The INGAA Foundation, Inc.

Mitigation of Land Movement in Steep and Rugged Terrain for Pipeline Projects:

Lessons Learned from Constructing Pipelines in West Virginia

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Executive Summary

Land movement, particularly in variable, steep, and rugged terrain, can pose a threat to the integrity of a pipeline if those threats are not mitigated. The INGAA Foundation Inc. contracted Golder Associates Inc. to review mitigation efforts on pipeline alignments or rights of way (ROWs), in an effort to educate and inform those in the pipeline industry about the threats of land movement and outline practical mitigative measures.

Golder has provided geotechnical and hydrotechnical engineering and geologic hazard assessment support to pipeline companies in the Appalachian Basin and has used its experience, expertise and technical resources from previous work in the area to develop this document. Many areas in Appalachia, and particularly West Virginia, contain conditions with rugged terrain that is variable, steep, rugged, geologically diverse, and can be very wet. All of these factors can contribute to land movement that could threaten new and existing pipelines and ROW corridors. While this report specifically addresses issues found in Appalachia, the concepts outlined in this document are applicable to other areas in the U.S. and Canada with similar hydrologic, topographic and geologic conditions.

This study identifies a number of critical items when mitigating land movement on pipeline ROWs. These include:

- The importance of identifying landslide and erosion hazards, and incorporating that information into the design, planning and construction phases of a project. Mitigation efforts should be tailored to address site-specific conditions as well as to balance costs with practicality of installation, operation and mitigation of risk. Note, the identification and characterization of landslide and erosion hazards represents a science all by itself, and is not directly addressed herein. This document focuses on the mitigation efforts related to these hazards;
- The critical role of route selection in identifying and avoiding hazards that may impact pipelines and ROWs. Careful planning and routing is always preferred to avoid or minimize potential threats from landslide and erosion hazards, but mitigation is usually required when such hazards cannot be avoided;
- The need to incorporate site-specific mitigation measures into the project planning process, to address threats to the pipeline and the ROW. The cause of any given landslide or erosion hazard is commonly the result of several contributing factors. Defining the governing geologic hazard and geotechnical/hydrotechnical engineering processes that are contributing to the land movement is critical in supporting the selection, planning, and design of an effective mitigation plan. Ultimately, the owner/operator must decide on the acceptable level of risk for any given mitigation package;
- The association between land movement and surface and subsurface water in combination with changes in the local ground conditions from recent or historical changes in geologic conditions and/or construction-related activities. Examples of mitigation options that address these conditions include re-grading the ROW surface to improve site conditions, modifying local surface drainage, conveyance of sub-surface drainage, modified ROW backfill materials, deformable backfill in the pipeline trench, removal of unstable soil and replacement with engineered performance materials, ground surface erosion protection, slope breakers, trench breakers, special pipeline coatings and protective sleeve-wraps, modified ROW configurations, monitoring and special pipeline design. These options are typically used in combination to develop a strategy for addressing the identified hazards at any given site;
- Structural measures are also available to address unstable slopes, such as retaining walls, soldier piles, sheet piles, wire mesh systems, mechanically stabilized earth systems and other mechanical structures. These options can be costly, have special equipment and access requirements in order to install in steep slope conditions, may limit future access or

expansion in constrained ROW corridors, and may also have special long-term maintenance requirements;

- Reducing ground disturbance through minimized ROW footprints, appropriately sized and applicable equipment, and planning construction during optimal seasonal conditions (i.e. dry versus wet) can minimize mitigation requirements;
- Consideration of the landslide and erosion processes, and the origin of the source(s) of water relative to the constructed pipeline ROW. In particular, mitigation measure selection should consider the disturbed temporary ground surface from the initial grading of the ROW and subsequent construction work and not just the finished and restored ROW surface;
- Organizing mitigation options into a framework of Typical Scenarios and supporting Typical Details that are consistent with how the ROW is built (i.e. ridge top, planar slopes, side slope, etc.). This allows for rapid development of conceptual site-specific mitigation plans during project planning and design;
- Designing to mitigate for all or only portions of targeted threats from land movement, thereby allowing the owner/operator to decide and select the level of mitigated risk, and allowing time for the owner/operator to plan, assess and make risk-based decisions on how to best manage the asset.

The most effective mitigation strategy requires recognition of the multiple factors governing a site, and may require long-term performance monitoring before full mitigation can be achieved. In some situations, the mitigation may not be intended to provide a long-term permanent mitigation and full elimination of the hazard. Instead, the pipeline ROW is mitigated to an acceptable level of risk. As such, mitigation measures should be tailored to address the site specific and potentially variable conditions, consider the risk tolerance of the owner/operator, consider the costs and benefits of long-term and short-term solutions, and incorporate construction considerations into the planning and design efforts and integrate with the construction process.

While mitigation efforts will not prevent every landslide or all erosion hazards, comparison of mitigated versus un-mitigated cost risk suggest that a comprehensive program of proactive mitigation and implementation on a system-wide scale can significantly reduce overall risk in a pipeline system, and can provide compounding benefits over time.

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1.0 INTRODUCTION

This document was developed in coordination with Golder Associates Inc. (Golder) and the INGAA Foundation, Inc. (INGAA), for the purpose of presenting ideas and concepts for mitigation of land movement on pipeline alignments and rights-of-way (ROWs). The background and technical basis for topics outlined herein are based on Golder's experience providing geotechnical and hydrotechnical engineering and geologic hazard assessment support to Williams Ohio Valley Midstream (OVM) projects in northern West Virginia (Williams 2015). Golder also has more than three decades of experience working with clients on similar landslide and erosion hazard pipeline projects in the northwestern United States. The northern West Virginia region (see dashed box, Figure 1-1) and the surrounding Appalachian Basin have a high incidence of landslides, as mapped by Radbruch-Hall et al. (1982), and shown by the red areas in Figure 1-1. This region is also mapped as having high landslide susceptibility (Radbruch-Hall et al. 1982). The potential high landslide incidence and susceptibility highlight the need for increased awareness of landslide hazards in the design, planning and construction of pipelines in West Virginia.

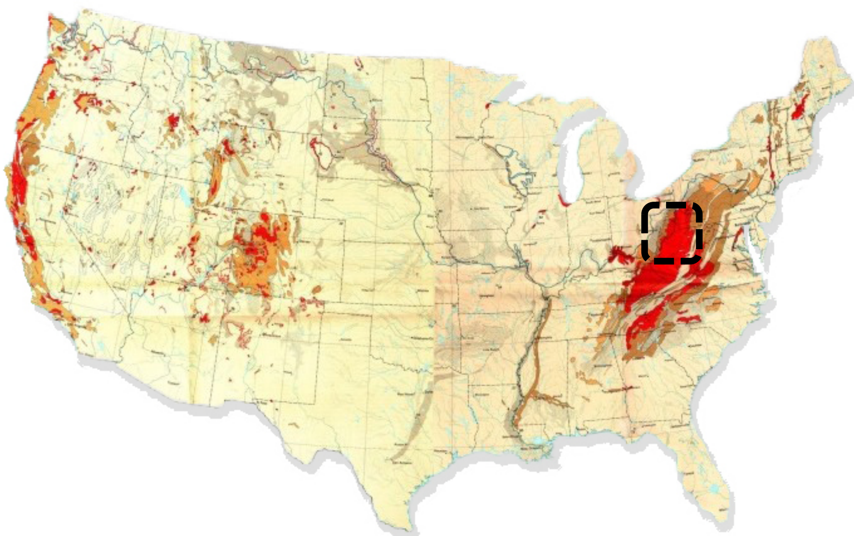

Figure 1-1: Landslide Incidence and susceptibility across the US (Radbruch-Hall, et al., 1982, USGS Professional Paper 1183)

The unique conditions in West Virginia include mountainous terrain that is variable, steep, rugged, geologically diverse, and can be very wet. All of these conditions contribute to land movement that could threaten new and existing pipelines and ROW corridors. The specific natural conditions observed in West Virginia provide the basis for development of mitigation efforts associated with land movement. Specifically, observed topographic conditions were used to define typical pipeline construction-related scenarios (i.e. ridge top, planar slopes, side slope, etc.) and corresponding typical mitigation measures for land movement. These construction scenarios can be used during the project design and planning phases or concurrently during pipeline installation as varying conditions are encountered. These mitigation efforts can be used in other areas around the United States with similar hydrologic, topographic and geologic conditions.

1.1 Project Objective

The objective of this study is to communicate the key topics to be considered when planning and implementing mitigation of land movement (i.e. landslides and erosion related hazards) that may threaten a pipeline including:

- The importance of identifying landslide and erosion hazards, and incorporating that information into the design, planning and construction phases of a project. Note: the identification and characterization of landslide and erosion hazards represents a science all by itself, and is not directly addressed in this document. This document focuses on the subsequent mitigation efforts;
- The critical role of route selection in identifying and avoiding hazards that may impact pipelines and ROWs;
- The need to incorporate site-specific mitigation measures into the project planning process, to address threats to the pipeline and the ROW. Ultimately, the owner/operator must decide on the acceptable level of risk for any given mitigation package;
- The association between land movement and surface and subsurface water in combination with changes in the local ground conditions from recent or historical changes in geologic conditions and/or construction-related activities. Therefore, mitigation measures should be tailored to address these site specific conditions;
- Reducing ground disturbance through minimized ROW footprints, appropriately sized and applicable equipment, and planning construction during optimal seasonal conditions (i.e. dry versus wet) can minimize mitigation requirements;
- Consideration of the landslide and erosion processes, and the origin of the source(s) of water relative to the constructed pipeline ROW. In particular, mitigation measure selection should consider the disturbed temporary ground surface from the initial grading of the ROW and subsequent construction work and not just the finished and restored ROW surface;
- Organizing mitigation options into a framework of Typical Scenarios and supporting Typical Details that are consistent with how the ROW is built (i.e. ridge top, planar slopes, side slope, etc.). This allows for rapid development of conceptual site-specific mitigation plans during project planning and design; and,
- Designing to mitigate for all or only portions of targeted threats from land movement, thereby allowing the owner/operator to decide and select the level of mitigated risk, and allowing time for the owner/operator to plan, assess and make risk-based decisions on how to best manage the asset.

