77	6799078.44	2077.86	2077.84
G-2	2284203.49	6799082.65	2077.87	2077.84
G-3	2284200.10	6799087.22	2077.74	2077.72



VICINITY MAP
NOT TO SCALE



PRELIMINARY

GHD

Client: CAL RECYCLE
Project: MORAN ROAD 2023
Title: MONITORING SURVEY
Date: May 2022

CONTROL POINTS △

PNT	NORTHING	EASTING	ELEVATION	DESCRIPTION
1	2217179.73	6649851.73	4000.00	REBAR
2	2217184.07	6649969.47	3994.51	IRON PIPE
3	2217216.55	6649724.89	4013.87	IRON PIPE

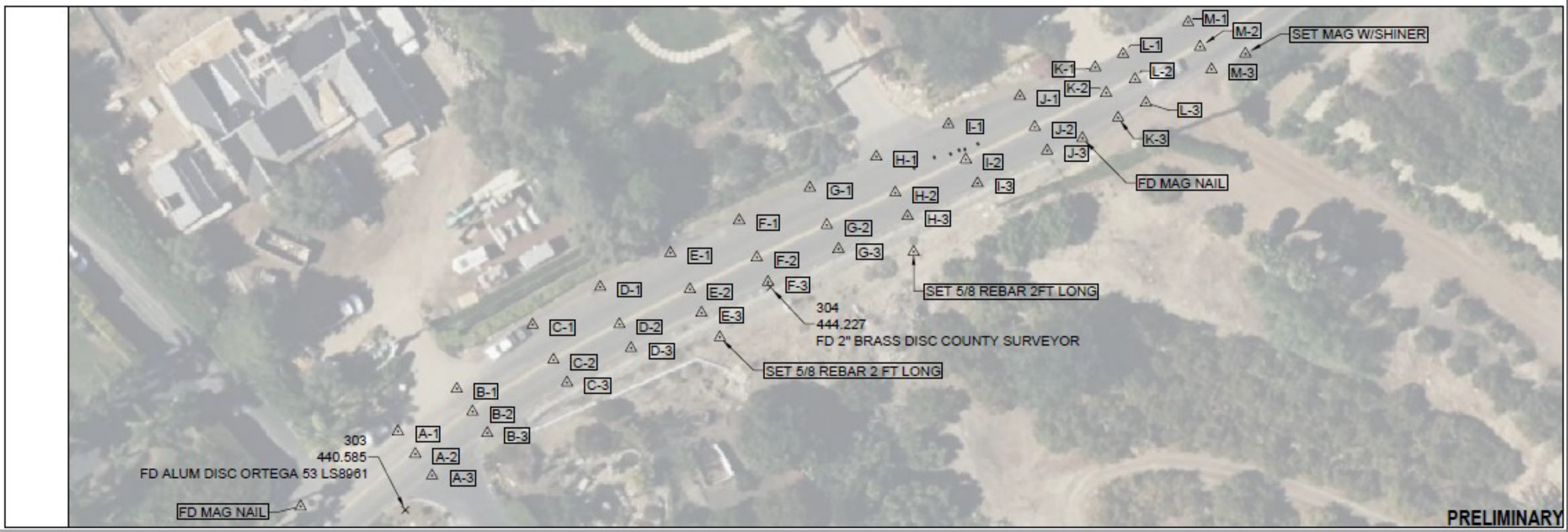
NOTES
1) COORDINATES AND ELEVATIONS SHOWN HERE ON ARE ASSUMED.
2) DATE OF SURVEY JUNE 22 AND JUNE 23.
3) MONITORING NAILS ARE SET IN THE RETAINING WALL
4) GAURD RAIL ELEVATIONS ARE ON THE TOP CENTER OF I–BEAM.

