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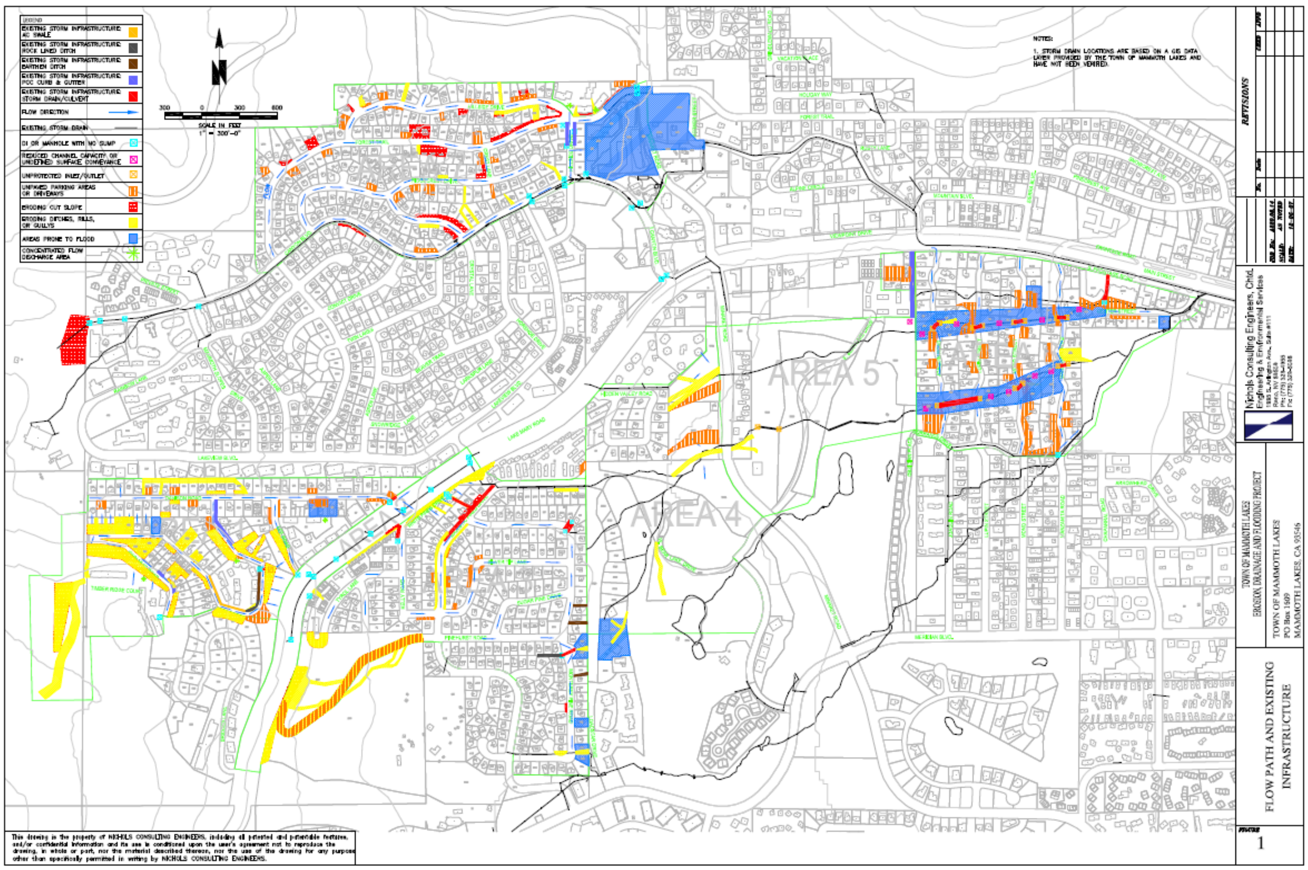
Town of Mammoth Lakes
Erosion, Drainage, and Flooding Project



Final

FINAL RECOMMENDATIONS REPORT

April 11, 2008

Town of Mammoth Lakes
437 Old Mammoth Rd, Suite R
PO Box 1609
Mammoth Lakes, CA 93546

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1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

The Town of Mammoth Lakes (Town) has contracted with Nichols Consulting Engineers (NCE) to assist Town Staff with the identification of existing erosion, drainage and flood related problem areas and to develop a prioritized list of localized solutions which will allow the Town to become proactive in the way it manages its stormwater. The work performed as part of this project is intended to supplement and enhance work previously conducted as a part of the 2005 Storm Drain Master Plan Update.

This document is the Final Recommendations Report and represents the culmination of many months of effort by Town Staff and NCE. This document is based in part on the previous work conducted as a part of this project including the analysis of existing conditions (Town of Mammoth Lakes Erosion, Drainage and Flooding Project Existing Conditions Report dated December 2007) and the Preliminary Geotechnical Investigation of John Muir Road (Appendix A – Preliminary Geotechnical Erosion Control Study for John Muir Road).

1.2 PROJECT BACKGROUND

In 2005, the Town of Mammoth Lakes commissioned a Storm Drain Master Plan Update. The purpose of the plan was to update the original 1984 Storm Drain Master Plan prepared by the Mono County Department of Public Works. The 2005 study performed a number of tasks including:

1. A review of area hydrology
2. A review of previous hydrologic methodologies developed as part of the 1984 plan
3. Development of stormwater runoff flows for the 20 year and 100 year events
4. An assessment of the adequacy of existing storm drain conveyance facilities
5. Proposed recommendations for improvements and or expansions to the existing storm drain system
6. An assessment of the impact of three potential regional detention facilities
7. Cost estimates and financing options for proposed enhancements or expansions
8. Brief overview of general stormwater regulations

The report did not specifically address:

- Flood prone areas
- Impacts of erosion and sedimentation on the storm drain system
- Existing condition of surface conveyance and capture facilities (i.e. earthen ditches, curb and gutter, AC dike, AC swale, drop inlets, catch basins, etc)
- Impact of runoff from private impervious surfaces
- Issues related to snow removal activities or snow storage

1.3 PURPOSE

Project

The purpose of the Town of Mammoth Lakes Erosion, Drainage and Flooding Project is to clearly identify and document existing issues and problem sites and develop localized solutions to supplement the 2005 Storm Drain Master Plan Update.

Final Recommendations Report

The purpose of the Final Recommendations Report is to present management strategies, project considerations and BMP improvements to the Town which address existing erosion, drainage and flooding problems.

1.4 GOALS AND OBJECTIVES

The principal goal or vision for the Town of Mammoth Lakes Erosion, Drainage, and Flooding Project is to shift the Town from a reactive to proactive stormwater management approach. Specific project goals are presented below.

GOAL #1: Clearly identify and document existing conditions (erosion, drainage and flooding) by type and location

GOAL #2: Prioritize problems and or problem areas identified by the Existing Conditions Report

GOAL #3: Develop and document localized solutions through proposed enhancements and or projects

GOAL #4: Integrate proposed enhancement and projects with the existing Town Capital Improvement Program and 2005 Storm Drain Master Plan Update

GOAL #5: Provide basic stormwater program assistance

2.0 PRIORITIZATION METHODOLOGY

As with any capital program, the ability to prioritize existing erosion, drainage and flooding problems is critical. Given the dynamic nature of the Town's stormwater drainage system, limited financial resources and a short construction season in the High Sierra, it is imperative that a logical and well thought out process be utilized to prioritize existing issues and develop clear recommendations. This section will present a basic discussion about prioritization processes, prioritization criteria and the application and results of the prioritization methodology used for the Town of Mammoth Lakes Erosion, Drainage and Flooding Project.

2.1 PRIORITIZATION PROCESS

A prioritization process is a means of evaluating existing conditions, information or data to develop a ranked outcome or identify high priority areas. It can be applied in a qualitative or quantitative manner and often utilizes some benefits of both. Through a prioritization process the highest priority issues or needs are clearly identified. This process provides a means of logically proposing solutions (i.e. improvements, projects, programs or policy enhancements) to address the high priority needs or issues. The proposed programs or projects can then be integrated into capital improvement programs for dedicated funding.

2.2 PRIORITIZATION CRITERIA

A critical factor in the success of the prioritization process is the development of clear and understandable evaluation criteria. Evaluation criteria used for erosion control and drainage projects varies and is often based on project specific attributes. Below is the list of criteria which have been used on other similar projects:

- Short and long term risk (potential for flooding or slope failure, financial loss, legal implications)
- Size
- Quantity
- Severity and
- Frequency of problems or problem sites
- Cost associated with maintaining current conditions
- Cost associated with permanent solutions for fixing the problem
- Implementation or construction considerations (opportunities & constraints)
- Maintenance requirements (cost, equipment, manpower, etc.)
- Feasibility
- Public concern
- Other benefits (public safety, recreation, permit compliance, water quality, etc.)

In some instances, criteria can be arranged by tiers to separate the more critical or applicable criteria from criteria that may be useful but is not of critical importance. Often, this is done when large and complicated systems are being evaluated.

2.3 EROSION, DRAINAGE, AND FLOODING PRIORITIZATION

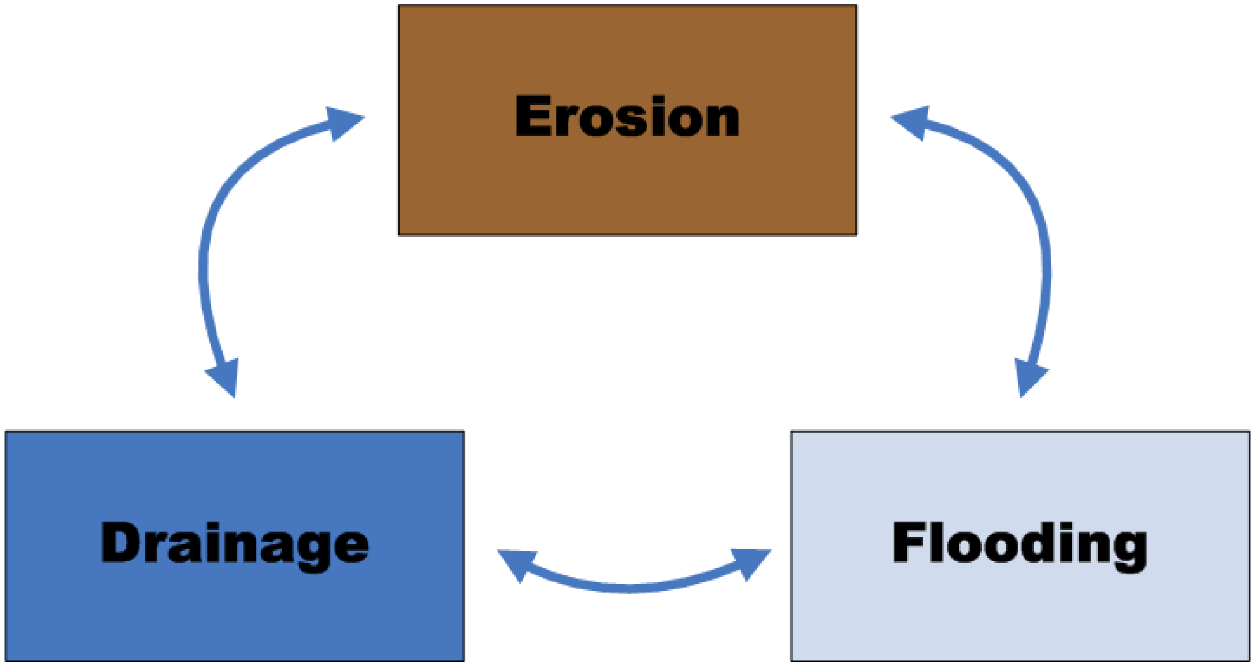
NCE, with assistance from Town Staff, developed and applied a very simple and straight forward prioritization process for the Erosion, Drainage and Flooding Project. The first phase of the prioritization process occurred during the project kickoff meeting and field visit. Initially, the project intended to perform a cursory evaluation of existing drainage and flooding conditions for the entirety of the Town's jurisdiction. Following the kickoff field visit, this effort was reevaluated. Due to the severity and extent of the existing erosion and drainage problems coupled with the limited resources available for the project, NCE recommended that a more focused effort be implemented in those areas of greatest concern to the Town. NCE and Town Staff discussed at length the areas where the most frequent and severe problems occurred. Based on this discussion, feedback provided to the Town by the Public, and a review of available resources, it was determined that seven areas would be further investigated as a part of the existing conditions analysis. These seven areas (Figure 2.1) are located within two defined flow paths or drainages. The first flow path includes the primary drainage from John Muir Road to Sierra Valley Sites and the second flow path includes the primary drainage from Forest Trail to the North Village.