There are many more parts of a pipeline project that address planning, design, and construction that are not specifically addressed in this study, such as (but not limited to): geologic hazard identification and characterization, environmental assessments, permitting, land access and acquisition, detailed design of the pipeline and associated facilities, materials specifications, safety and integrity considerations. These topics are important and need to be incorporated in the overall project planning process, but are outside the scope of this study.

1.2 Structure of the Study

This study is organized into Planning and Mitigation sections. The Planning section summarizes the routing process and key topics that are incorporated into selection of the optimal pipeline alignment. While Planning is not the primary focus of this document, and more detailed information can be found in other supporting studies, it is important to describe the key planning and routing issues and how these issues transition into the development of mitigation recommendations. Therefore, planning is described in a general sense as a precursor to the mitigation section. The discussion is focused on the key pieces of information, data and concepts that help identify hazards that may result in land movement, or could potentially impact the pipeline and the ROW. Ultimately, where identified hazards cannot be avoided, the planning and routing process allows the owner/operator to determine where potential hazards exist along a given pipeline alignment and serves as the starting point to mitigate those potential hazards.

The Mitigation section of the study, the primary focus of this document, discusses practical means for addressing landslide- and erosion-related hazards commonly observed along ROW alignments in OVM. Understanding the problem and defining the processes governing the hazard(s) is paramount to selecting the most effective and fit-for-purpose mitigation response. This section describes an approach using Typical Scenarios and supporting Typical Details, which allows for organizing, selecting and communicating appropriate conceptual mitigation measures. The Mitigation section provides a background overview of mitigation concepts, and a more detailed discussion of mitigation guidelines for specified Typical Scenarios encountered along the pipeline ROW and descriptions of corresponding Typical Details (i.e. individual typical mitigation measures). Tis section also includes a discussion that covers general relative costs in terms of cost risk associated with mitigating land movement

1.3 Limitations

Recommendations outlined herein are based on experience with geologic, geotechnical and hydrotechnical conditions typical to the geology, topography and hydrology of the area in and around the Williams OVM system in West Virginia (as described in Section 2.1), and as such are primarily applicable to addressing similar hazards observed in this area. At any given site, mitigation efforts should engage technical experts with experience in addressing the identified hazards and implementing the appropriate kinds of mitigation measures. Any recommendations should include an appropriate level of site-specific investigation, characterization, technical assessment and engineering to support continued planning, design and construction efforts.

2.0 PLANNING

The planning phase of any pipeline project consists of numerous tasks, including a project needs analysis and modeling, open season (FERC projects), project justification analysis, authorization and certification through regulatory agencies, environmental reviews, corridor reviews, routing alternatives and reviews, ROW negotiation and acquisition, surveys, design of line pipe and facilities, etc. (INGAA 2013). While this study focuses on mitigation efforts (Figure 2-1), it is important to understand where mitigation fits into the overall process for addressing hazards.

The following discussion addresses the routing portion of the pipeline project planning process. Routing is a critical step in the design and planning phases. Since routing identifies the location that a proposed pipeline will traverse the landscape, this routing portion of the project should also identify and define the hazards that the pipeline may encounter, and should dictate the level of effort needed to mitigate for hazards in the design, construction and operation of the pipeline.

The basic conceptual approach to address landslide and erosion-related hazards is shown in Figure 2-1. Routing occurs during the initial steps when the hazards are identified, and subsequent characterization and assessment studies are completed to better understand how the identified hazards may impact or threaten selected pipeline alignments.

Figure 2-1: Conceptual Approach to Geologic Hazard Management

Once hazards are identified and characterized, mitigation can be developed to address the hazards. Subsequent monitoring is needed to track the performance of the selected mitigation approach. When issues with the previously installed mitigation occur (i.e. subsequent operation and maintenance activities), or new hazards develop, the process continues by identifying the new hazards and characterizing them to better understand what new or additional mitigation is needed. This process is generally implemented in phases, and can move in either direction in the process, but it is typically more efficient when the sequential steps link to each other as shown.

2.1 Understanding the Project Setting

Understanding regional and site-specific geologic settings is critical for development of landslide and erosion mitigation recommendations and plans. The area of northern West Virginia that forms the basis for this study is located in the northern un-glaciated plateau section (i.e. the low plateau) of the Appalachian Basin (WVGES 2015). The eastern and southern portions of the Appalachian Basin transition into mountains (i.e. the high plateau). Our experience working in the low plateau area indicates that there exists a high potential for landslide and erosion related hazards. On a regional scale, this area corresponds to the red areas extending across much of the Appalachian basin, and in particular across much of West Virginia shown in Figure 1-1.

The local bedrock geology in northern West Virginia is mapped as the Dunkard Group, which is characterized by non-marine cyclic sequences of alternating sedimentary units (Nicholson et al. 2007). The Dunkard Group sedimentary rock is generally flat-lying, and consists of sandstone, claystone, siltstone, mudstone, shale, limestone and coal.

The alternating sedimentary bedrock layers have varying degrees of strong and weak physical properties, which dictate the rate at which the layers weather and erode. Through geologic processes of uplift and subsequent incision through the sequenced sedimentary layers, the increased strength of the limestone and sandstone units results in steeper exposure faces versus the claystone, siltstone, shale and coal units which erode to flatter sloping exposures. As a result of the varying rates of weathering and erosion in the alternating layers, the terrain has evolved to a stepped and benched configuration (Figure 2-2). Note in Figure 2-2 the location of a constructed pipeline ROW following a local ridge-line through the stepped and benched topography.

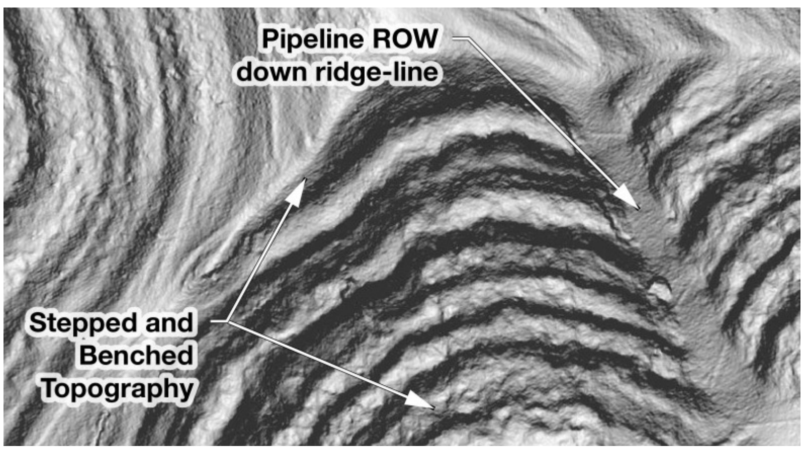

Figure 2-2: LiDAR hillshade example of stepped and benched topography in northern West Virginia [Notes: (1) Pipeline ROW following ridge down slope; (2) See discussion of LiDAR in Section 2.4; (3) Disturbed terrain along and below the benches describes landslide movement] (Williams 2015)

The benches can be well-defined where sequential sedimentary units alternate from strong to weak materials. They can also weather and erode to more consistent planar slopes where the units are less differentiated and weathering and residual soils are more prevalent, or the combination of weathering and in-filling has backfilled the benches.

Colluvium, accumulating and mantling the broader and flatter-sloped bedrock benches, along with the underlying residual soil from weathering of the sedimentary bedrock, result in ground conditions that are very sensitive and easily destabilized by saturation of soils from surface and subsurface water. The sedimentary layering of bedrock also governs groundwater flow conditions, creating generally flat or bedded horizontal pathways that tend to discharge groundwater in seeps and springs along the transitions between bedrock units. The benches can intercept and route surface flows. These surface and subsurface flow paths can be easily intercepted and changed through surface disturbance. These unique geologic conditions govern the dynamics of landslide and erosion hazards addressed in this study, and form the basis for the approach and methods of mitigation discussed herein.

2.2 Challenges of Routing in West Virginia

Routing includes the planning and decision making processes to select an alignment for a pipeline. The corresponding ROW design, planning and construction efforts incorporate a long list of variables addressing topography (with focus on variable, steep and difficult terrain), environmental resources, cultural resources, wetlands, rivers and streams, surface soils, subsurface geology, shallow bedrock, protected areas, developed areas, public properties, homes, wells, septic systems, existing ROWs, existing pipelines, roads, and surface and underground mining activities (where applicable).

In the mountains of West Virginia, the optimal routing alignments are along ridge tops and valley bottoms, which can often already be occupied with residential and commercial development, pushing pipeline corridors to more challenging alignments along sidehills and sloping terrain. This makes it difficult to find the combination of “good ground” that offers the shortest length alignment and meets the project needs. Existing infrastructure has developed to take advantage of the stability of the higher ridge top areas, which is why roads, homes and businesses are located in these areas. The rugged nature of the terrain in this region does not allow for much additional open and stable ground away from the already limited ridge top areas, which may push newer infrastructure into more challenging terrain.

From the simple perspective of project length, pipeline alignments in areas prone to land movement may be doubled or tripled to avoid identified hazards, or an alternate alignment may actually encounter more hazards by trying to avoid or traverse around a single targeted hazard. Because all hazards cannot be avoided and because the planning process must weigh the costs of longer alignments to avoid hazards versus cost of mitigation of the hazard, decisions are frequently made to mitigate a hazard in the design, construction or operational phases of a project.