LEGEND
△ CONTROL POINT
XXX NAIL POINT NUMBER

SCALE: 1"=40'
0 40 80

MONITORING NAILS ⭘ – POINT NUMER SHOWN BOXED XXX

PNT	NORTHING	EASTING	ELEV 22	ELEV 23
A–1	1982732.90	6079379.56	442.13	
A–2	1982723.75	6079386.62	441.94	441.96
A–3	1982714.93	6079393.43	441.00	441.01
B–1	1982750.27	6079403.50	442.83	442.85
B–2	1982740.95	6079409.88	442.66	442.68
B–3	1982732.25	6079415.94	441.74	441.73
C–1	1982776.31	6079434.40	442.88	
C–2	1982762.03	6079442.88	443.14	443.15
C–3	1982752.80	6079448.43	442.82	442.82
D–1	1982791.68	6079461.97	443.17	443.21
D–2	1982776.51	6079469.74	443.40	443.38
D–3	1982766.81	6079474.49	443.08	443.08
E–1	1982805.53	6079490.53	443.36	
E–2	1982790.71	6079498.50	443.59	443.59
E–3	1982781.18	6079503.22	443.33	443.34
F–1	1982818.80	6079518.58	443.79	
F–2	1982803.67	6079525.77	444.04	444.03
F–3	1982793.65	6079530.30	443.78	443.79
G–1	1982832.02	6079547.38	444.47	
G–2	1982816.92	6079554.29	444.77	444.81
G–3	1982807.11	6079559.03	444.39	444.43
H–1	1982844.69	6079574.43	445.50	445.61
H–2	1982830.03	6079582.17	445.79	445.85
H–3	1982820.49	6079587.20	445.42	445.48
I–1	1982857.96	6079603.85	446.76	446.92
I–2	1982843.54	6079610.91	447.24	447.29
I–3	1982833.87	6079615.73	446.83	446.86
J–1	1982869.37	6079632.95	447.85	447.88
J–2	1982856.77	6079639.03	448.40	448.42
J–3	1982847.15	6079644.07	448.12	448.15
K–1	1982881.04	6079663.65	448.91	448.93
K–2	1982870.61	6079668.13	449.71	449.73
K–3	1982860.55	6079672.99	449.57	449.61
L–1	1982886.48	6079675.02	449.52	449.54
L–2	1982876.21	6079679.89	450.26	450.30
L–3	1982866.59	6079684.34	450.35	450.42
M–1	1982899.42	6079701.51	451.15	451.21
M–2	1982889.38	6079706.37	451.89	451.97
M–3	1982880.20	6079711.05	451.90	452.03



CAL RECYCLE
ORTEGA RIDGE ROAD

MONITORING SURVEY

SEPT 2023

CONTROL POINTS △

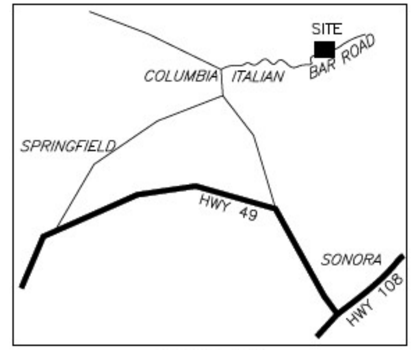
PNT	NORTHING	EASTING	ELEVATION	DESCRIPTION
21	2212720.74	6606167.43	1648.50	NAIL
22	2212571.55	6606016.60	1651.70	NAIL
24	2212830.98	6606233.70	1645.61	NAIL

LEGEND

I	I BEAM
△	CONTROL POINT
o	MONITORING NAIL
—·—·—	GUARD RAIL
— — — —	EDGE OF GRAVEL ROAD
XXX	NAIL POINT NUMBER

SCALE: 1"=10'