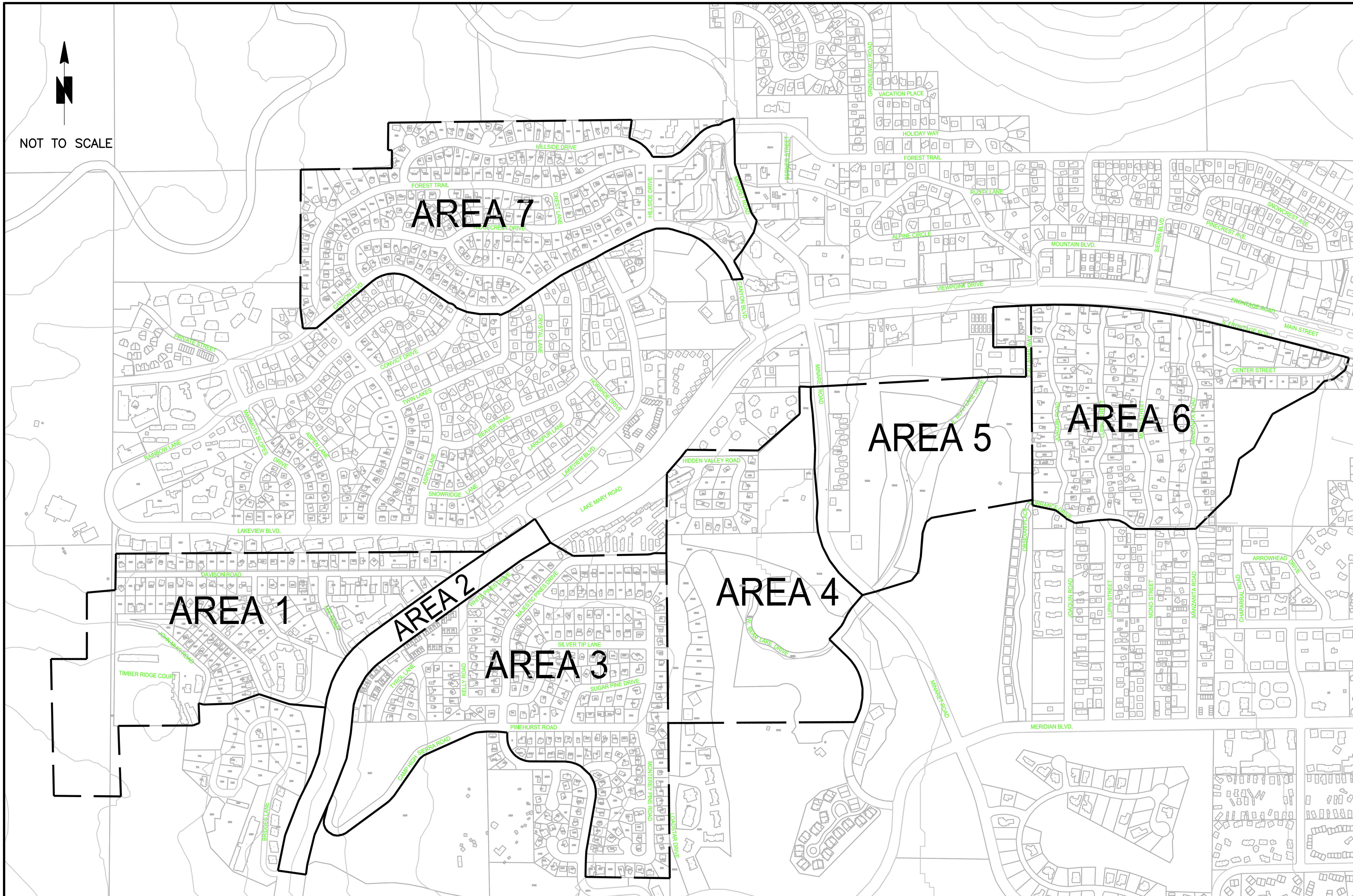
Following the completion of the Existing Conditions Report, NCE developed and applied a second prioritization process to rank existing erosion, drainage and flooding problems within the previously prioritized areas and assist in developing recommendations for the Town. Prior to the selection of evaluation criteria, NCE determined that the evaluation would prioritize based on area rather then problem type. The reason for this decision was two-fold. First, the interconnectedness of the existing erosion, drainage and flooding problems (Figure 2.2) made it difficult to consider one type of problem or problem site without considering the others. Second, due to the seven areas already determined for the Existing Conditions Analysis, a precedent had been set for utilizing the area theme. The four criteria chosen to further evaluate the seven areas in the two defined flow paths included:

1. Severity of Problems
2. Quantity of Problems
3. Size of Drainage Area
4. Amount of Public Concern or Complaints

These criteria were selected because they provided NCE a straight forward and quantitative way to compare the seven areas or two flow paths. After applying the criteria, it was determined that the John Muir to Sierra Valley Sites flow path was the higher priority of the two general flow paths. This area is significantly larger in terms of acreage, has a higher quantity of erosion and drainage issues and the erosion issues are more severe than that of the Forest Trail to North Village flow path. In addition, the Town received strong feedback from the John Muir Road, Davison Road and Sierra Valley Sites neighborhoods following the July and August 2007 storm events. Within the John Muir to Sierra Valley Sites flow path Areas 1 and 3 were identified as the highest priorities due again to the severity, quantity and size of the existing problem areas. NCE also reasoned that resolving erosion and drainage issues in areas 1 and 3 would likely reduce flooding in areas 4, 5 and 6. More detailed discussion and recommendations related to addressing the existing problem sites is included in Section 3.

Figure 2.2 – Relationship Between Erosion, Drainage and Flooding Problems in the Town of Mammoth Lakes





REVISIONS

No.	Date		CHKD	APPD

JOB No: A220.08.14
SCALE: AS NOTED
DATE: 12-05-07

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TOWN OF MAMMOTH LAKES
EROSION, DRAINAGE AND FLOODING PROJECT

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PROJECT AREAS

FIGURE
2.1

3.0 RECOMMENDED MANAGEMENT STRATEGIES, PROJECT CONSIDERATIONS, AND IMPROVEMENTS

3.1 MANAGEMENT STRATEGIES

Recommended management strategies to address existing erosion, drainage and or flooding problems include new or enhanced policies, development of new ordinances, and program enhancements. Below are brief overviews of the recommended management strategies for consideration by the Town.

Mammoth Mountain Ski Resort

It is recommended that the Town of Mammoth Lakes (Town) initiate discussions with the Mammoth Mountain Ski Resort and the United States Forest Service (USFS) to determine ongoing and future plans for erosion control and surface water management at the Ski Resort. As discussed in the Existing Conditions Analysis Report, erosion and stormwater runoff from the Ski Resort puts undue stress on the Town's infrastructure. By engaging the Ski Resort in discussions about permanent erosion control of the ski slopes and bike trails as well as mitigation of stormwater flows and volumes from structures, parking lots, access roads and maintenance yards, the Town and Ski Resort may find cost effective ways to cooperatively address these issues. Potential solutions may include development of a cooperative agreement, construction of shared facilities, shared maintenance resources or cost sharing opportunities on construction projects.

Commercial, Industrial and Residential Multi Family Properties

In order to address the impact of stormwater runoff from large impervious surfaces affiliated with commercial, industrial and residential multi family properties (townhome developments, condominium complexes, apartment buildings, etc) it is recommended that the Town engage owners or managers in discussions about opportunities to reduce stormwater runoff from private property. Some alternatives for addressing this issue include cooperative agreements, shared facilities and cost sharing opportunities. Other options include developing and implementing a low impact development education program or the passing of a local ordinance requiring erosion control and stormwater BMPs be implemented for all developed properties. Low impact development and BMP retrofit programs are becoming more popular among small communities in anticipation of National Pollutant Discharge Elimination System (NPDES) Phase II Permits being issued. NCE would recommend that prior to the development and adoption of any local ordinance requiring the retrofit of existing private development that an exhaustive outreach effort be employed to ensure all potentially affected parties are aware of the proposed requirements. This effort may include direct mailings, information flyers, public meetings and a local advertising campaign.

Unpaved Driveways, Access Roads and Parking Areas

Given the extent of existing unpaved surfaces throughout the Town's jurisdiction, NCE would recommend the Town develop and implement a program aimed at educating property owners about the importance of stabilizing or paving these sites. In addition, the Town may want to consider developing a paving ordinance requiring that all existing and future private driveways, access roads, and parking areas be paved and have functioning stormwater BMPs incorporated into the design. Again, NCE would caution the adoption of any ordinance with financial implications without first engaging those who may be affected by the requirement and providing a reasonable compliance deadline. NCE would also recommend that the Town require that all access or maintenance roads affiliated with new development be stabilized or paved as part of the projects winterization plan.

Drainage Infrastructure, Erosion and Flood Control Funding Strategy and Plan

The development of a clear and achievable funding strategy and plan is paramount to the Town's success in managing its drainage infrastructure and stormwater runoff. Considering the existing erosion, drainage and flooding problems within the Town's jurisdiction and the potential for more stringent regulations in the future (flood control, stormwater and water quality) now is the time to develop such a strategy and plan. NCE would encourage the Town to consider a variety of potential funding options including federal and state grant programs, local taxes, fees, assessments or bonds and public/private partnerships. It is likely that a comprehensive funding plan will include a combination of funding sources referenced above. The cooperative funding strategies developed in the Lake Tahoe Basin and San Francisco Bay are excellent examples for the Town to utilize in the development of its own plan.

3.2 PROJECT CONSIDERATIONS

In order to assist the Town in moving forward with addressing existing erosion, drainage and flooding issues, NCE has the following general recommendations:

General Project Recommendations

- Prior to the selection of individual projects, the Town should develop an overall strategy for erosion control and drainage improvements and apply the strategy to each flow path or area. This will ensure that adjacent projects easily integrate and improvements constructed in one area do not create more or new erosion and drainage problems in another area.
- Erosion and drainage problems should be addressed in concert whenever feasible and generally start at the top of the drainage and work down the system. This recommendation is based in part on our finding, in the Existing Conditions Analysis Report, that flooding in some lower areas is related to existing erosion and drainage problems in the upper drainage. This recommendation also ensures that improvements constructed at lower elevations are not overwhelmed by runoff or sediment from unimproved areas above.

<u>Project Delineation and Selection Recommendations</u>

NCE recommends the following items be considered during the identification, selection and delineation of projects:

- <u>Construction Season</u> - Projects should be delineated so that either the entire project or a stand-alone phase can be implemented within the May 1 through October 15 construction season, as required by the Lahontan RWQCB Basin Plan and the existing Memorandum of Understanding (MOU) between the Town and Lahontan.
- <u>Cost</u> – Project construction cost is often linked to a number of factors including project size and complexity, site construction constraints, material cost and traffic control. It is important to select projects which are large enough, in terms of cost, to attract interest among a variety of contractors. In addition, NCE has recognized that there are often significantly increased costs when a project extends beyond one construction season; therefore, NCE recommends that projects from a cost standpoint be delineated so either the entire project or a stand-alone phase can be implemented within the May 1 through October 15 construction season.
- <u>Integration with Other Projects</u> – Given the dynamic and interrelated nature of the erosion, drainage and flooding problems within the Town (as discussed in Section 2) it is essential that the delineation of projects consider previous and future projects within and adjacent to each flow path.

<u>Other Project Considerations</u>

- Consider capturing and conveying surface flows from above John Muir, Davison and Kelly Roads within the existing or enhanced storm drain system under Lake Mary Road. This will substantially reduce surface flows reaching the Sierra Star Golf Course and Sierra Valley Sites. Flow attenuation as part of the design for this area will be critical to ensure that peak flows delivered to Lake Mary Drive and ultimately Hot Creek do not increase.
- Another potential alternative is to partner with the Sierra Star Golf Course and utilize golf course open space for flow attenuation or capture and store runoff on site to be used for supplemental golf course irrigation.
- When feasible, separate urban runoff from upland runoff. This will minimize the volume of surface flow reaching the Town's storm drain infrastructure in some locations. As an example, work with Caltrans, the USFS and Mammoth Mountain Ski Resort to attenuate and separate upland flows above the Forest Trail and Hillside Drive neighborhoods to address flooding in the North Village. Another opportunity is to work with the USFS and Mammoth Mountain Ski Resort to implement erosion control and drainage improvements along the bike trail above the intersection of Minaret Road and Forest Trail.
- A major emphasis should be placed on reducing stormwater runoff peak flows and volumes through infiltration or detention. This is particularly important in the higher elevation areas of the Town in order to reduce the stress placed on drainage infrastructure in the lower portions of the Town.
- Open channels and earthen ditches in low gradient and highly developed areas (i.e. Sierra Valley Sites) should be further evaluated to determine if they should be more

frequently maintained, enhanced or replaced with storm drain to minimize the impacts of sedimentation, snow storage, parking, collection of residential garbage and the risk of flooding.

- Whenever possible, eliminate the discharge of concentrated surface flows to unprotected slopes greater than 2:1
- Identify opportunities to disperse flows at various locations eliminating concentrated discharge points to the maximum extent practicable.

2005 Storm Drain Master Plan Update Recommendations

- Storm drain enhancements proposed on John Muir Road, Davison Road and Lee Road are likely needed. Detailed design layout, sizing and discharge locations would need to be evaluated during project specific design.
- The proposed storm drain on Monterey Pine Road may not be necessary if the existing earthen ditch is enhanced and maintained frequently.
- Storm drain enhancements on Canyon Boulevard and Lakeview Drive seem warranted, but the design layout, sizing and discharge locations would need to be evaluated during project specific design.
- Minimal improvements were recommended in the Sierra Valley Sites drainage area. Given the existing drainage and flooding issues identified in the existing conditions analysis, NCE would recommend that a more thorough investigation of this area be conducted.

3.3 IMPROVEMENTS

This section is a resource for the Town to use as it moves forward with selecting and implementing projects which will address the existing erosion, drainage and flooding problems. This section provides an expansive list of improvements and BMPs which have been successfully deployed in other high alpine environments. The format of this section is presented to match the format of the Existing Conditions Analysis Report.

3.3.1 EROSION IMPROVEMENTS

3.3.1.1 CUT / FILL SLOPES

Soil Conditioning and Revegetation

Basic Description – Soil conditioning and revegetation restore natural soil function and encourage the establishment of native vegetative communities which minimize raindrop impact, reduce erosion and decrease runoff from a site. Soil conditioning and revegetation can be stand alone treatments or used in combination with erosion control blankets, turf reinforced mats, slope layback, toe walls, retaining walls or other slope treatments. Soil conditioning and revegetation treatments have proven to be highly successful in the Lake Tahoe Basin and High Sierra Regions at reducing or eliminating erosion on large, steep cut/fill slopes and other highly disturbed soils.

Design Considerations **(Figure 3.1):**

- The use of revegetation is generally most effective when the slope is 2:1 (50%) or flatter.
- Always use native or adapted species in the seed mix and if possible utilize seed collected from or near the site (Hogan 2005).
- Generally, it is recommended that an appropriate level of mulch (wood chips, pine needles or other native material) be applied to treated areas. At least one inch is recommended in high elevation dry environments.
- Temporary irrigation is recommended for at least the first growing season with most vegetation treatments.
- Where appropriate, the application of compost, fertilizer and or other soil amendments may be necessary.
- It is critical to eliminate disturbance from wildlife, foot traffic, bikes and by vehicles.