2.3 Routing – An Art and a Science

The general approach to routing a pipeline includes: collecting available data, completing a desk-top assessment, ground verification of the preferred and alternative alignments, collecting more data (as needed) and going through the final assessments and reviews to determine the final alignment. It is difficult to generalize the routing conditions that apply to any given pipeline project, because every project is unique, having its own site-specific conditions. As such, routing a pipeline should be considered as much an art as a science, based on expertise of local conditions. Project planners should recognize that a standard approach to route all pipelines does not exist and that some level of project-specific planning is needed to fit the project needs (ASCE 1965). However, some qualitative guidelines, skills, experience, and expertise that may apply include the following:

- Sufficient knowledge to understand the engineering planning that supports the proposed project;
- Ability to work with planners to develop alternative routing alignments;
- Knowledge of pipeline design and construction practices;
- Understanding what is needed to maintain a pipeline over the operational lifespan;
- Understanding and knowledge of the environment and use of subject-matter-experts (SMEs) that work in specific environmental fields;
- Ability to consider input and advice from geologists, geotechnical and hydrotechnical engineers, and environmental SMEs;
- Awareness of local issues and concerns in the proposed pipeline route area(s);
- Knowledge of the rules, regulation and laws in the project area(s);
- Awareness of the political, landowner and regulatory stakeholder issues along the proposed pipeline route that may influence alignment;

- Skills, expertise and experience to explain the proposed route to stakeholders, in both official or informal communications, and the ability to consider criticism of proposals and develop reasonable alternatives; and,
- Detailed preparations and technical support efforts that will help develop the basis for routing decisions, making it possible to discuss and defend such decisions.

2.3.1 Initial Routing Considerations

The pipeline corridor selection depends on supply locations and delivery markets, with an end goal of finding the most economical route that balances regulatory, environmental, engineering and operational requirements (INGAA 2013). Routing may use existing pipeline corridors, which in some situations may have already taken the best route location. In some cases, even short offsets of tens or hundreds of feet can make the difference between a good or bad route. These kinds of micro-routing adjustments can address targeted sites, but may not address regional conditions that have persistent landslide or erosion hazards.

Where broader, more prevalent landslide and erosion hazard conditions exist in combination with sensitive environmental resources and topographic features such as large rivers, lakes, mountain ranges, manmade structures, populated areas, and existing infrastructure, the options for routing are much more limited and challenging. Localized site-specific land owner input and requirements for access across properties can further add limitations that push alignments into less than desirable routing scenarios. Where the pipeline and the ROW intersect landslide and erosion hazards, and other routing inputs do not allow for avoiding the hazards, mitigation may be needed.

2.4 Conceptual Routing Approach

Any routing study includes some aspect of the following basic steps:

- Preliminary Route identification relative to possible hazards, and review of option(s);
- Desktop assessment and review of routing option(s) and corresponding hazards;
- Field reconnaissance of routing option(s);
- Selection/evaluation of route(s) (note that review and assessment of options may include risk-based methods); and,
- Design and planning of targeted mitigation measures to address identified hazards (addressed in subsequent sections of this study).

The simplest approach to route a pipeline is to locate the alignment on ridge tops, or in flat valley bottom areas, or when going between these two areas to traverse straight down planar valley slopes. Landslide and ROW surface erosion hazards associated with land movement are not typically located along ridge tops or in flat valley bottom areas, although valley bottom areas can have other types of hazards, most notably stream and river crossings and associated bank erosion and lateral channel migration hazards. Landslide and erosion hazards are more commonly found, or created, on steep slopes and where the proposed alignment intersects existing landslide and erosion hazards in planar, oblique alignment and side-hill conditions. While disturbance of the ground and construction of the ROW can trigger landslides, reactivate existing native landslides, or result in erosion, the failure to mitigate for potential instability in steep and rugged terrain can result in failure of construction backfill and ROW restoration efforts. Careful planning to identify these at-risk areas in the project planning phase or during construction is needed, and where the risk of land movement is high enough, targeted mitigation should be employed to address identified hazards.

The routing process should include the identification and review of potential hazards along proposed corridor or alignments, as well as consider the logistics for constructing the pipeline in the types of terrain and conditions encountered along the selected or alternate route(s). In particular, the feasibility of a given route relies heavily on the ability to construct the pipeline in a safe, economical and practical manner. To accomplish this, a certain amount of temporary ROW is needed to support construction, particularly in challenging terrain scenarios mentioned above (i.e. oblique and sidehill conditions), and then a corresponding permanent ROW is needed to maintain pipeline access. Routing review for proposed or alternate alignments needs to consider the construction feasibility relative to the required temporary and permanent ROW width when making decisions on route placement. The constructed ROW and methods used to build the ROW directly affect the stability of the disturbed ROW footprint and subsequent restoration work, and directly impact the potential for land movement.

Typical routing efforts start with desktop work using publicly available data and information, and are supplemented with ground reconnaissance and helicopter or fixed-wing reconnaissance of possible routes. Subsequent site surveys, or other more detailed site investigations or mapping efforts, are conducted as route options are pushed through the review process.

A generalized routing process can be organized into a series of logical decision steps designed to fit the purpose of any project. An example of a routing decision process flowchart developed by Williams is shown in Figure 2-3. The Williams process is designed to incorporate available relevant information, assess conditions, and identify possible impacts and hazards to the pipeline and ROW, to provide for iterative reviews and development of alternatives. A brief summary of the process is outlined below.

The following provides a summary of the conceptual routing approach steps from Figure 2-3:

- After the project kick-off, the initial step in the process is to develop desk-top reviews and feasibility studies for preferred and alternate routes. The feasibility studies may include geologic hazard assessments using specialized mapping and data sets that highlight landslide, subsidence, erosion, or other applicable hazards, and thereby support evaluation of multiple routing alternatives to allow selection of the optimal available option;
- Once a corridor and/or applicable options have been identified, preliminary permission for access to possible route alignments is secured to review, survey and assess conditions on the ground. Studies at targeted sites may be needed, including environmental, geotechnical or hydrotechnical engineering, or geologic assessments and investigations to assess site-specific conditions, and to consider constructability. This series of steps is typically an iterative process, that incorporates technical and environmental assessments with ground-based reviews of the proposed alignment to work out special planning considerations and support continued project planning, design, permitting and construction efforts. As ground conditions are better understood, site-specific field evaluations can be completed and re-route assessments considered. Any review of options on the ground requires continued coordination for land access and authorizations from property owners along the primary or alternate alignments;
- When routing modifications are needed, the process must reconsider feasibility, and may require additional studies and land access and coordination with technical experts and with land owners to further vet a re-route option(s);
- Once a route is approved, the operator then conducts more detailed civil surveys, completes environmental surveys, finalizes maps and alignment sheets, completes easements and completes detailed “on the ground” inspection of the full alignment;
- A final design review is completed after the final project alignment is established. Any issues with the route that may impact final approval can iterate back through the route modification process; and,
- After completing the final route review, and no additional routing modifications are needed, then the route is finalized and issued for construction.

This example of the routing process is intended to provide ideas and a framework for the general components of an applicable approach, and recognizes the details and specific steps would still need to be developed for any given project. The routing approach for each project should be developed to best fit the purpose of that project, include input and consultation from the project team, in particular getting input from the regulatory and environmental SMEs on the project, to address the anticipated regulatory planning and review.

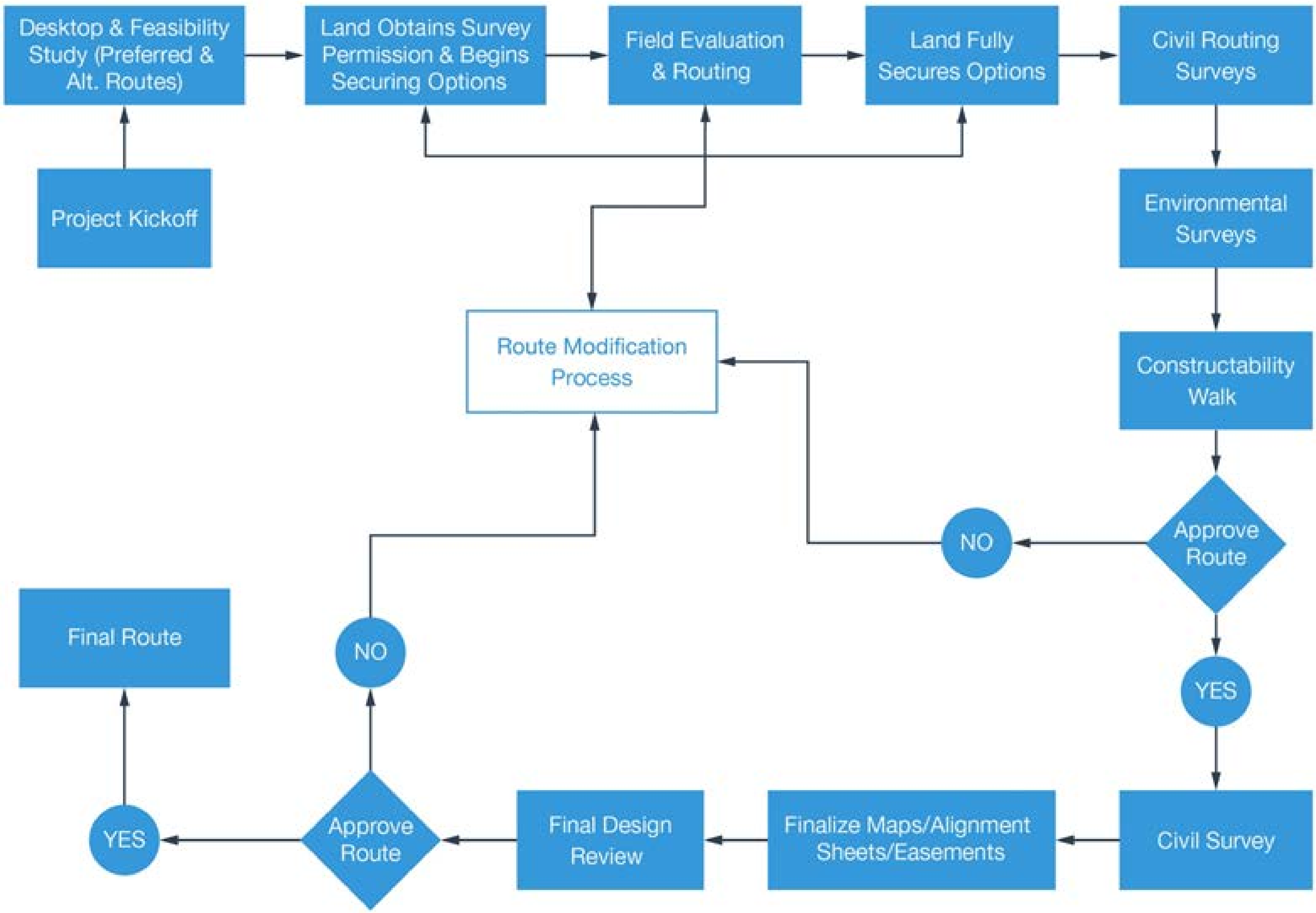

Figure 2-3: Conceptual Williams Project Planning and Routing Approach (Williams 2015)