0 10 20

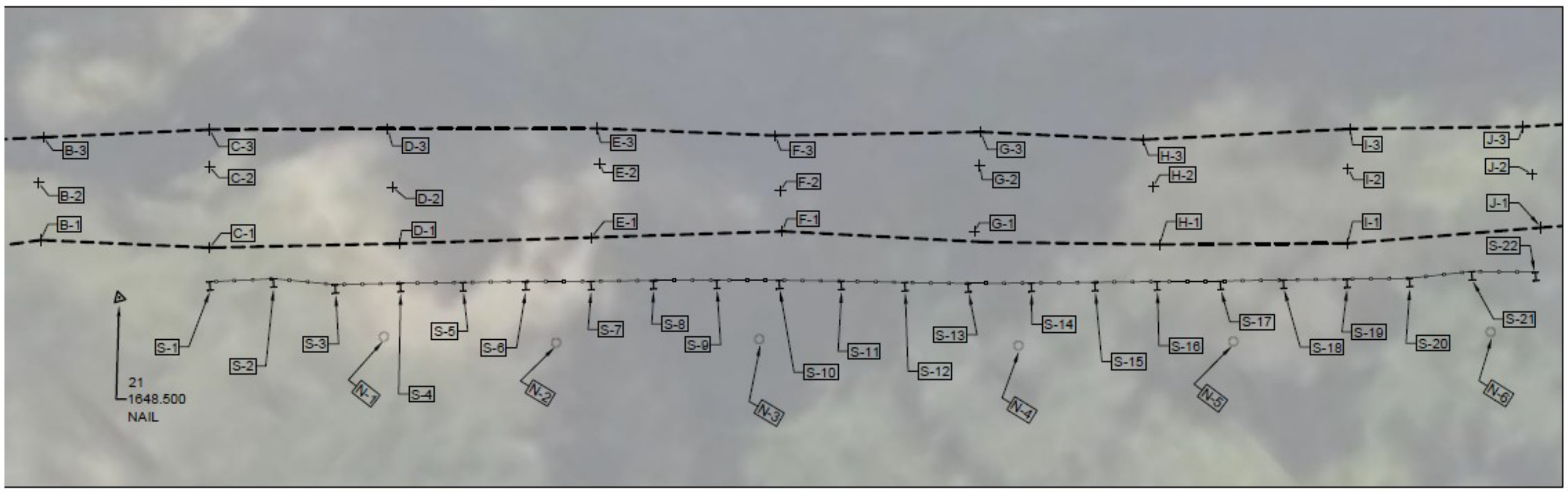


VICINITY MAP
NOT TO SCALE

MONITORING NAILS o – POINT NAME SHOWN BOXED XXX

PNT	NORTHING	EASTING	JAN 2022	AUG 2023
N-1	2212704.97	6606146.20	1645.91	1645.91
N-2	2212693.35	6606133.76	1645.11	1645.14
N-3	2212678.91	6606119.77	1645.23	1645.29
N-4	2212661.23	6606101.25	1645.98	1646.03
N-5	2212645.94	6606086.48	1646.34	1646.32
N-6	2212627.27	6606069.16	1647.22	1647.19

NOTES
1) COORDINATES AND ELEVATIONS SHOWN HERE ON ARE ASSUMED.
2) DATES OF SURVEYS JAN 19, 2022 AND AUG 10, 2023.
3) MONITORING NAILS ARE SET IN THE RETAINING WALL.
4) GAURD RAIL ELEVATIONS ARE ON THE TOP CENTER OF I-BEAM.



PRELIMINAR

GHD Inc.
Conditions of Use

Client: CAL RECYCLE
Project: ITALIAN BAR ROAD 3
Title: MONITORING SURVEY
Project No. 12581260
Date May 2022

LOCATION (LINK)	No READINGS	DELTAS		
		NORTHING	EASTING	ELEVATION
A-1	1	0	0	0
A-2	2	0.001	0.038	0.047
A-3	2	0.000	0.010	0.043
B-1	2	0.004	0.023	0.062
B-2	2	0.012	0.006	0.070
B-3	2	0.051	0.003	0.004
C-1	2	0.023	0.055	0.138
C-2	2	0.038	0.049	0.053
C-3	2	0.008	0.023	0.030
D-1	2	0.049	0.032	0.044
D-2	2	0.007	0.035	0.039
D-3	2	0.029	0.008	0.023
E-1	2	0.030	0.010	0.115
E-2	2	0.033	0.058	0.173
E-3	2	0.023	0.024	0.055
F-1	2	0.024	0.050	0.057
F-2	2	0.079	0.006	0.180
F-3	2	0.004	0.008	0.062
G-1	2	0.033	0.058	0.137
G-2	2	0.009	0.005	0.022
G-3	2	0.000	0.061	0.034
H-1	2	0.013	0.029	0.081
H-2	2	0.030	0.055	0.124
H-3	2	0.026	0.003	0.121
I-1	2	0.034	0.043	0.018
I-2	2	0.026	0.002	0.084
I-3	2	0.015	0.041	0.023
J-1	2	0.023	0.001	0.105
J-2	2	0.032	0.047	0.146
J-3	2	0.026	0.029	0.010
N-1	2	0.015	0.030	0.006
N-2	2	0.191	0.112	0.027
N-3	2	0.049	0.072	0.061
N-4	2	0.037	0.021	0.039
N-5	2	0.109	0.011	0.022
N-6	2	0.054	0.009	0.035
S-1	2	0.003	0.003	0.083
S-2	2	0.018	0.025	0.080
S-3	2	0.095	0.008	0.113
S-4	2	0.005	0.029	0.077
S-5	2	0.003	0.031	0.072
S-6	2	0.006	0.028	0.080
S-7	2	0.013	0.030	0.087
S-8	2	0.016	0.038	0.084
S-9	2	0.001	0.021	0.083
S-10	2	0.006	0.022	0.083
S-11	2	0.022	0.000	0.088
S-12	2	0.020	0.017	0.087
S-13	2	0.010	0.002	0.082
S-14	2	0.015	0.020	0.081
S-15	2	0.014	0.011	0.079
S-16	2	0.005	0.024	0.073
S-17	2	0.007	0.006	0.078
S-18	2	0.018	0.014	0.084
S-19	2	0.013	0.022	0.078
S-20	2	0.004	0.010	0.079
S-21	2	0.007	0.005	0.061
S-22	2	0.021	0.002	0.058