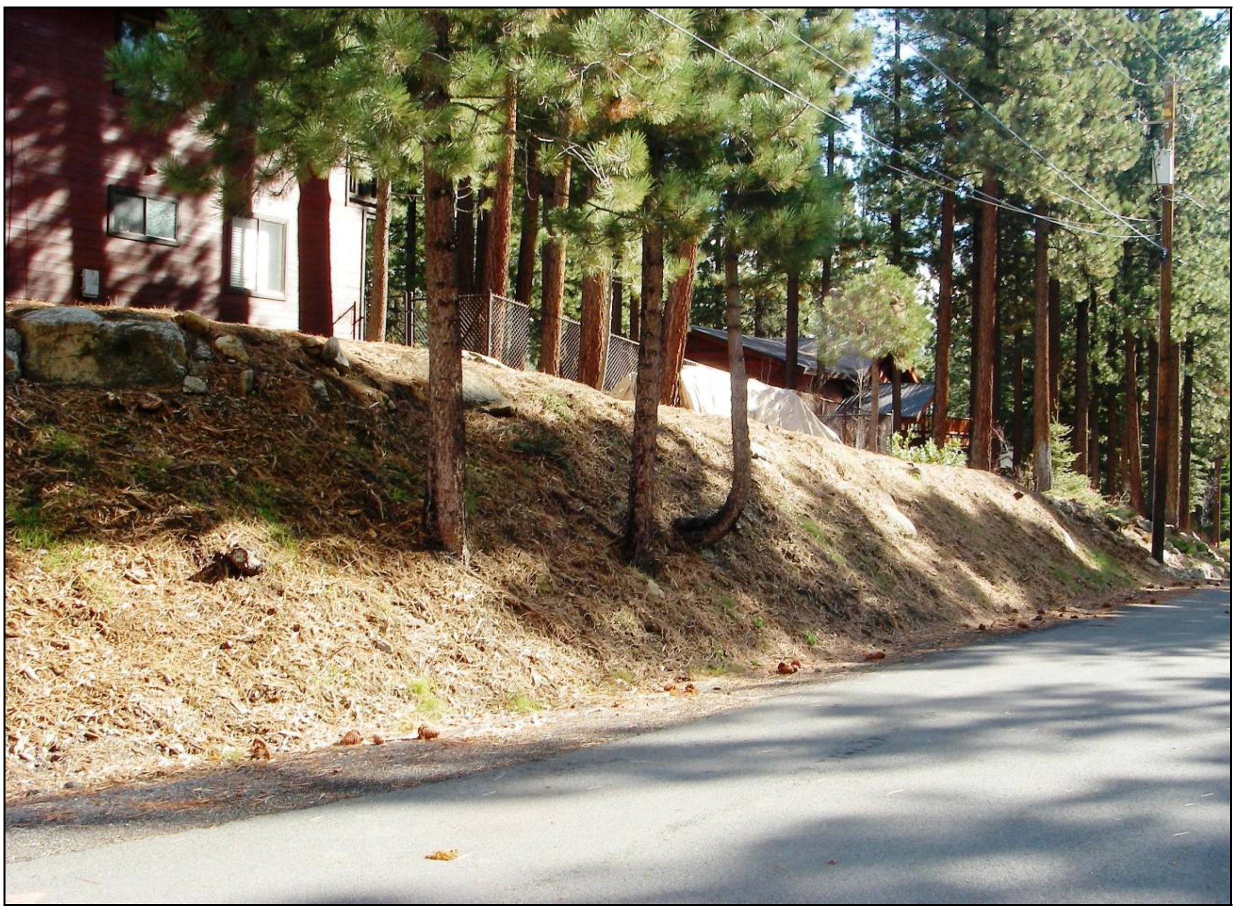


Figure 3.1 – Soil Conditioning and Revegetation of Cut Slope in the Lake Tahoe Basin

Erosion Control Blankets

Basic Description – A temporary degradable rolled erosion control product composed of processed natural or polymer fibers which are mechanically, structurally or chemically bound together to form a continuous matrix to provide erosion control and facilitate vegetation establishment (ECTC 2008). Erosion control blankets (ECBs) are placed over the surface of the soil and are generally applied on short, steep slopes where vegetation is slow or difficult to establish (NHI 2001). NCE has utilized ECBs on a number of projects to provide short term (1-2 growing seasons) erosion control on cut and fill slopes until natural soil function is achieved and a strong vegetation community is established.

Design Considerations **(Figure 3.2):**

- Generally applied when slopes are 3:1 or steeper.
- Not recommended for sites with very rough or rocky surfaces.
- Installation and proper staking are key components of successful application.
- ECBs should not be used in areas that are mowed or disturbed by snow removal equipment.
- The functional longevity of ECBs varies (less than 3 months to roughly 3 years); therefore, it is imperative to select products on site specific basis.

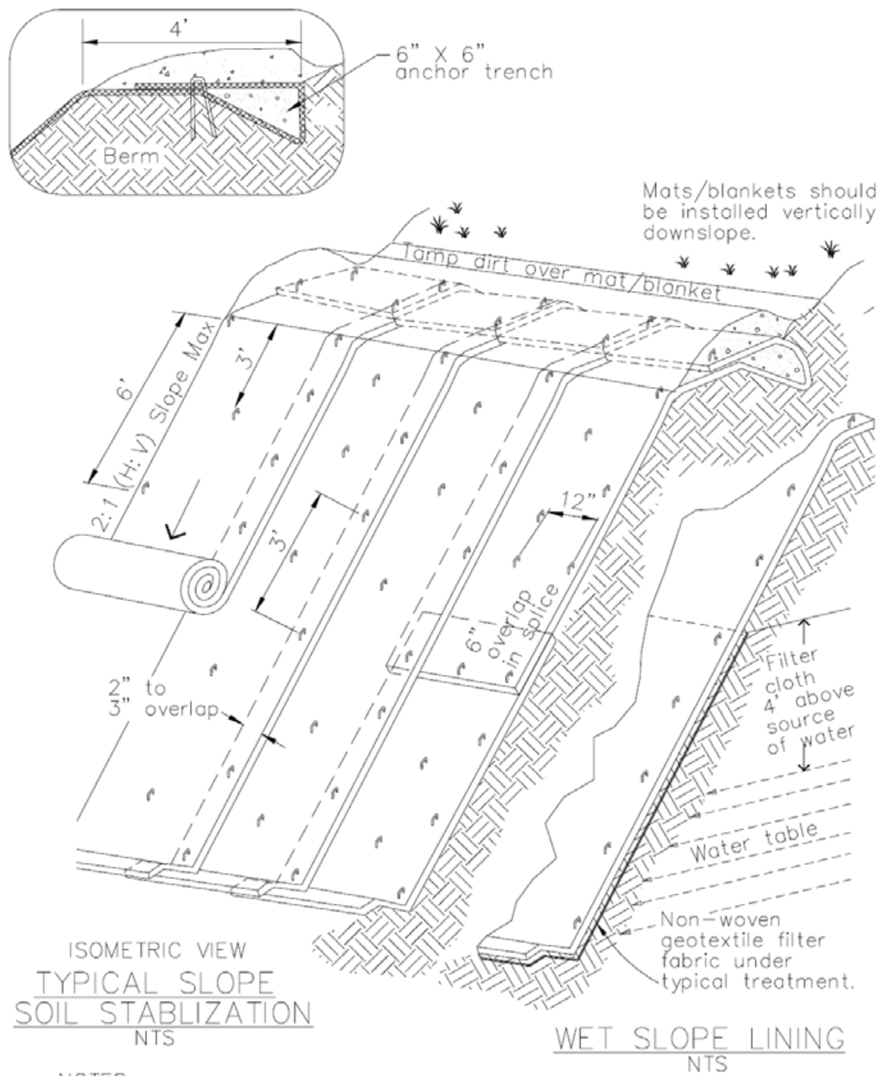
Turf Reinforced Mats

Basic Description – A rolled erosion control product composed of non-biodegradable synthetic fibers, filaments, nets, wire mesh and or other elements, processed into a permanent, three-dimensional matrix of sufficient thickness. Turf reinforced mats (TRMs), which may be supplemented with degradable components, are designed to impart immediate erosion protection, enhance vegetation establishment and provide long-term functionality by permanently reinforcing vegetation during and after maturation. TRMs are typically used in hydraulic applications, such as high flow ditches and channels, steep slopes, stream banks, and shorelines, where erosive forces may exceed the limits of natural, unreinforced vegetation or in areas where limited vegetation establishment is anticipated (ECTC 2008).

Design Considerations (**Figure 3.2):**

- Recommended for very steep slopes where vegetation is unlikely to grow or will take long periods of time to establish.
- Cost effective alternative to hard armor solutions (i.e. rip rap, retaining walls or shotcrete).
- Need to consider wildlife implications of deploying three dimensional structures.
- Need to place perpendicular to the contour for cut and fill slopes.

EC-7 Geotextiles and Mats



NOTES:

1. Slope surface shall be free of rocks, clods, sticks and grass. Mats/blankets shall have good soil contact.
2. Lay blankets loosely and stake or staple to maintain direct contact with the soil. Do not stretch.
3. Install per manufacturer's recommendations

TYPICAL INSTALLATION DETAIL

10 of 11 | California Stormwater BMP Handbook | January 2003

Construction

www.cabmphandbooks.com

Figure 3.2 - Erosion Control Blanket or Turf Reinforced Mat detail (CASQA 2003)

Retention Systems including Retaining Walls (Rock, Block and Wood)

Basic Description – Where reduction in slope angles or cut slopes is not cost effective and or feasible due to erosion considerations and or site constraints, a diverse number of retaining wall systems are available. Generally, retaining walls are a vertical structure constructed to restrain a vertical-faced or near-vertical-faced mass of earth. The earth behind the wall may be either native soil or backfill. Retaining walls must resist the lateral pressure of the earth, which tends to cause the structure to slide or overturn. There are numerous types of retaining walls and retaining wall material and the selection of a system is based in part on whether the site is a cut or fill slope. Types of cut slope retention systems include slurry walls, soldier pile and lagging, soil nailed, and permanent ground anchors (tie-back). Fill slope retention systems included mechanically stabilized earth, crib, bin, gabion, gravity and reinforced earth walls. The material used to construct these walls includes concrete, articulated block, rock, wood, steel and other material. The selection of an appropriate retaining wall system should consider and is strongly dependent on:

- Soil and rock type
- Depth to groundwater
- The presence of rock (bedrock or boulders can present difficulties in excavation and drilling penetration)
- Height and length of retained slope
- Performance of adjacent structures and roads that might be sensitive to lateral and vertical movements as well as vibration
- Existing utilities and other obstructions
- Disturbance to root mats and erosion protection afforded by forest duff

Design Considerations (**Figure 3.3)**:

- Subsurface soil, rock, and groundwater conditions will strongly control the selection of the appropriate wall type, material and design and should be further evaluated within the context of a geotechnical investigation.
- Conduct site specific Geotechnical Investigation to develop conclusions and recommendations for:
    - Local geology and geologic hazards
    - Subsurface soil, rock, and groundwater conditions
    - Feasible alternative wall types
    - Earth pressures (static and seismic)
    - Bearing capacity for retaining wall footings
    - Drilled element capacities
    - Erosion control
    - Subsurface and surface drainage (including winter icing)
    - Seismicity
    - Backfill loads
    - Freeze, snow loads
- Critical to establish strong vegetation community and or hardy mulch layer in areas above or between gravity wall structures.
- Ensure there are no concentrated surface water discharge points above the wall.
- Construction equipment access may influence the type of retention system is utilized.

Figure 3.3 - Rock Retaining Wall Photo

Rock Slope Protection

Basic Description – Use of large stacked riprap to protect soil surface from wind and water erosion. NCE has used rock slope protection (RSP) on numerous projects where soils were unlikely to return to natural conditions and the establishment of vegetation was not a viable option. It can be significantly more expensive than other treatments, but requires minimal to no maintenance was constructed. The specification and selection of the appropriate size, color and shape of rock is key to ensuring long term stability and meeting scenic requirements.

Design Considerations (**Figure 3.4**):

- Slopes which are very steep (>1.5:1) may encourage rock migration.
- Toe of riprap must be properly keyed in to native soil.
- Use solid and durable rock material that can withstand the freeze thaw cycles of the High Sierra (City of Reno 2003).
- The use of a geotextile under the rock rip rap may be necessary depending on site conditions and the physical properties of the underlying soil.
- Riprap can be placed around mature or established vegetation.
- In areas of active snow removal, toe protection in the form of concrete curb or asphalt concrete berm is recommended.