2.5 New Tools for Routing and Monitoring

Routing traditionally relies on experienced SMEs who can assess ground conditions. Their work is supported by walking, driving, or airborne reconnaissance work, and review of publicly available topographic maps, geologic mapping resources, and remote sensing imagery to assess alignment options. Some new tools have been incorporated into pipeline routing studies in recent years, including airborne light detection and ranging (LiDAR) mapping techniques. LiDAR and satellite-based interferometric synthetic aperture radar (InSAR) have been used in some applications for monitoring. This study is not intended to provide a detailed discussion of LiDAR and InSAR technologies, only to provide a high-level overview of these new tools. The following sections provide only brief summaries of these topics.

2.5.1 LiDAR

Airborne LiDAR is an active laser scanning system that measures the time of flight of an emitted laser signal returned from a target, and uses it to determine elevations and to develop digital elevation models (DEMs) of the ground surface (Fugro 2011, ESRI 1995-2013). Airborne LiDAR systems can be used to acquire three-dimensional data characterizing landform elevations along defined corridors or mapping areas (Figure 2-4). This has obvious advantages for mapping ground conditions along pipeline alignments, by allowing remote acquisition of detailed ground conditions to support project design, planning and construction efforts.

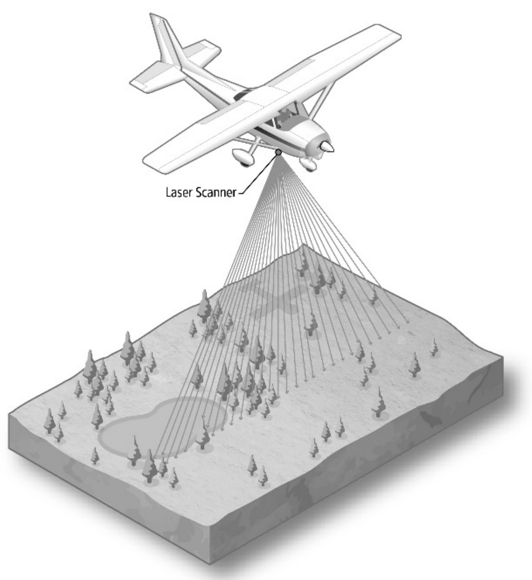

Figure 2-4: Airborne LiDAR data collection system schematic (Williams 2015)

LiDAR works by emitting multiple laser pulses over the same area, such that some pulses are reflected off intermediate surfaces (i.e. variable height vegetation, buildings, power lines, etc.) and some of the pulses find the underlying ground surface (Figure 2-5). The resulting data can be processed to differentiate the "returns," and classify data that represent the ground surface. The resulting "bare Earth model" can show detailed topographic and geomorphic landforms that can be used to look for potentially hazardous landslide and erosion related processes, as well as support the continued engineering assessment and development of mitigation plans to address threats. This is especially useful for identifying and assessing potential geologic hazards, because LiDAR can detect the subtle ground morphologies that define natural and human-triggered landslide and erosion hazards (i.e. scarps, settlement, hummocky terrain, depletion zones, accumulation zones, sag ponds, disrupted drainage, etc.).

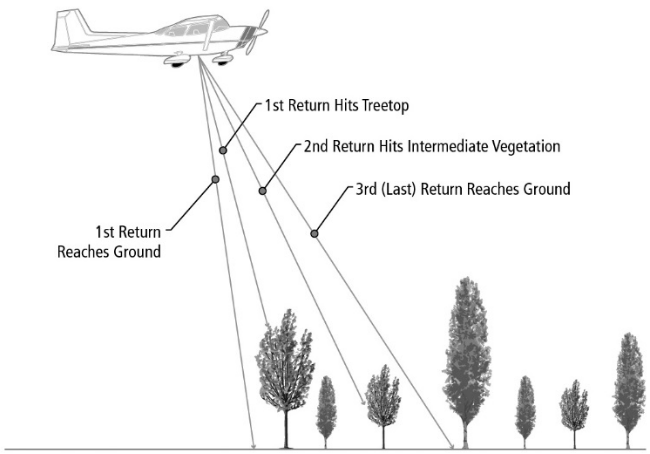

Figure 2-5: Multiple Returns from LiDAR Laser Pulses (Williams 2015)

The planning and design for the specification of LiDAR mapping data acquisition is critical. In particular, the acquisition of LiDAR mapping laser pulses can be blocked, diffused, or degraded in dense vegetation and/or rugged terrain. The specification for LiDAR mapping typically incorporates the following types of parameters (Watershed Sciences 2010, USGS et al. 2008):

- Laser Pulse Rate;
- Returns per Pulse;
- On-ground Laser Beam Diameters;
- Scan Angle;
- Aircraft Altitude;
- Aircraft Speed;
- Ground Swath Width;
- Swath Overlap;
- Aggregate Pulse Density (i.e. “points per m^2”, or ppsm);
- Flight Line Direction;
- GPS Bare-line Length;
- GPS PDOP; and
- Survey Conditions.

LiDAR data acquisition should consider “leaf-on” versus “leaf-off” conditions in areas where deciduous trees can dramatically change the effective and available “view” of the ground from the perspective of the data acquisition platform (i.e. fixed wing or helicopter aircraft). The preferable season for data acquisition is during leaf-off conditions, which can be a narrow window in late winter or early spring with no snow covering the ground. This is also a good time to capture the effects of winter-time landslide and erosion processes. Other seasons for LiDAR data acquisition can be fall through early winter after the leaves have fallen off the trees, the low-lying bushes and grass are thinned out or dead, and no snow cover exists. In times of no snow cover, data acquisition can continue through the winter months into spring until leaves start to come in and the bushes and grasses grow, creating a dense ground cover. The actual leaf-off period depends on the site and geographic region. LiDAR specifications can be relaxed during leaf-off, because there is better access for laser pulses to reflect from the ground surface.

LiDAR technology is changing rapidly, resulting in improvements in both hardware and software associated with data acquisition and processing. The final specification for a LiDAR mapping data acquisition mission typically incorporates some, or all of the parameters listed above, and should be planned in coordination with an experienced mapping professional to best fit the seasonal conditions and mapping requirements of the project area. A common parameter used to provide planning level guidance to project team members and mapping contractors is the "aggregate Pulse Density," which is often referred to as the "points per square meter" (ppsm). Typical points ppsm parameters are listed as follows:

- Open country with low-level and sparse brush or ground cover: ~2-4 ppsm;
- Leaf-on rolling moderate terrain in light trees and brush: ~8-10+ ppsm;
- Leaf-off rugged terrain in trees and bush: ~10-15 ppsm; and,
- Leaf-on rugged terrain in trees and bush: ~15-20 ppsm.

The processing of LiDAR data is typically completed by specialty mapping contractors for defined dataset specifications, to develop the bare Earth DEM data that strips away vegetation and provides a view of the underlying ground. This data can be further processed to support routing and other project related work.

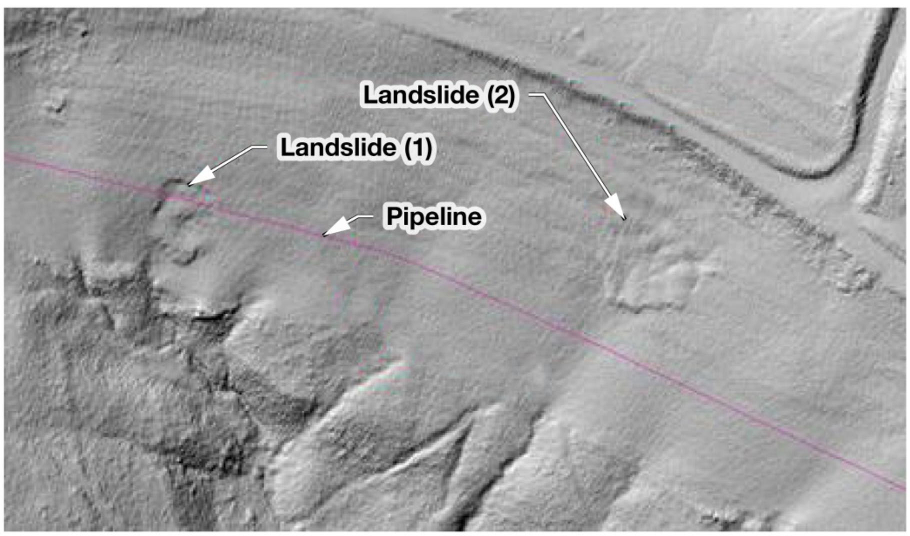

Figure 2-6: Example of LiDAR hillshade data presentation highlighting landslides across and adjacent to a pipeline alignment (Williams 2015)

LiDAR data allow for desk-top review of proposed routes, or existing ROWs, to identify possible landslide and erosion hazards. Figure 2-6 shows an example using "hillshade" views derived from LiDAR DEM data to review a pipeline alignment for possible landslide hazards. In Figure 2-6, landslide (1) crosses the pipeline alignment and would be reviewed for an increased potential threat to the existing pipeline, or in the case of a proposed alignment, this hazard would be considered for mitigation measures. Landslide (2), located away from the pipeline alignment, may have a lower threat potential and therefore not require further studies or mitigation.