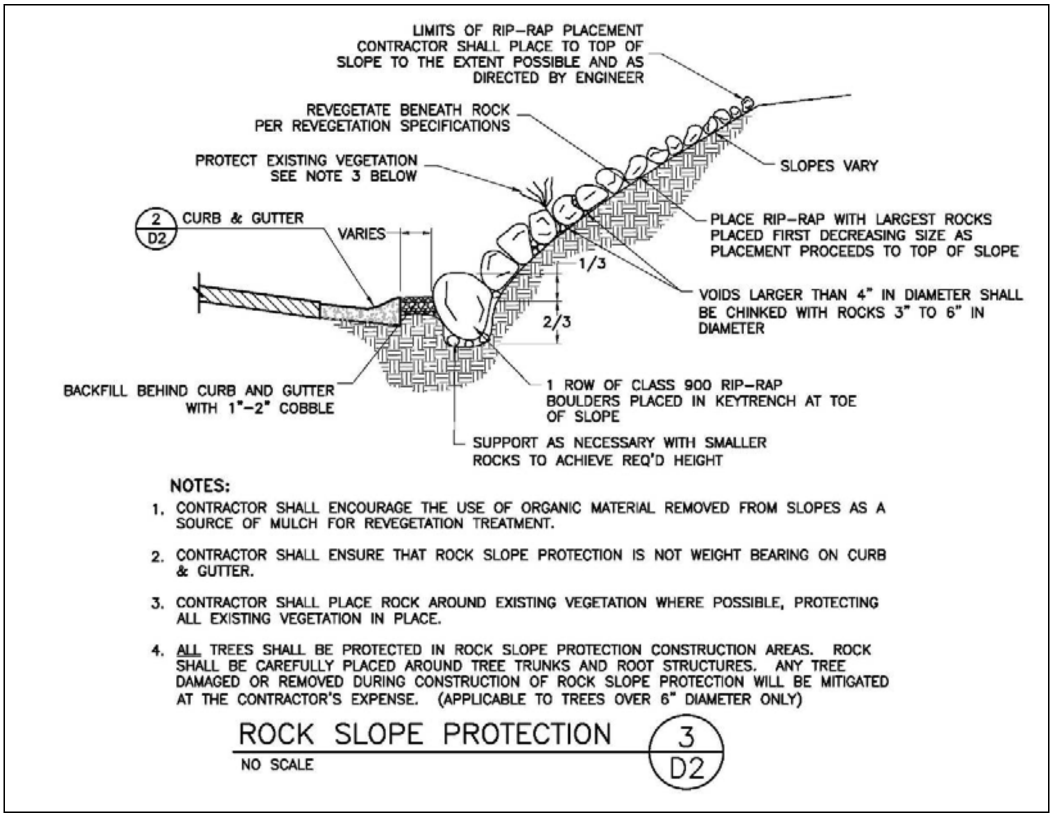


Figure 3.4 – Rock Slope Protection (RSP) Detail from Nichols Consulting Engineers

3.3.1.2 ERODING DITCHES

Turf Reinforced Mats

Basic Description – A rolled erosion control product composed of non-biodegradable synthetic fibers, filaments, nets, wire mesh and or other elements, processed into a permanent, three-dimensional matrix of sufficient thickness. TRMs, which may be supplemented with degradable components, are designed to impart immediate erosion protection, enhance vegetation establishment and provide long-term functionality by permanently reinforcing vegetation during and after maturation. TRMs are typically used in hydraulic applications, such as high flow ditches and channels, steep slopes, stream banks, and shorelines, where erosive forces may exceed the limits of natural, unreinforced vegetation or in areas where limited vegetation establishment is anticipated (ECTC 2008). TRMs are a cost effective alternative to concrete and riprap lined channels.

Design Considerations (**Figure 3.8**):

- Not recommended in channels where vegetation mowing or heavy foot traffic occur.
- All TRMs have a maximum flow rate limitation. If flow rate (velocity) or shear stress exceed the manufactures design recommendation then a more structured solution is necessary.
- Proper installation and staking is critical for long term erosion control.
- Should not be used in channels with consistent high velocity flow conditions or in locations where the establishment of permanent vegetation is unlikely. (Nelsen et. al. 2006)

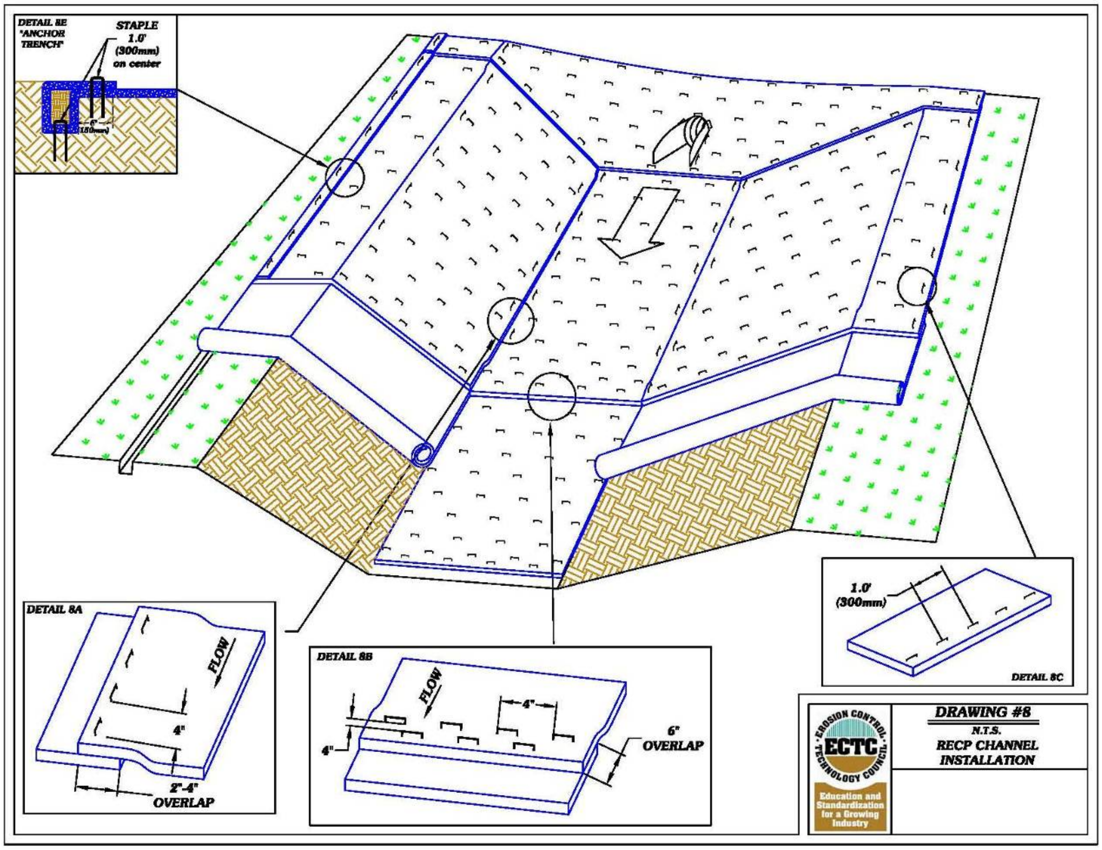


Figure 3.8 – Turf Reinforced Mat Detail (ECTC 2008)

Cobble or Riprap Lining

Basic Description – A very durable treatment of a blanket of rock placed in a channel to protect surface soils from erosion by wind and water. Design often requires the deployment of a geotextile between the riprap and soil surface. Typically used in steep or high velocity channels where structural long term protection is required. NCE has utilized this BMP on numerous projects in the Lake Tahoe Basin. It has been particularly effective in steep ephemeral drainages in urban areas.

Design Considerations (**Figure 3.9**):

- Generally deployed in channels with an average slope of >5% (CASQA 2003).
- Hydrologic and hydraulic analysis is required to determine peak flows, velocity and shear stress.
- Critical to select rock size (D_{50}) which will be immobile during the largest flow events (100 year flood).
- Angular rock provides greater surface roughness as compared to smooth or round rock.
- Use solid and durable rock material that can withstand the freeze thaw cycles of the High Sierra (City of Reno 2003).
- Place riprap so it extends to the maximum flow depth, or to a point where vegetation will be satisfactory to control erosion (EPA 2008).

Figure 3.9 – Rock Lined Channel Photo

<u>Eco Blocks</u>

Basic Description – Eco blocks are generally manufactured plastic units or precast concrete blocks which interlock together to form a stable surface structure. Some products are flexible and can be deployed over curved surfaces or around bends. The most prominent feature is the open grade or void space. Generally these units provide overall void space between 5% and 35%. The open void space can be filled with drain rock, gravel or topsoil. In the case of topsoil the void space can be seeded with grass species to allow for vegetative growth. In some instances, eco blocks can be a cost effective alternative to heavy riprap or concrete.

Design Considerations (**Figure 3.10**):

- Generally, require that a woven geotextile be placed between the native soil surface and the bottom of the eco block unit(s).
- Void space can be filled with drain rock or soil depending on site specific conditions. In areas with continuous high velocity flows, larger drain rock is recommended.
- When slopes are steep it is recommended that the units are held together with cable or staked at a specified frequency.
- Eco blocks are relatively new in the Sierra and NCE recommends the Town consult the manufacture's design staff prior to specifying this product for a project.

Figure 3.10- Picture of Armorloc as outlet protection
(http://www.contech-cpi.com/ess/products/contech_hard_armor/armortec_family/armorloc/221)

Prefabricated Plastic Channels

Basic Description – Prefabricated plastic channels are generally made of thermoformed High Density Polyethylene (HDPE) and can be formed in a variety of sizes and dimensions. The preformed channel is delivered to the construction site in units and is assembled on site.

Design Considerations (**Figure 3.11**):

- Most products have a minimum flow velocity required to maintain self scouring and eliminate sedimentation in the prefabricated channel.
- Not recommended in locations where riparian vegetation or riparian habitat are desired.

Figure 3.11- Picture of Smartditch (www.smartditch.com/index.htm)

Other options for addressing actively eroding ditches include earthen ditches, vegetated swales and concrete lined channels.

3.3.1.3 Unpaved Parking Areas

Soil Conditioning and Revegetation

Basic Description – Soil conditioning and revegetation restore natural soil function and encourage the establishment of native vegetation communities which minimize raindrop impact, reduce soil particle detachment, reduce erosion and decrease runoff from a site. Generally, soil conditioning and revegetation treatments include tilling of the soil to a predetermined depth, incorporation of soil amendments or compost, seeding and mulching. Revegetation can also be accomplished through hydroseeding and or hydromulching. These treatments are generally recommended as temporary erosion control measures until more permanent revegetation treatments can be implemented.

Design Considerations –

- Not recommended for sites with frequent disturbance from snow removal equipment, vehicles, bicycles or foot traffic.
- For compacted areas, it is critical to de-compact the soil to at least 18" below the surface.
- Hardy mulch is recommended.

Eco Blocks or Pavers

Basic Description – Eco blocks and pavers are generally manufactured plastic units or precast concrete blocks which interlock together to form a stable surface structure. Some products are flexible and can be deployed over curved surfaces or around bends. The most prominent feature is the open grade or void space. Generally these units provide overall void space between 5% and 35%. The open void space can be filled with drain rock, gravel or topsoil. In the case of topsoil the void space can be seeded with grass species to allow for vegetation growth. In some instances, eco blocks can be a cost effective alternative to heavy riprap or concrete.

Design Considerations (**Figure 3.12**):

- Some products are not designed to handle loading from vehicles. Consult the manufacturer before specifying on any project.
- Generally, require that a woven geotextile be placed between the native soil surface and the bottom of the eco block unit(s).
- Void space can be filled with drain rock or soil depending on site specific conditions. In areas with continuous high velocity flows, larger drain rock is recommended.
- When slopes are steep, it is recommended that the units are held together with cable or staked at a specified frequency.
- Eco blocks are relatively new in the Sierra and NCE recommends the Town consult the manufacturers prior to specifying this product in future projects.

Figure 3.12 – Picture of the Pavestone Conlock II
(http://www.pavestone.com/commercial/paver_erosion_control.html)

Porous Pavement

Basic Description - Porous pavement is a permeable road surface made up of open grade asphalt or concrete. Below the pavement is a granular working platform and below that is a storage reservoir made of large clean stone aggregate. Run off infiltrates the pavement surface and drains to the storage reservoir before infiltrating into underlying soils. Porous pavement systems provide stormwater management systems that promote infiltration and improve water quality.

Design Considerations (**Figure 3.13**):

- The reservoir is designed as an underground detention basin based on the expected run off at the site.
- Reduce space requirements by placing detention basin under the pavement, which eliminates the need for stormwater drainage systems.
- Water table, depth to bedrock, frost depth, and permeability of native subgrade need to be accounted for.
- Excessive sanding as part of winter maintenance can clog porous pavements.
- Works best in flat terrain or very gentle slopes.

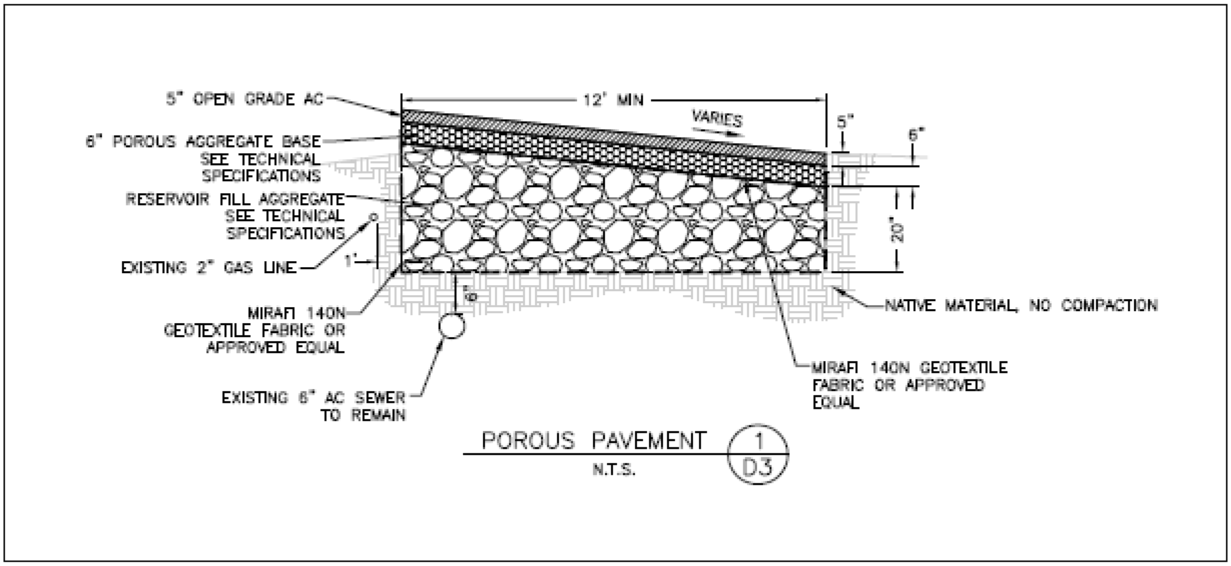


Figure 3.13 – Porous Pavement Cross Section Detail from Nichols Consulting Engineers

3.3.2 Drainage and Flooding Improvements

Infiltration Basin

Basic Description – An infiltration basin is a shallow impoundment that is designed to infiltrate stormwater. Infiltration basins use the natural filtering ability of the soil to remove pollutants in stormwater runoff. Infiltration facilities store runoff until it gradually infiltrates into the soil and eventually percolates to the water table. This practice has high pollutant removal efficiency and can also help recharge groundwater, thus helping to maintain low flows in stream systems (CASQA 2003b). Infiltration of stormwater, primarily through infiltration basins, has been used extensively in the Lake Tahoe Basin. NCE has successfully designed and constructed numerous infiltration basins on a variety of sites with a multitude of soil types.