LiDAR data can also be used for periodic monitoring of landslide and erosion hazards on existing pipeline ROWs (i.e. post construction). Such repeated LiDAR monitoring can be used in programs to compare and identify areas where there are differences in the elevations, which could correspond with possible land movement, landslides, erosion areas, or subsidence areas, creating a tool in which new hazards can be delineated and previously identified hazards can be monitored. In this case, sequential resultant data can be configured as a "heat map," whereby changes in ground elevations are highlighted to depict possible landslide, erosion or subsidence activity (Williams 2015). These areas of movement would then need to be reviewed and field-verified to confirm the actual conditions and governing reasons for the topographic changes.

An example of this tool is illustrated in Figures 2-7 through 2-9. Figure 2-7 shows an example of a LiDAR-derived hillshade view of a site where a valve set is located along a recently constructed pipeline alignment (i.e. before land movement). Figure 2-8 shows the same location approximately one year later, clearly showing land movement (in the dashed box) along the outside slope of the constructed pad (i.e. post land movement). Figure 2-9 shows an example of a “heat map” depicting the difference in ground elevations resulting from the failure of the pad embankment.

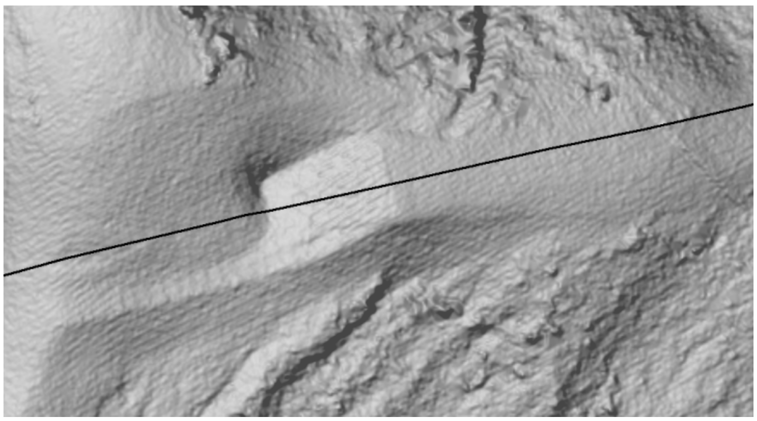

Figure 2-7: Example of Pre-movement LiDAR derived hillshade (Williams 2015)

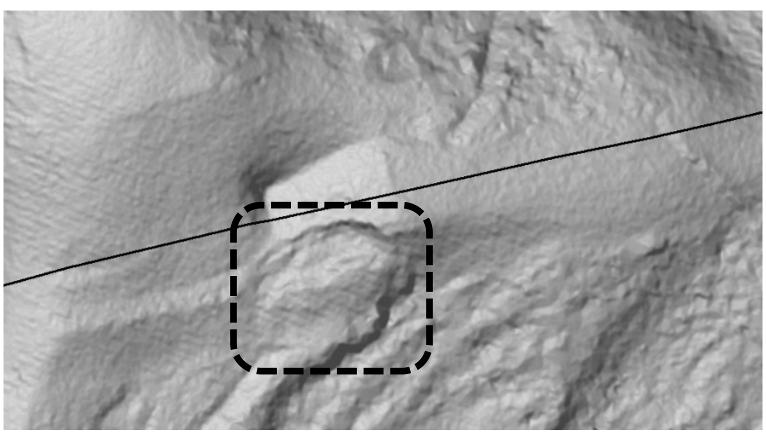

Figure 2-8: Example of Post-movement LiDAR derived hillshade (Williams 2015)

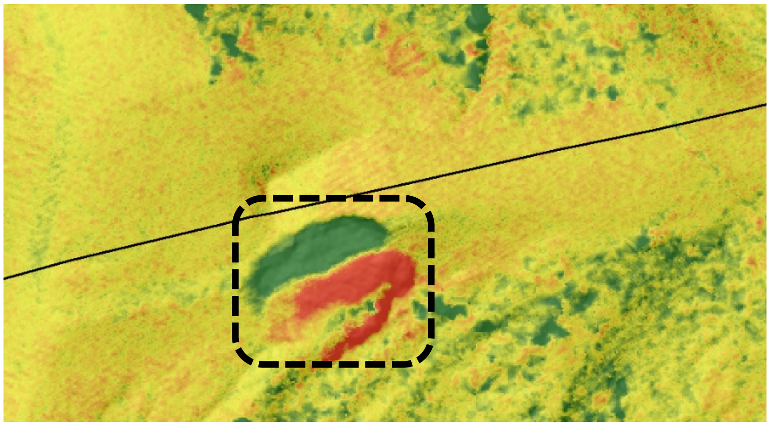

Figure 2-9: Example of “heat-map” showing comparison of successive data sets (Williams 2015)

The heat map is developed by comparing successive LiDAR mapping data sets. It shows the upslope depletion zone as the green shaded area (loss of elevation), and the downslope depositional zone as the red shaded area (gain of elevation). Acquisition of successive datasets, combined with review of compiled heat map results, allows for rapid monitoring assessment of possible land movement in a pipeline system.

2.5.2 InSAR

InSAR is a form of side-looking radar that uses a moving platform, typically satellite-based, to look at an angle toward the ground, perpendicular to its direction of travel (PRCI 2009). The phase of the returned signal is measured and used to estimate ground elevation. Comparison of successive datasets allows for identification of ground deformation. Datasets are generated by regularly scheduled satellite passes at approximate monthly timescales, such that data for a given site can be requested, where available, from historical archives. Typical applications of InSAR are focused on ground deformations resulting from earthquakes, volcanoes and large-scale subsidence (PRCI 2009). It is not generally used as a tool for looking at routing or land movement or other related hazards for pipeline alignments.

There are several factors that can affect the suitability of using InSAR data for a given site. When the moisture content and/or height of vegetation changes between datasets, this change can be detected as ground movement. Polar orbiting satellites collecting InSAR data have a “look direction” that is generally east or west, making them more sensitive to identifying movement along slopes facing the same direction, and less sensitive to slopes facing north and south. Steep slopes may also be difficult to monitor using InSAR due to layover, foreshortening, and shadow effects related to the satellite incidence angle (PRCI 2009). The use of corner reflectors (~1 meter orthogonal metal structures set on immobile foundations) can help in addressing some of these issues, but requires placement of a structure at targeted locations.

Depending on the site conditions and intent for use of the data relative to a given project, InSAR may be more applicable as a historical monitoring tool for tracking possible ground elevation changes where the data limitations fit the site conditions, rather than a tool for supporting routing assessments for new projects. The suitability of InSAR should be reviewed on a case-by-case basis, to best determine the suitability and feasibility for any given project application.

2.6 Typical Land Movement Processes

The typical landslide- and erosion-related land movement observed in the Williams OVM system in West Virginia include rock fall (typically from bench edges), ROW backfill “blowouts” (typically resulting from excessive groundwater seepage resulting in saturation of soils in the pipeline trench or within the restored ROW fills along sloped terrain), rotational and translational slides, debris flows, and slope soil creep. Shallow translational landslides appear to be the most common, and are often described by local residents as “slips” because of the locally, self-described nature of the observed ground deformations. While this represents local terminology, the correct technical description is as the applicable technically defined landslide or erosion process.

Landslide hazards typically pose a greater threat to pipeline integrity, because the nature and magnitude of ground movement may impose differential loading on the pipeline(s) that can exceed pipe strength capacity. Slope erosion hazards typically have a lower potential for integrity threat to pipeline(s), but often have an increased potential environmental impact (e.g. sediment delivery to water bodies), and increased potential for pipe corrosion or mechanical coating damage.

Native landslide or erosion hazards are common in the terrain and ground conditions throughout the OVM system and can exist prior to pipeline construction. They can be triggered or exacerbated through construction activities and related disturbance. Native landslide or erosion hazards, or hazards that result from failed backfill or other construction-related disturbance, can be activated or accelerated by:

- Constructing the ROW through a landslide which can leave portions of the landslide up- or downslope of the ROW;
- Excavating through the toe of a landslide;
- Placing soil surcharge (i.e. temporary or permanent spoil piles) on the landslide causing it to re-activate; or
- Changing the surface or near-surface hydrologic conditions at the site that can impact landslides on the ROW, or in areas away from the ROW.

The following descriptions provide a general overview and conceptual schematics and descriptions for the various common landslide types and processes, recognizing that correctly characterizing the mode of land movement is critical to define the corresponding relevant mitigation options. Landslide and erosion hazards observed in northern West Virginia are not limited to steep sloping terrain, but can also occur in lower sloping ground depending on the level of ground disturbance, occurrence of surface- and groundwater, local soil conditions, etc. Site-specific assessments are typically needed, with input from SME's, to confirm site geologic, geotechnical, and hydrotechnical conditions.

Rock falls, rock slides and rock block failures (Figure 2-10) typically occur where stronger bedrock units transition to weaker or weathered units and become undercut. Rock falls and slides are also commonly controlled by failure planes (e.g., joints, faults) within the rock mass. Slopes where bedrock failures occur are typically high-angle.

Figure 2-10: Example Rock Slide (USGS 2004)

Rotational landslides (Figure 2-11) have the traditional arc-shaped failure surface that typically intersects through residual soils on flatter benched weaker bedrock units. Slopes where failures occur can range from low- to high-angle, where benches have become overloaded with colluvium, through placement of excess spoils; or in areas where higher slopes are created by deeply-incised erosion processes, such as at large rivers and streams that have cut deeper, and have steeper valley geometries. They tend to be deep-seated, and in the context of this study, they are considered shallow where they occur above the buried pipeline and deep-seated where they engage or extend below the pipeline.

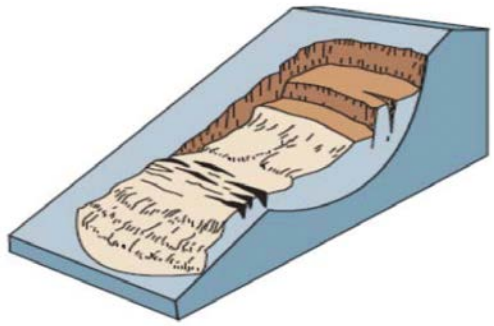

Figure 2-11: Example Rotational Landslide (USGS 2004)

The majority of land movement observed in northern West Virginia involve shallow translational landslides (Figure 2-12) that occur where native landslides are intercepted by disturbance through construction of the ROW, or from failure of the ROW backfill materials. Slopes where translational failures occur can range from low- to high-angle. These translational slides are typically limited to the depth of the backfill, or depth of residual soil in flatter-sloping and benched conditions. This may or may not engage the buried pipeline, depending on the placement of the pipeline relative to the backfill or residual soil conditions.

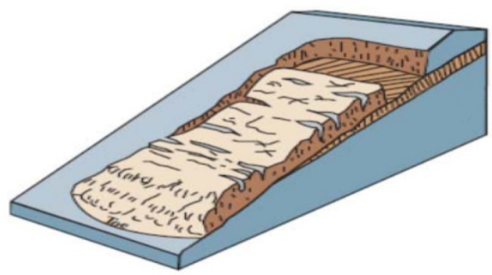

Figure 2-12: Example Shallow Translational Landslide (USGS 2004)

The ground can become unstable and result in earth flows or debris flows where the local soil, either in native slope areas or the disturbed ROW backfill materials, becomes over-saturated from near surface groundwater (i.e. seeps, springs, seasonal runs, etc.), or increased, focused surface discharges from seasonal response to precipitation or changes resulting from construction (Figure 2-13). Earth flows are typically slower and will be saturated with water, but are predominately soil and rock and other local materials. Debris flows have higher water saturation and can fail and move very rapidly, as well as have long run-out lengths.

Figure 2-13: Example Earth or Debris Flow (USGS 2004)

Slow earth flows, also called slope creep (Figure 2-14), are usually extremely slow moving, with a steady downslope trend. Slope creep is generally very shallow (e.g., < 1 meter [3 ft] thick), and occurs in the regolith, the soil layer overlying bedrock. Slopes where slope creep occurs can be low- or high angle. Slope creep may be seasonal, occurring with seasonal saturation events in the surface soils, or continuous or progressive where it may lead to landslide displacement. Slope creep is commonly expressed by the formation of “pistol-butted” tree trunks in forested areas.

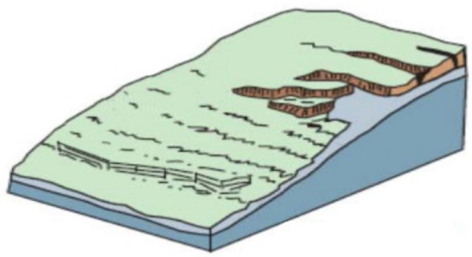

Figure 2-14: Example Slope Soil Creep (USGS 2004)

Slope creep is typically localized, but can be observed to occur in multiple localized areas in similar topographic conditions. The velocity of slope creep is extremely slow to very slow. Creep generally occurs shallower than typical pipeline burial depths, and thus rarely poses a threat to buried pipelines.

2.6.1 Hazard Classification

To prioritize sites for further investigation, assessment, mitigation and monitoring, a hazard classification scheme is needed that defines and differentiates the nature and characteristics of the identified landslide or erosion hazard(s). The hazard classification scheme for any given pipeline system, or for a specific site needs to be custom built to fit the purpose and needs of the project. Typically, a hazard classification scheme is qualitative, and takes into account the type, nature, proximity, magnitude and level of activity of the hazard, as well as the degree to which the hazard affects, engages or can engage the pipeline.

Making the hazard classification system too complex can complicate current and future efforts. Keeping the classification system as simple as possible is preferred. In some situations, a simple range of hazard classification levels from high to moderate to low is sufficient. In other situations, a more complex system that recognizes pipeline integrity versus possible environmental threats may be needed to address the required site and project conditions. This topic is limited in discussion because it represents a technical specialty in of itself and is not the focus of this study. Appropriate time and effort should be taken in developing a hazard classification scheme to catalog hazards and their relative risks to the pipeline. Engaging a geosciences professional in the development of the classification system for a given project is recommended.

2.6.2 Hazards Database and GIS information

Developing an inventory of identified landslide and erosion hazards in a pipeline system or project area provides a basis for tracking changes and provides a reference for developing mitigation and monitoring strategies on a system-wide scale. As more information is collected, some form of database is needed to organize the information and data, and allow for practical and orderly queries and management of the data. A database platform can be developed for this purpose. This provides a simple and practical tool to support operations, maintenance and emergency response. The database should contain landslide and erosion related site information, geospatial data, pipeline integrity, or potential environmental impact information, field investigation reports and photographs, slope monitoring data, and documentation for mitigation and remedial construction efforts at identified sites. The database can be housed in any number of commercially available software platforms, depending on what best fits the owner’s information management and integrity operations requirements.

Geospatial data should be created and stored to provide a spatial representation of the identified sites using a geographic information system (GIS) platform. LiDAR images are often used as a baseline mapping data set to show topographic features and landslide size, shape and location relative to other features of interest, such as pipelines, permanent easement boundaries, property boundaries and construction boundaries, as well as the location of critical features such as roads, structures and water bodies. Site-specific survey or other publically available mapping data can also be used to develop baseline mapping information.

The geospatial data should include available pipeline information such as pipeline name, product (gas, liquids, etc.), pipeline diameter, and milepost or engineering stationing. Base maps included in GIS should include available current or historical aerial imagery, current or historical geologic maps, current or historical topographic maps, and may include site-specific slope analysis maps developed using GIS tools (where applicable).

3.0 MITIGATION OVERVIEW

The following sections assume that routing efforts to avoid hazards for a given project corridor have been exhausted, but hazards still remain along the alignment that cannot be avoided. Mitigation should be 'fit for purpose,' meaning the level of protection should match the site conditions and should balance costs with practicality of installation, operation and mitigation of risk. Ultimately, the owner/operator must decide on the acceptable level of risk for any given mitigation strategy that is used for an identified hazard(s).

All reasonable mitigation options should be considered in the design and planning process, to best fit the purpose of the project, and to best mitigate the hazard threatening the pipeline. Experience with OVM suggests that in most cases the occurrence of land movement is associated with surface and subsurface water, in combination with changes in the local ground conditions from recent or historical activities related to construction or geologic conditions conducive to land movement. Therefore, the mitigation strategies presented in subsequent sections of this report target sources of surface and subsurface water, as well as understanding and improving local site conditions. Based on experience in OVM, examples of mitigation options include: re-grading the ROW surface to reduce soil loading or otherwise improve site conditions; modifying local surface drainage to reduce discharge to the site; collection and conveyance of sub-surface drainage contributing to land movement; modified ROW backfill materials; deformable backfill in the pipeline trench; removal of unstable soil and replacement with engineered performance materials; ground surface erosion protection with slope breakers, trench breakers, sack-crete breakers; special pipeline coatings and protective sleeve-wraps; modified ROW configurations; monitoring; special pipeline design (i.e. increased pipeline wall thickness, material, bend geometries); and targeted monitoring (PRCI 2009). These options are generally not singular components of a mitigation approach, and are typically combined to develop a strategy for addressing the identified hazards at any given site.

Structural measures are available to address unstable slopes, such as retaining walls, soldier piles, sheet piles, wire mesh systems, mechanically stabilized earth systems and other mechanical structures. In specific instances, structural measures may be preferable. However, these structural measures typically were not developed for pipeline applications, but were originally intended to be used on roads, bridges and other infrastructure developments. These options can be costly, require site-specific designs, have special equipment and access requirements for installation, require specialized/proprietary construction techniques that can be unforgiving if not precisely installed, may be unable to be field-fit to unexpected site conditions, may limit future access or expansion in constrained ROW corridors, and may also have special long-term maintenance requirements. Therefore, this document presents an approach that uses materials and methods frequently used in pipeline construction, does not require specialized equipment, can be modified in the field to fit site conditions, and easily can be adapted with future expansions.

The cause of any given landslide or erosion hazard is commonly the result of several contributing factors. Defining the governing geologic hazards, and geotechnical/hydrotechnical engineering processes that contribute to the movement is critical in supporting the selection, planning and design of an effective mitigation plan. The process is most effective when considering the approaches discussed earlier in this study (Section 2.0, and Figure 2-1). The most effective mitigation strategy requires recognition of the multiple factors governing any given site and may require long-term performance monitoring before full mitigation can be achieved.

In some situations, the mitigation may not be intended to provide a long-term permanent mitigation and full elimination of the hazard. Instead, the rate at which a potential threat could engage or engages the pipeline is delayed or prolonged to an acceptable level of risk (e.g. use of deformable backfill and monitoring to schedule stress relief excavations over time). As such, mitigation measures should be tailored to address the site specific and potentially variable conditions, consider the risk tolerance of owner/operator, consider the costs and benefits of long-term and short-term solutions, and incorporate construction.

Pipeline projects have a unique construction planning and execution process, typically characterized by a series of sequential steps to build the ROW and install the pipeline. A successful mitigation effort, whether at a single site or on a larger project scale, must integrate with the construction process. Mitigation strategies should always account for overall construction considerations in the planning and design efforts.

The following sections address these topics and outline general guidelines for mitigation.

3.1 Typical Construction Sequence

A typical construction sequence for building cross-country pipelines includes the following general steps:

- Pre-construction survey;
- ROW clearing and grading;
- Trenching;
- Pipeline stringing and bending;
- Welding, pipeline coating and weld inspection;
- Lowering the pipeline and backfilling;
- Testing; and
- ROW restoration.

These steps are generalized, but represent the basic sequential components of construction activities that occur when building pipelines. A simplified graphical depiction of the construction process, such as the one provided by Williams (Figure 3-1), is commonly included in planning and permitting documents in the early stages of a pipeline project.