Design Considerations (**Figure 3.14**):

- Basin design requires a thorough understanding of site soils and permeability rates.
- Drain down time for any infiltration basin must comply with local, state and federal vector control requirements. Generally drain down must occur between 48 and 96 hours depending on local climate and seasonal variability.
- Critical to site basin in locations where it can be easily accessed by maintenance personnel.
- Pretreatment is recommended to minimize clogging, maximize infiltration capacity and extend the functional life of the improvement.

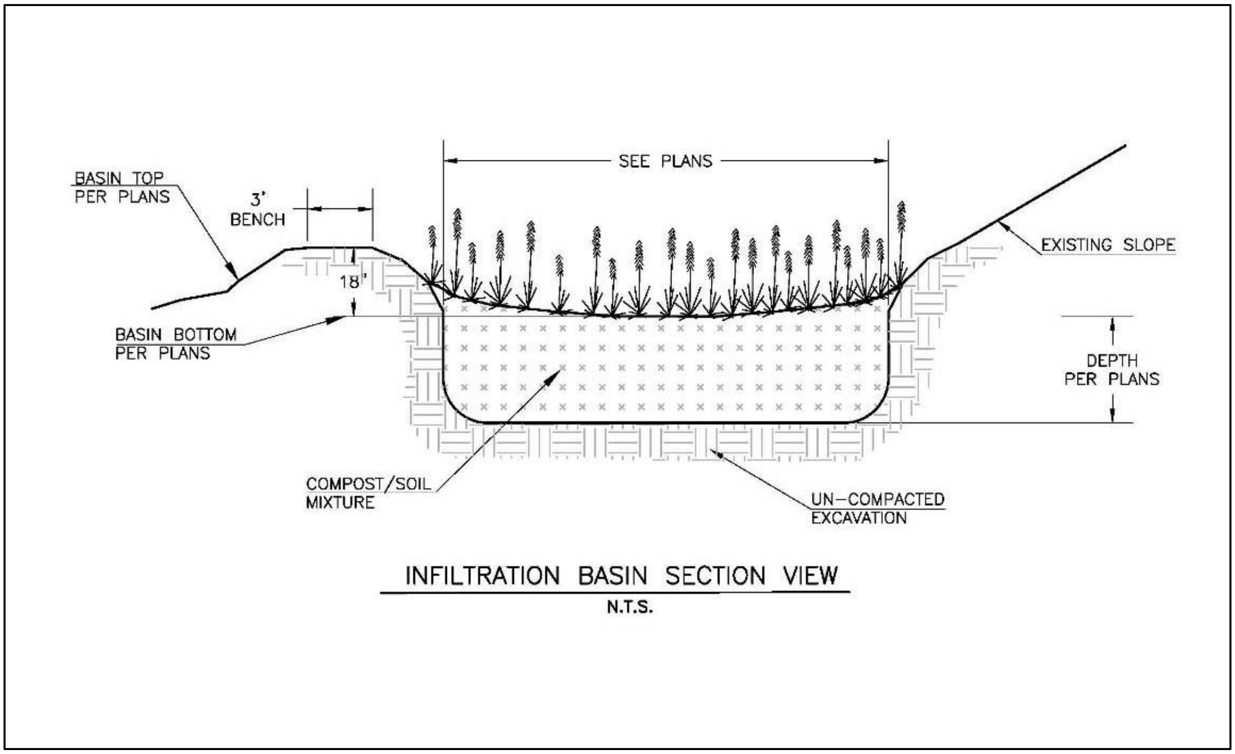


Figure 3.14 – Infiltration Basin Detail Nichols Consulting Engineers

Infiltration Trenches

Basic Description – Infiltration trenches are generally long and narrow and have no outlet. Generally they are filled with drain rock, prefabricated plastic cells or perforated pipe which provide storage (through void space) until stormwater can be infiltrated.

Design Considerations (**Figure 3.15**):

- Trench design is generally based on site hydrology, soil physical characteristics and permeability rates.
- Maintenance can be difficult and expensive, particularly when drain rock is used as the primary trench media.
- Pretreatment is recommended to minimize clogging, maximize infiltration capacity and extend the functional life of the improvement.

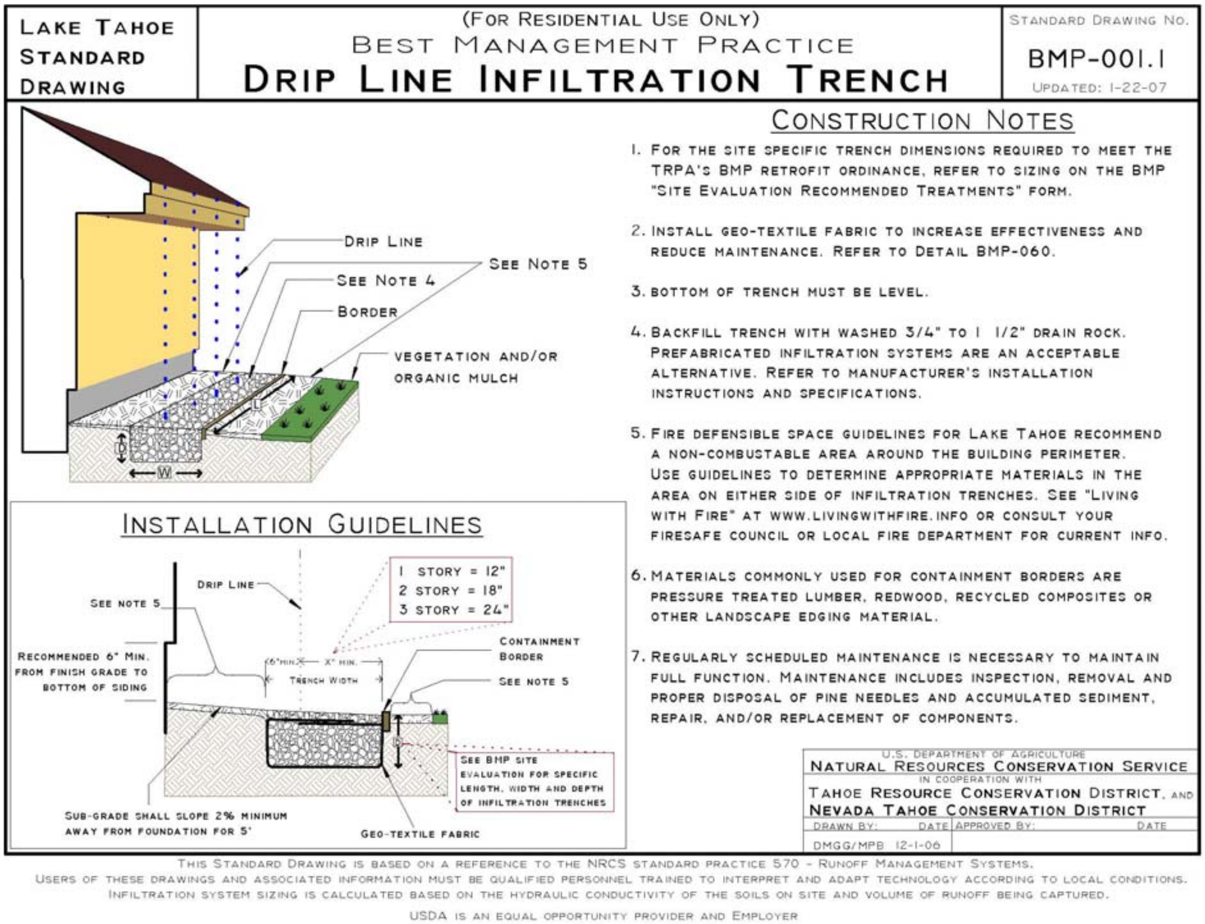


Figure 3.15 – Infiltration Trench Detail from (NRCS 2007)

Drywell

Basic Description – A drywell is a subsurface structure which captures stormwater and slowly releases it via infiltration over an extended period of time. This process reduces stormwater volumes and peak flows (lowers the peak of the hydrograph) for a design storm. Several design alternatives exist for drywells but they generally fall in to one of two categories 1) structural chambers made of concrete, corrugated metal pipe and plastic or 2) excavated pits which are filled with drain rock, riprap or prefabricated plastic cells (State of New Jersey 2004). Most drywells have open bottoms and most of the structural chamber type drywells have perforated sides to enhance infiltration capabilities.

Design Considerations (**Figure 3.16**):

- Placement of drywell must ensure stormwater will gravity flow into improvement.
- Must be sized with sufficient storage volume to prevent surcharging before water has time to infiltrate.
- Soil type, physical characteristics and permeability are critical design criteria.
- Depth to seasonally high groundwater and or impervious layers (i.e. bedrock) are critical design factors. Generally, the bottom of the drywell should be a minimum of 18 -24” above the seasonal high groundwater level.

- During construction, it is essential that grading and other equipment do not compact subgrade soils.
- Drywells are a volumetric control for stormwater and pretreatment of sediment laden water is recommended prior to discharge into the drywell.
- Pretreatment is recommended to minimize clogging, maximize infiltration capacity and extend the functional life of the improvement.

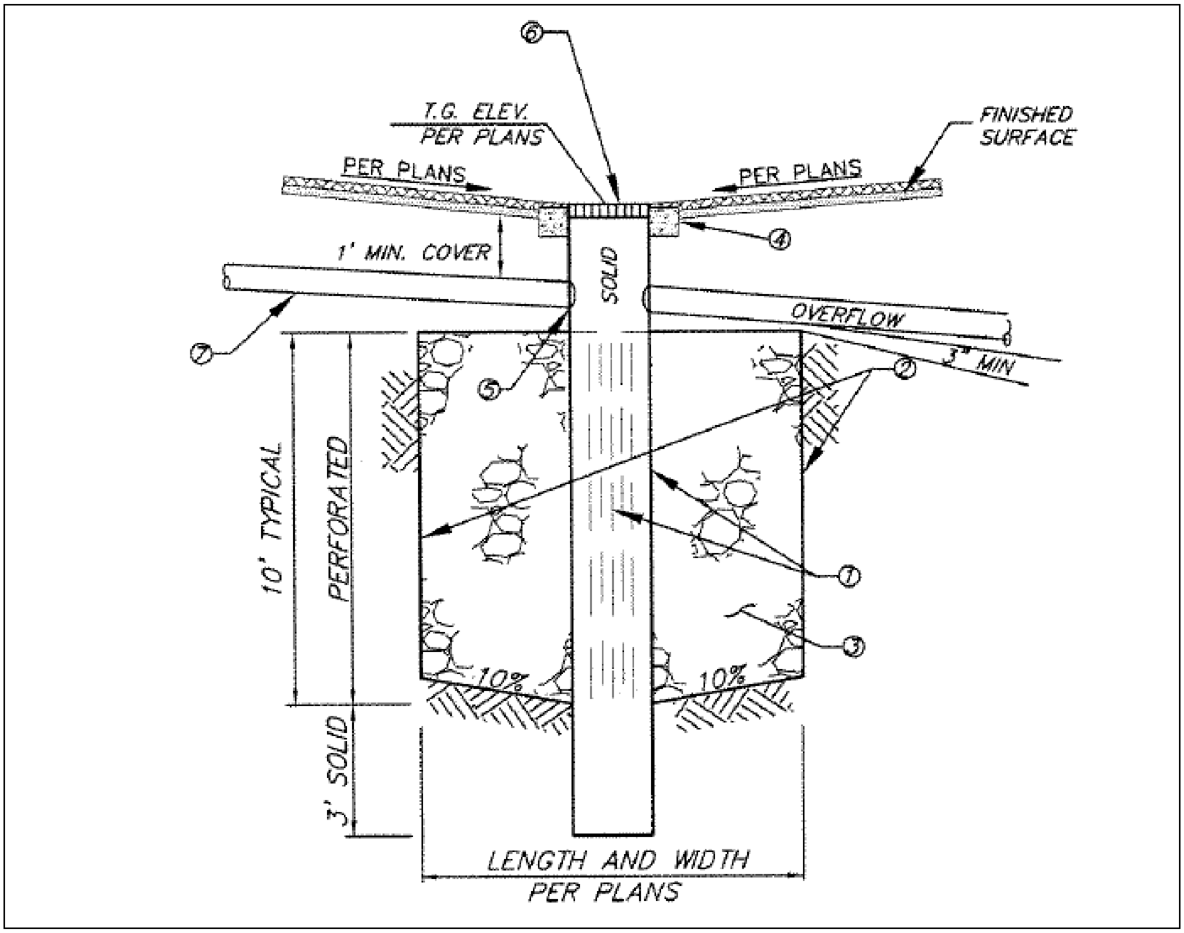


Figure 3.16 – Drywell Detail from Town of Mammoth Lakes Standard Plans 2006

Level Spreader

Basic Description – A level spreader is a BMP designed to reduce storm water velocity and encourage infiltration. In some cases, level spreaders can provide treatment of stormwater through filtration. Level spreaders are placed at the discharge point and essentially convert concentrated flow to sheet flow. They consist of a level (0% grade) berm constructed perpendicular to the stormwater flow followed by a gentle slope of varying length. The berm must be level to ensure the water is evenly discharged to the downstream receiving slope. The receiving slope must be constructed relatively flat (1:50 maximum slope) to allow the stormwater time to infiltrate and minimize the potential for surface erosion.

Design Considerations (**Figure 3.17**):

- Generally large flat areas are best for sighting level spreaders.
- Spreader depth should be no less than 6" (final height is based on design flow) and the width of spreader should generally be a minimum of 6' (Truckee Meadows 2003).
- The channel and berm must be level (0% grade) so water can be evenly dispersed across the rest of the slope.
- Soil characteristics and permeability rates must be considered.
- Typically a sediment filtration device is required upstream from the level spreader to prevent buildup of sediment at the berm.
- Spreader should only be constructed on undisturbed soil (do not construct on fill material) (NHI 2001).

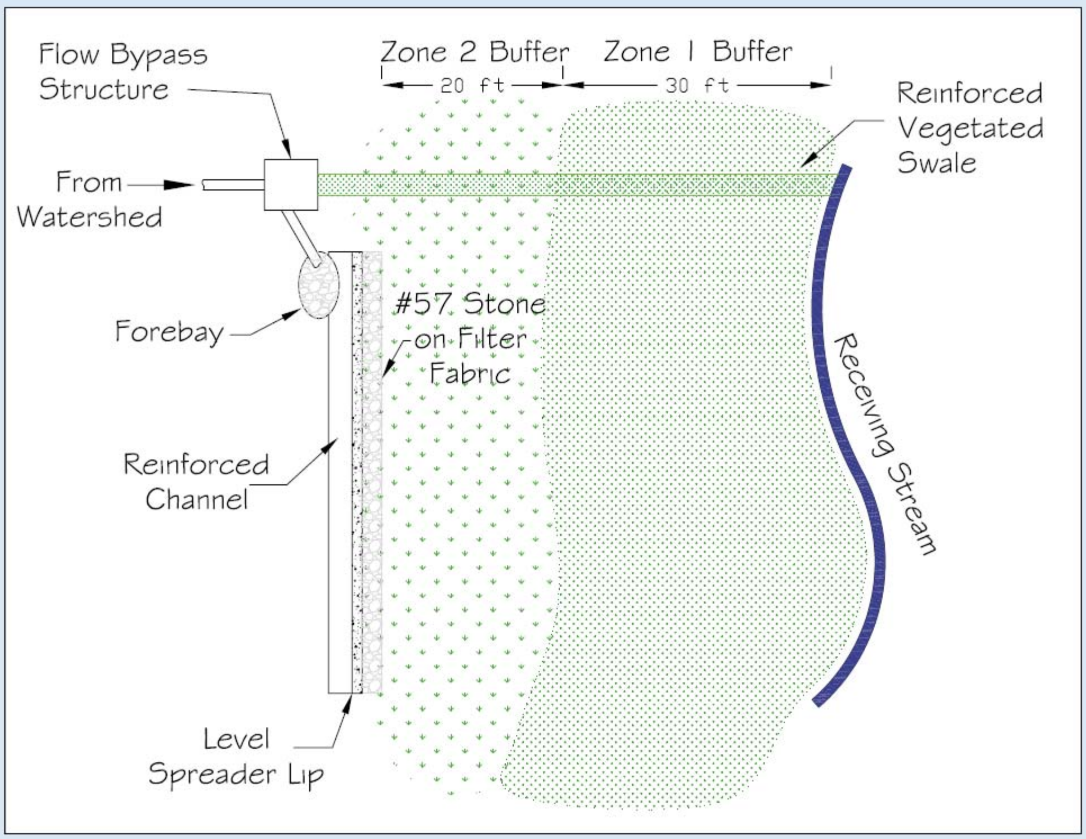


Figure 2. Level spreader system

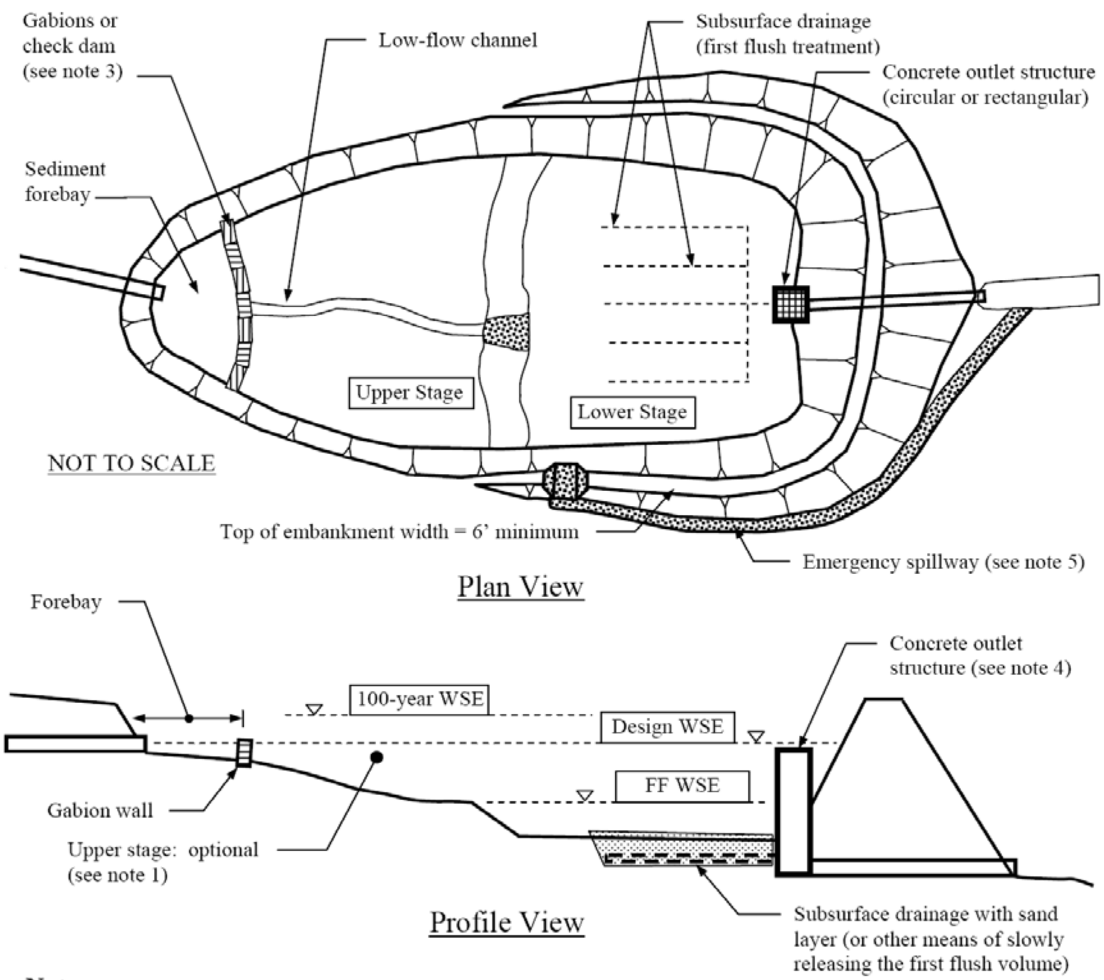
Figure 3.17 – Level Spreader Design Layout from
NC State University Cooperative Extension Urban Waterways Series Fact Sheet

<u>Detention Basin</u>

Basic Description – Detention basins are ponds or low areas with an outlet designed to hold water for a specified period of time (generally 48 to 72 hours). Detention basins are usually dry (do not have a permanent pool of water) and can be lined to eliminate the potential for infiltration.

Design Considerations **(Figure 3.18)**:

- Basin size depends on local hydrology and project specific goals.
- Drain down time for any infiltration basin must comply with local, state and federal vector control requirements. Generally, required drain down is between 48 and 96 hours depending on local climate and season.
- Critical to locate basin in an area that can be easily accessed by maintenance personnel.



Notes:

1. This example of a typical dry detention basin layout shows an upper stage which is used for stormwater detention on infrequent storms. An upper stage can also be located on the side of a dry detention basin, eliminating the need for a low-flow channel.
2. The lower stage is sized to handle the first flush volume.
3. A forebay can be constructed from gabions, rock check dams, or a separate berm with culvert. A forebay can facilitate the capture and cleanup of coarse sediments, debris and trash.
4. The outlet structure typically has orifices or weirs at computed elevations that will release the 1-year, 2-year, 5-year, 10-year and 25-year storms at the specified predevelopment peak flow rates.
5. The emergency spillway is generally constructed on natural ground or excavated areas (rather than fill soils) to reduce the potential for erosion and washout.
6. There are several types of first-flush and outlet structures available. The designer should check with the design reviewing authority before submitting novel or alternative design approaches.

Figure 3.18 – Detention Basin Detail Tennessee MS4 Working Group (http://www.franklin-gov.com/engineering/STORMWATER/ms4/detention/detention.pdf)

4.0 REFERENCES

Hogan, M. (2005). *The Sediment Source Control Handbook.* California Alpine Resort Environmental Cooperative. Prepared for the Sierra Business Council in Cooperation with the Lahontan RWQCB.

CASQA. (2003). *California Stormwater Best Management Practice Handbook: Construction.* California Stormwater Quality Association, ed., Menlo Park, CA.

CASQA. (2003b). *California Stormwater Best Management Practice Handbook: Municipal.* California Stormwater Quality Association, ed., Menlo Park, CA.

City of Reno. (2003). *The Truckee Meadows Construction Site Best Management Practices Handbook* Truckee Meadows Regional Stormwater Quality Management Program, Reno, NV.

ECTC. (2008). "Standard Terminology for Rolled Erosion Control Products." Erosion Control Technology Council (ECTC), ed. Retrieved February 2008 from http://www.ectc.org/terminology.asp.

EPA. (2008). "National Menu of Stormwater Best Management Practices," part of the National Pollutant Discharge Elimination System (NPDES) series. Environmental Protection Agency (EPA), ed., Retrieved from http://cfpub1.epa.gov/npdes/stormwater/menuofbmps/index.cfm, Last updated Jan. 2008.

NHI. (2001). *Design and Implementation of Erosion and Sediment Control,* Course Number 134054 Reference Manual. US Dept. of Transportation, Federal Highway Administration, National Highway Institute (NHI).

Nelsen, R., Chirbas, K., and Myrowich, M. (2006). "Turf Reinforcement Mattings: An EPA Recognized Storm Water Best Management Practice " Land and Water, Fort Dodge, IA. 50(14), 14.

NRCS. (2007). "Best Management Practice: Drip Line Infiltration Trench," Lake Tahoe Standard Drawing. Natural Resources Conservation Service (NRCS) in cooperation with the Tahoe Resource Conservation District and the Nevada Tahoe Conservation District, available at http://tahoercd.org/linkeddocs/SD%20Drip%20Line%20Infiltration%20Trench.pdf.

State of New Jersey. (2004). *New Jersey Stormwater Best Management Practices Manual.* New Jersey Department of Environmental Protection, Division of Watershed Management, ed., Trenton, NJ.

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February 15, 2008
Project #: A220.08.14

Mr. Ray Jarvis
Director of Public Works
Town of Mammoth Lakes
P.O. Box 1609
Mammoth Lakes, California 93546

Report
Preliminary Geotechnical Erosion Control Study for John Muir Road
Mammoth Lakes, California

Dear Mr. Jarvis:

Nichols Consulting Engineers, Chtd (NCE) is pleased to submit this preliminary geotechnical study for the slope area at the switch backs along John Muir Road. The purpose of this study is to address concerns of potential slope instability from active erosion on public land adjacent to John Muir Road.

PROJECT BACKGROUND

NCE is currently working with the Town of Mammoth Lakes (Town) to assist Town Staff with the identification of existing erosion, drainage and flood related problem areas and to develop a prioritized list of localized solutions which will allow the Town to become more proactive in the way it manages stormwater. This work follows major storm event(s) which occurred in July and August 2007 and resulted in significant stormwater runoff, erosion, and flooding within the Town. The project is also intended to supplement and enhance work previously conducted as a part of the 2005 Storm Drain Master Plan Update. We have recently published a report titled *Town of Mammoth Lakes Erosion, Drainage, and Flooding Project Existing Conditions Report*, dated December 2007.

During the course of performing field work for the Existing Conditions Report, NCE staff identified significant localized surface erosion and were concerned about slope instability near the switchback on John Muir Road. The area of concern is identified on the vicinity map (Figure 1) and the limits of the study area are shown on Figure 2. We understand that these road cuts have been in place for roughly 20 years and that frequent maintenance has been required to remove sediment and tree fall deposited on the road from erosion of these slopes. During the July 2007 storm event significant erosion occurred at the slope area of John Muir road resulting in outwash of sediment onto the road surface.

In response to NCE's concern about slope instability, the Town has authorized NCE to perform this preliminary geotechnical erosion control study to assess existing surface erosion and its impacts to slope stability in the project area. This study is based entirely on field observations of surface conditions and review of limited available geotechnical information. This report should in no way constitute the basis of design for erosion control structures and measures. NCE recommends that all site specific design be based on final geotechnical conclusions and recommendations from a geotechnical investigation which includes soil borings and laboratory testing. This study is also limited to public land within the project area and the extent to which the impacts of surface erosion from public roadways and slope stability at road cut slopes might impact private residences. This study should not be used as an assessment of slope stability or erosion at individual private properties, which if evaluated should be performed within the context of a geotechnical investigation for each property.

PURPOSE AND SCOPE OF SERVICES

The purpose of this study is to address concerns of potential slope instability from active erosion occurring on public land at the slope area along John Muir Road. In accordance with our proposal dated October 24, 2007, our scope of work to accomplish the stated purpose included the following:

Initial Research

NCE obtained and reviewed local geologic maps and geotechnical reports to assess local geology, evaluate potential for landslides and or identify historic landslides. The preliminary research built upon the information collected as part of the ongoing existing conditions report.

Field Reconnaissance and Preliminary Geotechnical Study

NCE Technical Staff conducted a one day field reconnaissance of the site, noting surficial conditions such as topography, erosion and drainage features, exposed soils and rock formations, soil and rock related distress including landslides, vegetation cover, or any other obvious geotechnical or geologic concerns. These features were located and mapped in the field as appropriate on a topographic based map and/or aerial photos.

Technical Letter

NCE prepared this technical letter report which outlines the findings of the preliminary geotechnical study and provide a summary of our general assessment of slope stability and landslide potential and if any further geotechnical investigations are warranted. The letter also identifies the impacts of the localized surface erosion on long term slope stability and present conceptual design options for addressing existing erosion.

Limitations/Exclusions

The following services may be required but are not a part of NCE's scope of work as we understand it:

1. Detailed geotechnical investigation with soil boring and or test pits to evaluate further geologic and slope stability issues.

2. Stamped design drawings for slope stabilization measures.
3. Any permits or environmental studies required of the subject area.
4. Engineering, Construction Management or Materials Testing Services in support of planned erosion control or slope mitigation measures.