Mitigation efforts typically occur during the ROW clearing and grading, trenching and ROW restoration phases of work. This conceptual sequence of construction shows generally flat ROW conditions, which is typically not the case in rugged and steep terrain. The presence of rugged terrain can increase the complexity of the work and requires added planning of construction activities during the implementation of landslide and erosion mitigation efforts. For example, drainage improvements may need to be installed as temporary measures in early phases of the work to maintain a usable ROW, and may then be damaged or require modifications resulting from intermediate construction activities, requiring final drainage measures to be installed with the final restoration work.

Pre-construction activities need to include planning for the sequencing of construction activities in steep, rugged, mountainous terrain that is common on many pipeline projects, particularly where mitigation of landslides and erosion hazards should be integrated into the overall process. This may also be a consideration in challenging wet or winter weather conditions, or where construction is interrupted by winter conditions and temporary measures are installed to carry through until construction starts again. When designing and planning the mitigation work, the designer should understand how the proposed mitigation will integrate with the planned sequence of construction to maintain the most efficient, functional, and cost effective installation of the measures.

The following sections define and discuss general ROW construction scenarios that are consistent with the conceptual pipeline construction sequence.

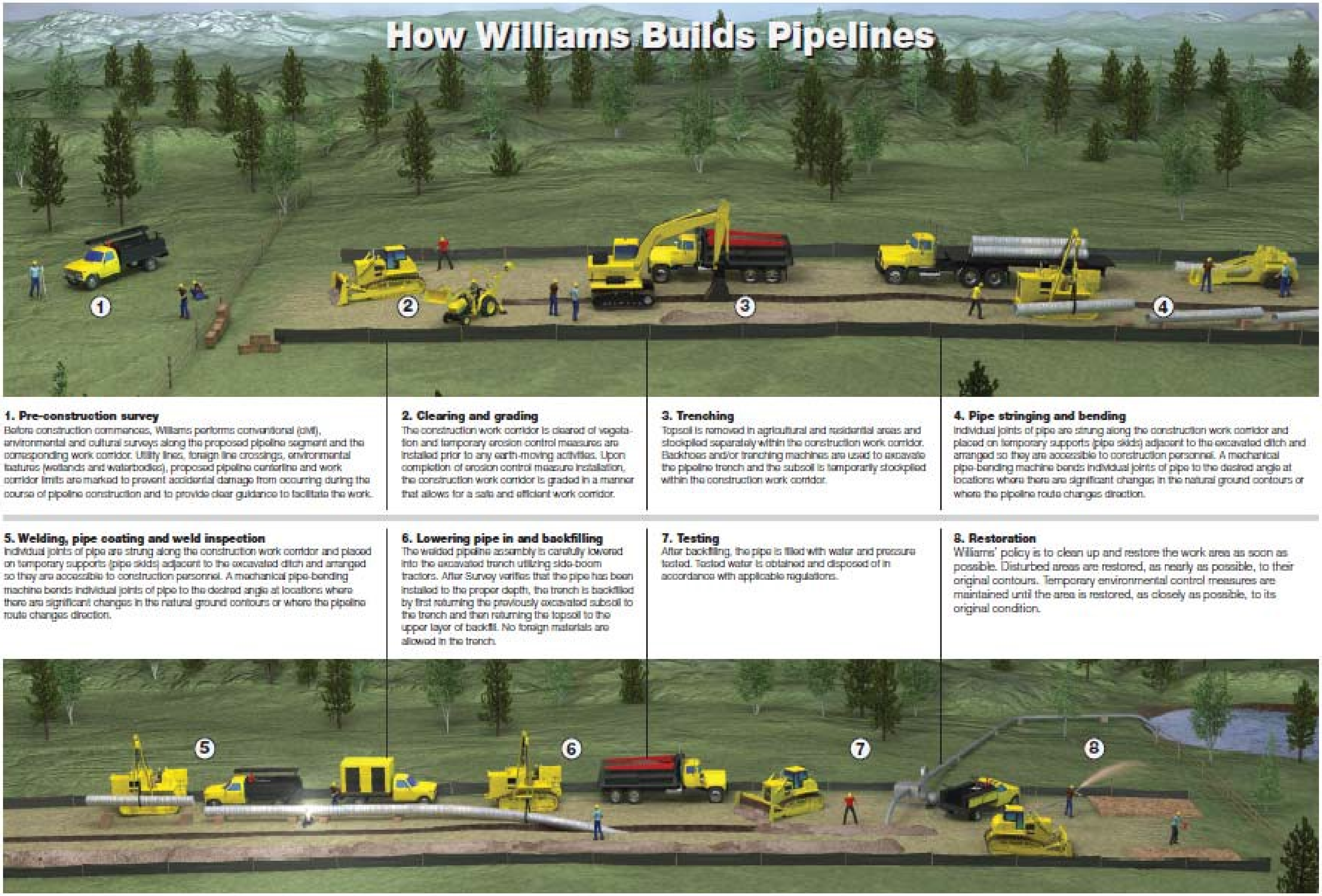

Figure 3-1: Williams Typical Construction Sequence (Williams 2015)

3.2 ROW Construction Scenarios

Looking at a simplified model of typical pipeline construction in mountainous terrain, consistent with the general model for pipeline routing and pipeline construction sequencing (Figure 3-1), we can identify several key construction planning related scenarios for building the ROW (Figure 3-2): on flat valley bottom ground; on ridge tops; on planar slopes (connecting between flat ground and ridge top alignments); and on sidehill slopes and oblique angles (alignment traverses planar slopes and cannot employ ideal routing principals [i.e. straight down the slope]).

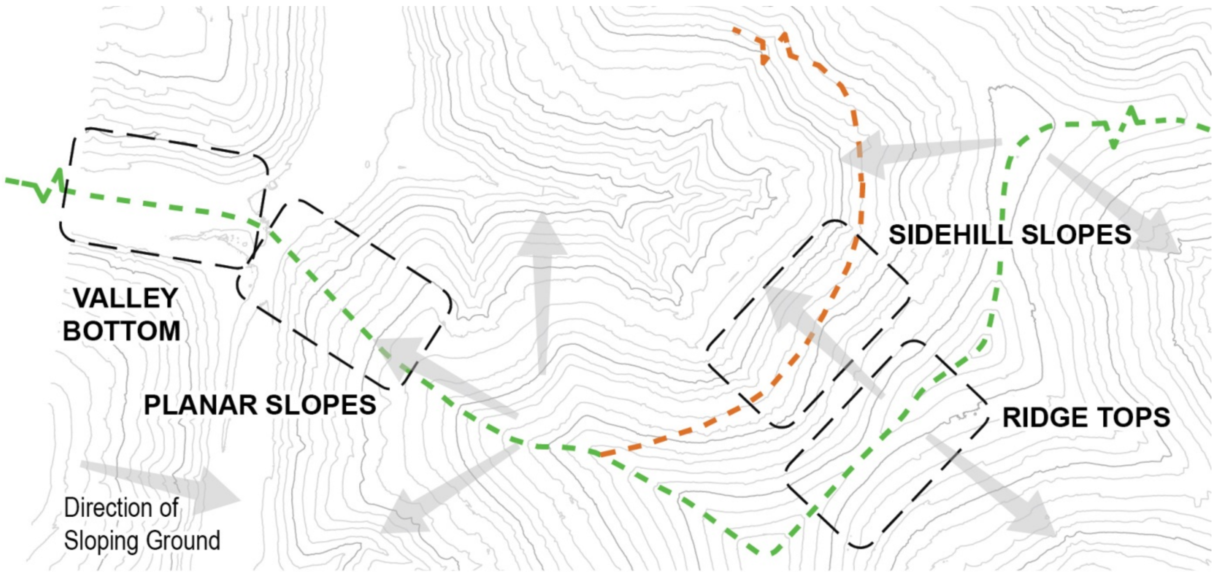

Figure 3-2: Typical Basic Pipeline Construction Scenarios in Mountainous Terrain (Williams 2015)

3.2.1 Valley Bottom ROW Construction

Building ROW on flat valley bottom areas (Figure 3-3) is least likely to encounter land movement hazards, as the ground is typically flat or mildly sloped and not prone to landslide-related hazards. Surface erosion or other challenges from existing infrastructure, rivers, or streams may exist, but not the landslide characteristics of earth or debris flows that would initiate in steeper ground. These valley bottom areas can be subject to depositional and run-out scenarios from earth and debris flows, but typically do not impact the pipeline in such areas.

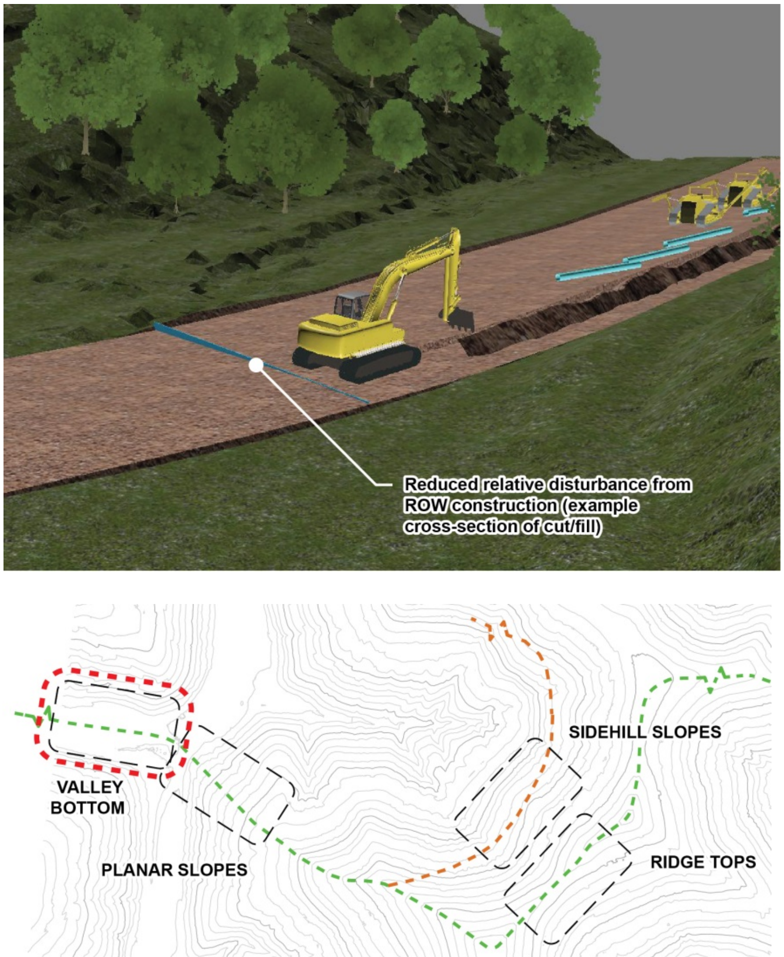

Figure 3-3: Typical Valley Bottom ROW Construction (and inset showing conceptual location of the construction scenario referenced on Figure 3-2) (Williams 2015)