METHODS OF INVESTIGATION

Review of Available Information

We reviewed readily available geotechnical reports, EIR documents, and geologic/seismic references and maps. Topographic and aerial photographs were obtained and assembled to utilize in field mapping. The following published and unpublished references were reviewed for the preparation of this report:

1. *Aerial Photographs*, by North American Mapping dated 2003.

2. *Aerial Topographic base map with two foot contour intervals,* by North American Mapping, dated August, 2000.

3. *Fault Activity Map Of California and Adjacent Areas With Locations And Ages Of Recent Volcanic Eruptions (Scale 1:750,000),* Department of Conservation, Division of Mines Geology, Geologic Data Map No. 6, Charles W. Jennings, 1994. (referred to hereafter Jennings 94).

4. *Geologic Map of the Long Valley Caldera, Mono-Inyo craters Volcanic chain, and Vicinity, Eastern California (Scale 1:62,500),* United States Geological Survey, Roy A Bailey, 1989. (Referred to hereafter Bailey 1989).

5. *Landslides from the May 25-27, 1980 Mammoth Lakes, California, Earthquake Sequence (Scale 1:62,500)*, United States Geological Survey, Map No. I-1612, Edwin L Harp, Kohei Tanaka, John Sarmiento, and David K. Keefer, 1984. (Referred to hereafter Harp 1984).

6. *Geotechnical Investigation Report, Lot 1, Timber Ridge Estates No 1, APN 31-051-01* by Sierra Geotechnical Services, dated January 8, 2007 (referred to hereafter SGS, 2007). (For residence approximately south of Davison Road and John Muir Road)

7. *Town of Mammoth Lakes Erosion, Drainage, and Flooding Project Existing Conditions Report, by Nichols Consulting Engineers, Dec, 2007* (referred to hereafter as Existing Conditions Report)

Site Reconnaissance

Our field engineer and geologist performed a site reconnaissance and field mapping. The area of interest included the steep slope area in public lands along John Muir Road from Davison Road to the top of the ridgeline above Timber Ridge Court as identified by the project limits on Figure 2. Mapping was concentrated in this area, although some slopes beyond this area were examined to get an understanding of the surrounding terrain. Mapping was completed on Nov 14, 2007. Weather was clear and cool, with no precipitation. Some snow was present within the study area but did not significantly obscure soil or rock surfaces.

Features that were noted and observed included surficial conditions such as topography, erosion, vegetative cover, drainage features, erosion surfaces, and exposed soils and rock formations. During the course of field mapping we looked for surface expressions or features that would be indicative of slope instability (landslides). These features were then located and mapped in the field on a topographic and aerial base map and are described in greater detail in the following section.

Mapping

Mapping was done utilizing the site topographic base map at 1"=50 ft scale, with 2 ft. contour intervals. The topographic base was generated for the Town of Mammoth Lakes by North American Mapping in August, 2000, for the exclusive use by the Town of Mammoth Lakes. The topography was surveyed in California State Plane zone III, North American Datum, 1983 (NAD 83) coordinates, and is tied into local control benchmarks provided by Triad Homes. In addition, aerial photos of the site were utilized for locating purposes. The site aerial photos from North American Mapping, flown in 2003, were printed and used in the field (aerials furnished by Town of Mammoth).

Mapping was completed in the traditional method of traversing slopes and terrain, and noting geologic features and contacts against landmark references. The level of accuracy using this method is approximately 10 to 20 ft., with greater accuracy in areas with fixed reference points, such as near buildings and roadways, or natural features such as ridgelines, drainages, and along roadways where there is a grade break in topographic lines. Because of vegetation and soil cover, all contacts between geologic units are approximate, and are indicated with dashed lines on the geologic map. Roads, parking areas, and building footprints are shown as impervious surfaces.

SITE CONDITIONS

Geologic Setting

The study area is located in the Sierra Nevada geologic province near the western margin of the Basin and Range geologic province. Mesozoic granitic batholiths intruded into country rock and gave form to and are the core material of the Sierra Nevada Range. A roof pendant of paleozoic metamorphic rocks composed of meta-volcanic rocks over-lies the younger granitic rocks directly to the west of the study area. In the Tertiary, these older metamorphic and granitic rocks were covered by volcanic rocks which generally originated from the east. Tertiary and Pleistocene age volcanic rocks were deposited at the site as intrusions, flows, and ash flow ash-fall deposits over the course of multiple events of volcanic eruptions. This localized volcanism formed the caldera complex that exists today. A combination of this volcanic activity as well as tectonic uplift gave rise to the Sierra Nevada mountain range that is present today. The adjacent Basin and Range geologic province was also the result of tectonic activity that resulted in roughly north-south oriented normal faults giving shape to the mountains and valleys of this area.

The volcanic deposits in the Mammoth Lakes area are primarily dacite and rhyolitic flow deposits of Pleistocene age. The bedrock is undivided andesite, dacite, flows, lahars (debris flow deposits), and volcanoclasitc sediments. During the Pleistocene, glaciation carved into the older rocks creating current landforms and deposited glacial till and outwash deposits. Recent (Quaternary) unconsolidated colluvial and alluvial sediments are being deposited along much of the site area from active weathering, erosion, and downward migration of soil and rock materials.

Seismicity and Faulting

The project site is located within a seismically active region with moderate to relatively large earthquakes associated with nearby faults. Faults in this area generally trend to the North-North West. Active faults are considered to be those that have moved during the past 11,000 years, and generally only active faults are considered in evaluating seismic risk for building construction. The more significant active faults in the region are capable of generating future moderate and relatively large earthquakes.

The May 25-27, 1980 Mammoth Lakes earthquake sequence triggered thousands of rock falls and landslides throughout the area to the south and southeast of Town; while the majority were within 10 miles of the epicenter, rock falls occurred up to 26 miles from the epicenter. Rock falls occurred predominantly on slopes greater than 40 degrees in fractured bedrock and glacial deposits with loose boulders. While the majority of rock falls and landslides occurred to the south and southeast of the study area, the closest rock falls associated with this event were approximately 1.5 miles to the south of the site.

Surface Conditions and Site Geology

Surface Conditions

The sloped area around John Muir Road that is contained within the project limits shown on Figure 2 is generally developed residential parcels on forested land with steep topography. The area slopes steeply down to the north with elevations ranging from approximately 8400 to 8700 feet above mean sea level with slopes generally ranging from about 5% to 50%. However, as John Muir Road makes switch backs up the road, there are two road cuts that are significantly steeper slopes. The first lower road cut slope (Road Cut #1, shown on Figure 2) and in the photograph below is approximately 10 to 20 feet high and ranges in slope from 40% to 60%. The slope is bounded above and below by John Muir Road.

Photograph – Road Cut #1

The second upper road (Road Cut #2), shown on Figure 2 and in the photograph below, is quite large and is approximately 20 to 25 feet high with a slope of approximately 40% near the toe and steepens to a 2-foot near vertical section at the top. Near this vertical location soil is being stabilized by the tree root zone. The closest structure upslope of this cut slope is a condominium complex which is approximately 130 feet upslope to the closest edge (northeast corner of the building). Active erosion was apparent at both slopes, especially at the second larger road cut. The Town indicates that the slope requires periodic maintenance to remove soil/rock material and fallen trees behind the K-rail at the base the slope due to slope erosion.

Photograph – Road Cut #2

The site areas around the residential properties are covered with conifer trees, shrubs, brush, boulders, and occasional bedrock outcrops. Organic soil/topsoil and forest duff was also observed and thickness varied across the site, with the thickest topsoil in areas of dense vegetation cover.

The surface drainage along John Muir Road can be predominantly characterized as sheet flow over the road surface with some redirection afforded by curbs along residences and limited catch basins. However the majority of the surface flow appears to flow off the road and down adjacent slopes into public lands and private residences at various locations. Significant flow paths or rilling observed at the time of our site visit are approximately shown on Figure 2. The forest duff appears to afford protection from surface erosion on much of the slope.

However, concentrated run-off from John Muir Road and residential properties adjacent to John Muir Road have created erosion and rilling of soils on steeper slopes and have stripped off the duff layer. As indicated on Figure 2, many of the flow paths were adjacent to homes built on these steep slopes and exhibited erosion adjacent to these structures. It was also observed that at the downhill side of many of the homes, fill appears to have been loosely pushed out from earthwork related to home construction.

Geologic Units

A geologic map is an expression of surface geologic features. Inferences about depth or thickness of units may be made based on the topography, nature of contacts, and adjacent outcrop exposures;

however, information on true thickness is best obtained using intrusive methods such as drilling and trenching.

The three main geologic units encountered at the site were volcanic bedrock, quaternary colluvium (with alluvium), and artificial fill. The extent of these units are mapped on Figure 2 and described in greater detail below

Volcanic Bedrock

Bedrock in this area is volcanic rocks of Pleistocene age and in our field mapping we encountered outcrops that were primarily porphyritic dacite. Abundant boulders of dacite and ryodacite were also observed, and it is unclear if these are concentrated boulder fields or floaters associated with shallow bedrock. The rock observed in outcrops was generally moderately hard to hard, moderately strong to strong, and showed little to moderate weathering. All rock descriptions are based on macroscopic field identification and do not have the benefit of thin-section analysis or laboratory testing. The depth to bedrock may be highly variable and vary considerably in hardness, strength, and degree of weathering, both laterally and vertically. In the SGS 2007 geotechnical report for a home in the project area, no bedrock was encountered in the test pits that were excavated for the project.

Quaternary Colluvium

Much of the site is blanketed with Colluvium that generally consists of silty sand with abundant cobbles and boulders. Colluvium is a soil formed by the outwash and downward migration of soil and rock onto slopes and at the base of slopes and for the purposes of this study also includes alluvium, as in some cases the colluvium contained alluvium. Soil is generally pale brown to pale olive brown silty sand and well-graded sand with gravel. Soils matrix was so similar across the site that soil distinctions were made and mapped based only on the size of boulders within the soil. The distinctions fall into three groups, soils with boulders less than one foot diameter, boulders one to two feet in diameter, and boulders greater than two feet in diameter. These dimensions apply to the average diameter, as the volcanic rocks tended to range from angular to sub-rounded shape. At the surface the colluvium appeared to be loose to medium dense. However at the road cuts the steeper angle of repose would indicate that the colluvium at depth may be denser. The native soils encountered in the SGS 2007 geotechnical investigation test pits were described as being loose to dense sands and silty sands with gravels, cobbles, and boulders to approximately two feet in diameter.

In addition we observed a layer of forest duff and organic topsoil blanketing the colluvium. The thickness of this material varied across the site and generally ranged from 3 to 4 inches thick in the un-developed parcels, and was less than one inch thick to non-existent in some of the developed parcels. The thickest topsoil was in areas of dense vegetation cover, while the thinnest was in open, disturbed areas.

Fill Materials

Fill soils were observed associated with road beds, parking areas, and around building footprints. The fill was often a mix of crushed rock with some native soil component. Because the fill occurs under or directly adjacent to impervious surfaces, it was not called out on the geologic map. On the downhill side of many of the homes, fill appears to have been loosely pushed out from earthwork related to home construction.

In the SGS 2007 geotechnical investigation fill soils were encountered up to 6 ft below ground surface and were generally loose, uncompacted silty sands with gravels, cobbles, boulders, debris, and roots.

OBSERVATIONS AND PRELIMINARY RECOMMENDATIONS

Slope Stability (Landslides)

Based on the readily available information and our recent site reconnaissance, we did not observe surface features that would be evidence of significant landslides or soil or rock movement in the study area. However, we base this opinion on limited geotechnical and geologic information reviewed by NCE and the surface features which were readily observed in the field. Historic landslide features may not be expressed at the surface or may be covered with colluvial soils, organic soil, forest duff, or may be obscured by manmade improvements. If greater certainty of the presence of the larger slide planes or failure surfaces is required further evaluation should be given within the context of a full geo-hazards geotechnical investigation with soil borings and laboratory testing. In addition, if the oversteepened slopes at the two road cuts along John Muir road are allowed to remain in their present state with active erosion, further deterioration will develop and slope instability may develop. Other hazards may develop and may include rock and tree fall hazards as cobbles, boulders, or trees become displaced and/or undercut from surface erosion. Instability of the first cut slope (Road Cut #1) could lead to deterioration and pavement distress to the portion of John Muir Road above this slope. Instability of the second upper road cut (Road Cut #2) could eventually impact the condominium complex, which is directly upslope.

The site is also within a seismically active region and based on the abundant number of rock and landslides that occurred during the 1980 Mammoth Lakes earthquake sequence, seismically induced landslides should also be considered. Because of the steepness of existing native slopes and road cuts, seismically induced landslides may be possible and should be further evaluated. This study did not include analysis for the potential for seismically induced landslides and would need to be evaluated within a geotechnical investigation to characterize subsurface soils and rock and develop appropriate ground motions to employ pseudo-static slope stability analyses.

NCE would recommend that surface drainage from roads and housing development be directed away from these cut slopes. In advance of the subsurface data and information from a geotechnical investigation, preliminary options that might be feasible for addressing slope stability would include slope layback to create a smaller angle of repose and/or the use of engineered retaining walls. Block retaining walls may also include the use of slope reinforcement such as tie backs or soil nails. In areas where over steepened slopes introduce potential hazards from rock or tree fall from eroded slopes, barriers should be placed to retard movement of these materials down slope. NCE would recommend that slope mitigation methods be further investigated and evaluated in the context of a geotechnical investigation during site specific design.

Surface Erosion

Active surface erosion was observed throughout the project site. The most prominent surface erosion included rill and gully erosion near the switchback on John Muir Road, which is shown on Figure 2. Surface water from John Muir road is not properly conveyed downslope. Stormwater surface flows from impervious surfaces such as road pavements become concentrated with high velocities that run down the slope removing beneficial organic soils and forest duff. In some cases active surface erosion is significantly rilling and removing the soil adjacent to existing homes, with locations of significant surface flow paths and rilling shown on Figure 2. Although not part of this study, we would recommend that Town consider further study of the active erosion adjacent to existing residential structures and potential impacts to the foundations of these structures.

NCE would again recommend that all surface flows be directed away from road cuts, slope areas, and structures or conveyed through the area in stable structures within the context of a comprehensive area wide erosion, drainage and flood control plan. In addition, existing eroded slopes next to structures should be repaired by benching and filling with engineered fill. Depending on the area repair, benching and filling with engineered fill may be less feasible based on existing constraints by residential structures, and in these cases soil nailing and/or retaining walls may need to be employed. There are numerous other potential techniques and methods which can be deployed to address surface erosion of over steepened cut and fill slopes. Below is a brief overview of these options.

1. Structural Solutions including rock slope protection, stacked rock walls, manufactured concrete block systems, retaining walls (wood, rock or block) and shotcrete

2. Non-structural solutions including soil conditioning, revegetation (may require slope layback), heavy mulch application, turf reinforced mats and erosion control blankets

More detailed descriptions of the erosion control solutions presented above will be provided in the final report for the Town of Mammoth Lakes Erosion, Drainage and Flooding Project.

ADDITIONAL GEOTECHNICAL SERVICES

The intent of this study was to assess and evaluate concerns of potential slope instability from active erosion occurring at on public land on the slope area along John Muir Road. These findings are preliminary and we recommend that we should be retained to confirm our findings within the context of a geotechnical investigation with appropriate recommendations tailored specifically to planned erosion mitigation plans and slope/wall design at the two road cuts. Under no circumstances should the information contained herein be used for design of slope repairs, erosion control measures, and/or retaining walls without undertaking a more comprehensive field and laboratory geotechnical investigation.

For consideration;

Yours very truly,
Nichols Consulting Engineers, Chtd.,

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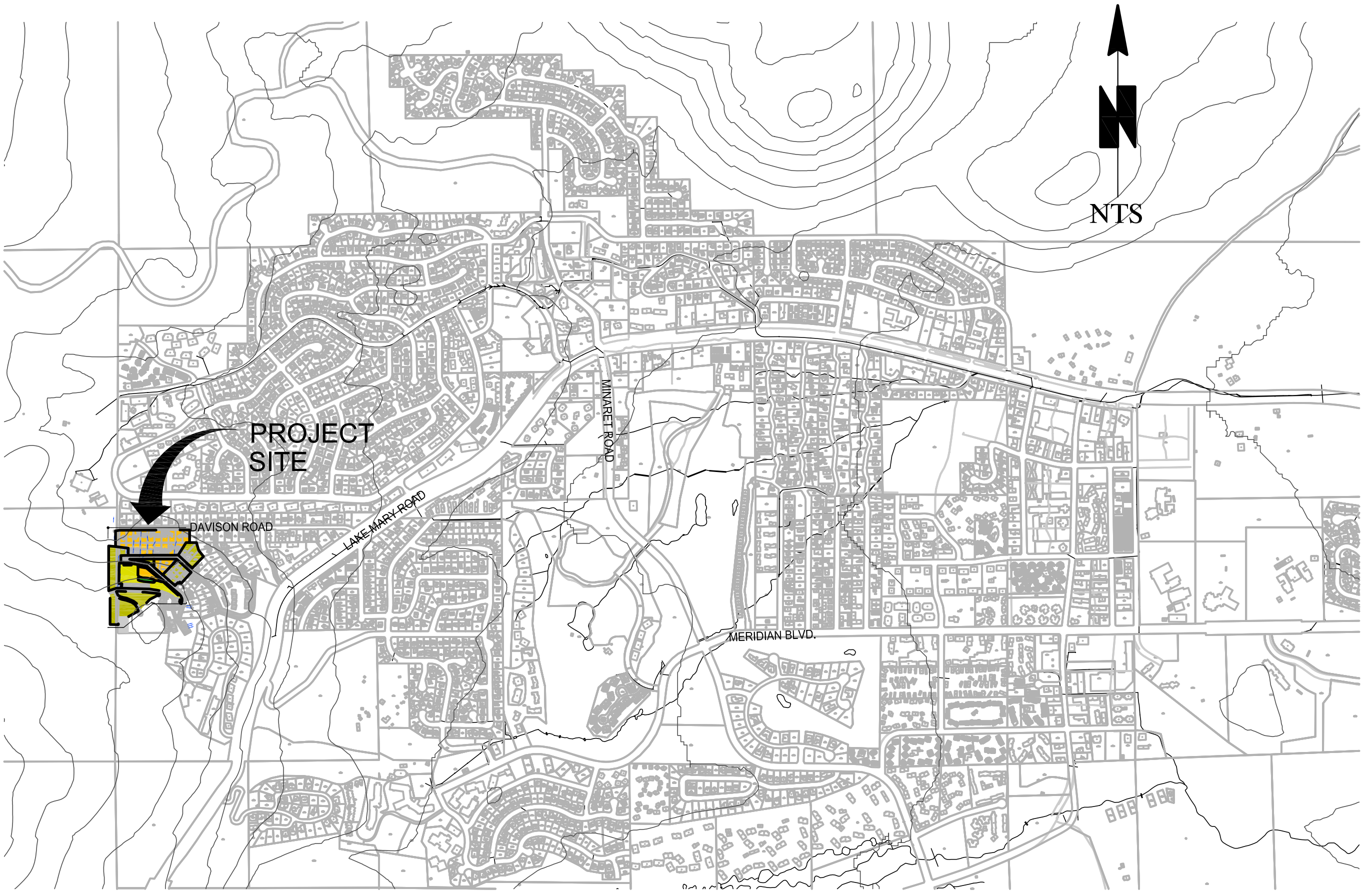
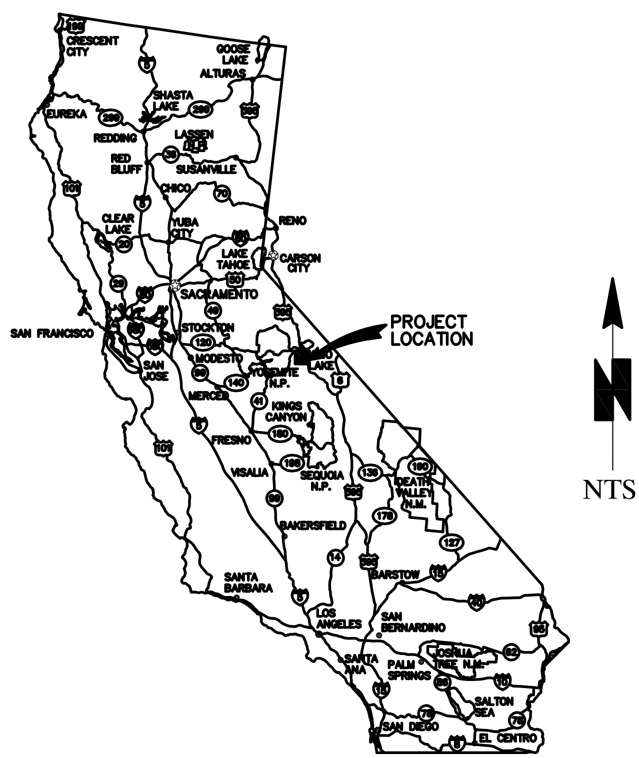
Attachments: Figure 1 – Vicinity Map
Figure 2 – Geologic Features



SITE MAP



VICINITY MAP

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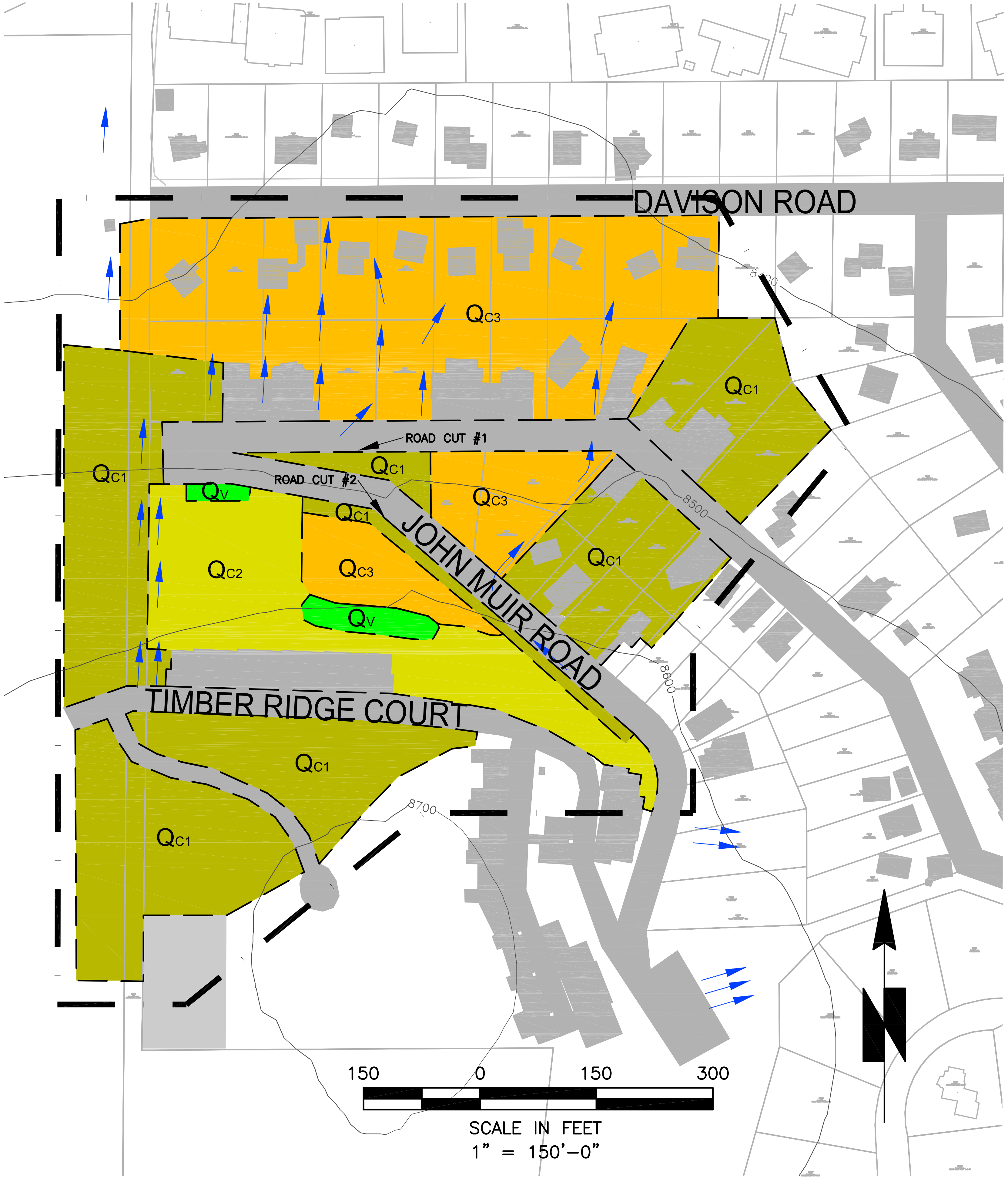
VICINITY MAP
PRELIMINARY GEOTECHNICAL EROSION STUDY FOR JOHN MUIR ROAD
TOWN OF MAMMOTH LAKES, CA

FIGURE 1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED DATE
CNH	A220.08.14		12/12/07	



LEGEND	
DEVELOPED AREA (PAVEMENTS, ROADS AND RESIDENTIAL PROPERTIES)	
Qc1: QUATERNARY COLLUVIUM (WITH ALLUVIUM). PALE OLIVE BROWN SILTY SAND WITH GRAVEL (SM) AND BOULDERS LESS THAN 1'.	Qc1
Qc2: QUATERNARY COLLUVIUM (WITH ALLUVIUM). PALE OLIVE BROWN SILTY SAND WITH GRAVEL (SM) AND BOULDERS 1'–2'.	Qc2
Qc3: QUATERNARY COLLUVIUM (WITH ALLUVIUM). PALE OLIVE BROWN SILTY SAND WITH GRAVEL (SM) AND BOULDERS GREATER THAN 2'.	Qc3
Qv: QUATERNARY VOLCANICS – UNDIVIDED DACITE, RYODACITE, AND QUARTZ LATITE (PLEISTOCENE AGE). (FROM GEOLOGIC MAP OF LONG VALLEY CALDERA, MONO–INYO CRATERS VOLCANIC CHAIN, AND VICINITY, EASTERN CALIFORNIA)	Qv
GEOLOGIC CONTACT, DASHED WHERE INFERRED	
OBSERVED SURFACE FLOW PATHWAY OR RILLING	
LIMITS OF PROJECT AREA	

NOTES:

1. AERIAL TOPOGRAPHY ARE BASED ON CALIFORNIA STATE PLANE, ZONE III NAD 83.
2. EXISTING RESIDENTIAL STRUCTURES AND PARCEL BOUNDARIES ARE BASED ON THE MAMMOTH LAKES ZONING MAP PROVIDED BY THE TOWN OF MAMMOTH LAKES.
3. BECAUSE OF VEGETATION AND SOIL COVER, ALL CONTACTS BETWEEN GEOLOGIC UNITS ARE APPROXIMATE, AND ARE INDICATED WITH DASHED LINES ON THE GEOLOGIC MAP. THE GEOLOGIC CONTACTS AND OTHER FEATURES ARE BASED ONLY ON SURFACE FEATURES AND AVAILABLE INFORMATION AND DATA AT THE TIME OF THIS STUDY, AND MAY OR MAY NOT REFLECT THE CONDITIONS AT DEPTH WHICH SHOULD BE EVALUATED BASED ON EXPLORATORY BORINGS, TEST PITS, OR OTHER METHODS WITHIN THE CONTEXT OF A GEOTECHNICAL INVESTIGATION.

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GEOLOGIC FEATURES
PRELIMINARY GEOTECHNICAL EROSION STUDY FOR JOHN MUIR ROAD
TOWN OF MAMMOTH LAKES, CA

FIGURE 2

DRAWN	JOB NUMBER	DATE	REVISED DATE
CNH	A220.08.14	12/12/07	