The general magnitude of disturbance necessary to construct the pipeline ROW is represented by the stylized section shown in Figure 3-3 (just behind the excavator), and represents the cut/fill necessary to remove the topsoil and level the ROW for access. Additionally, trenching in generally flat ground does not require special planning or equipment or contingencies for design or restoration. Valley bottom areas are subject to the highest potential accumulation of surface run-off from upslope areas, inherently because they are typically at the bottom elevation of a valley in ridge-valley terrain. As such, valley bottom construction typically encounters floodplains and associated rivers and streams; as well as seeps/artesian conditions, ponded water, lakes, and wetlands.

3.2.2 Planar Slope ROW Construction

Building ROW in planar slopes (Figure 3-4) is generally similar to flat ground, except the ground may be inclined steeply, which requires enhanced construction planning and results in a higher potential for landslide and erosion related hazards. The general magnitude of disturbance necessary to build the pipeline ROW is represented by the stylized section shown in Figure 3-4 (just ahead of the excavator). This may increase to address longitudinal changes in the ROW profile, especially in benched topography or on planar slopes that change grade due to local geology or other topographic variations.

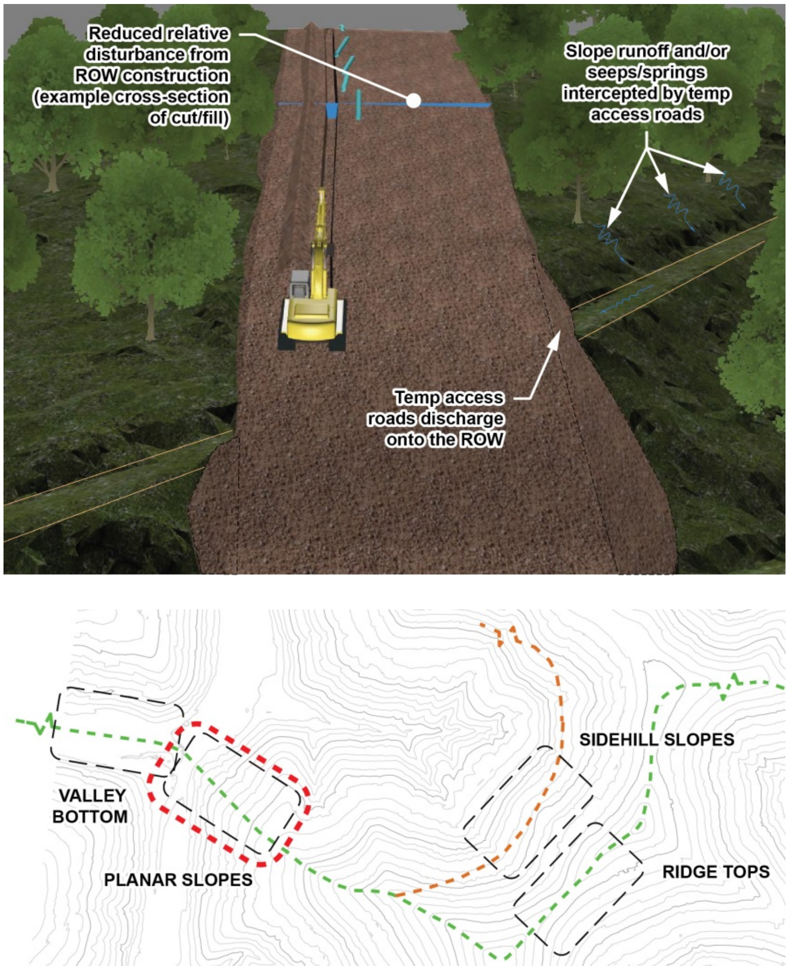

Figure 3-4: Typical Planar Slope ROW Construction (and inset showing conceptual location of the construction scenario referenced on Figure 3-2) (Williams 2015)

Where planar slopes are oriented along the 'fall line' of the slope, there is a minimized contribution of upslope surface run-off. As such, planar slopes are particularly sensitive to access roads and other transportation access points that can re-direct surface and intercept sub-surface water back to the ROW from adjacent off-site upslope contributing basin areas that would not normally discharge onto the disturbed ROW (Figure 3-4). Erosion and landslide hazards can be re-activated or triggered from increased sources of water collected in the pipeline trench or re-directed along the surface of the disturbed ROW. Trench breakers and slope breakers (water bars) are critical in these scenarios as a minimum first line of defense for short- and long-term mitigation.

3.2.3 Ridge Top ROW Construction

Building ROW on ridge tops (Figure 3-5) or inclined ridge tops (i.e. steep sloping ridges) is the preferred location for pipeline routing in rugged ridge-and-valley terrain. The ridge top alignment is generally the most stable ground. It has changed the least over geologic timescales, making it the least likely location for landslide and erosion type hazards.

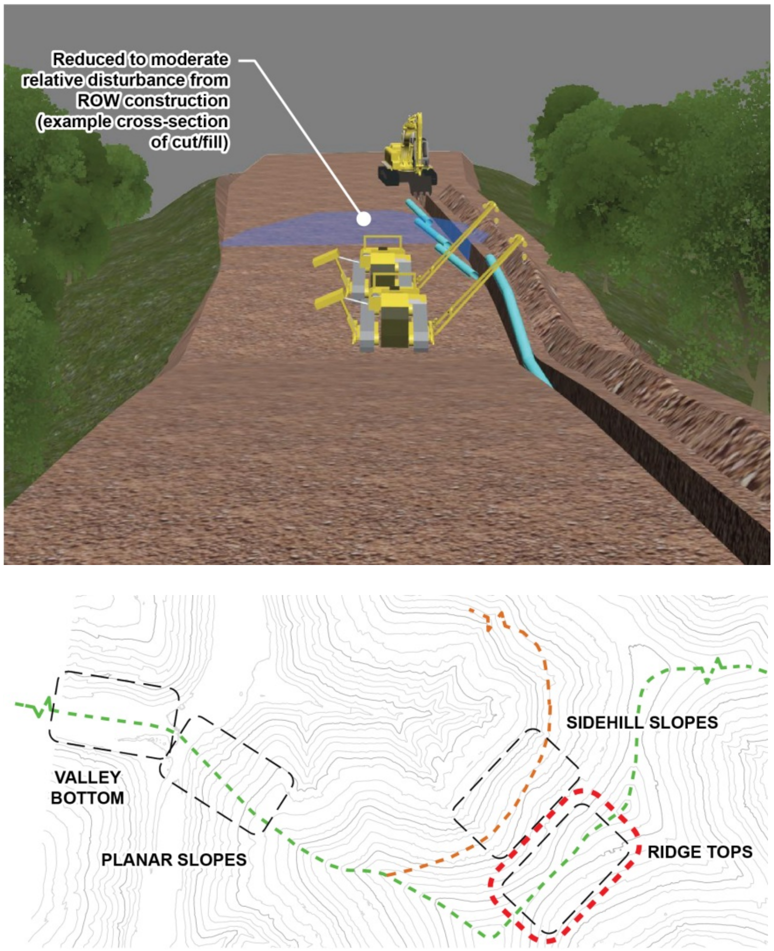

Figure 3-5: Typical Ridge Top ROW Construction (and inset showing conceptual location of the construction scenario referenced on Figure 3-2) (Williams 2015)

This stable ground is largely due to the lack of contributing drainage basin area discharging to the disturbed ROW (i.e. no slopes or basin draining to it). Potential sources of water that may require mitigation are limited to precipitation and the reduced potential of a seep or spring located along the ridge.

The general magnitude of disturbance necessary to build the pipeline ROW on ridge tops is represented by the stylized section shown in Figure 3-5 (just ahead of the side booms). This is somewhat larger than the valley bottom flat areas or planar slopes but still relatively small in comparison to the following described scenarios. The challenge for ridge top areas is the management of temporary construction spoils and limiting the loss of the spoils to the adjacent steep valley sides sloping away from the ridge.

3.2.4 Sidehill ROW Construction

Building ROW in sidehill conditions presents the greatest challenge for the design, planning and mitigation of landslide and erosion hazards (Figure 3-6). The conceptual figure depicts a full sidehill geometry, where the alignment is running parallel to the slope contours. Similar issues would exist with sidehill alignments traversing the slope at oblique angles (relative to the fall line straight down the slope). The general magnitude of disturbance necessary to build the sidehill pipeline ROW is represented by the stylized section shown between the excavator and the side booms in Figure 3-6. This demonstrates how sidehill construction has the largest relative volume of excavated materials, and the corresponding largest footprint of disturbance area for any of the typical construction scenarios.

To construct a temporary flat ROW surface that provides access and allows for handling and installation of the pipeline, and to develop the necessary permanent and temporary ROW widths, significant additional ROW excavations are required toward the upslope direction. In steep sidehill conditions, this upslope excavation depth can be deep, resulting in a compounding effect where a wider ROW is needed to work in the steep and rugged terrain. Therefore, side hill excavation generates more spoils that need to be managed.

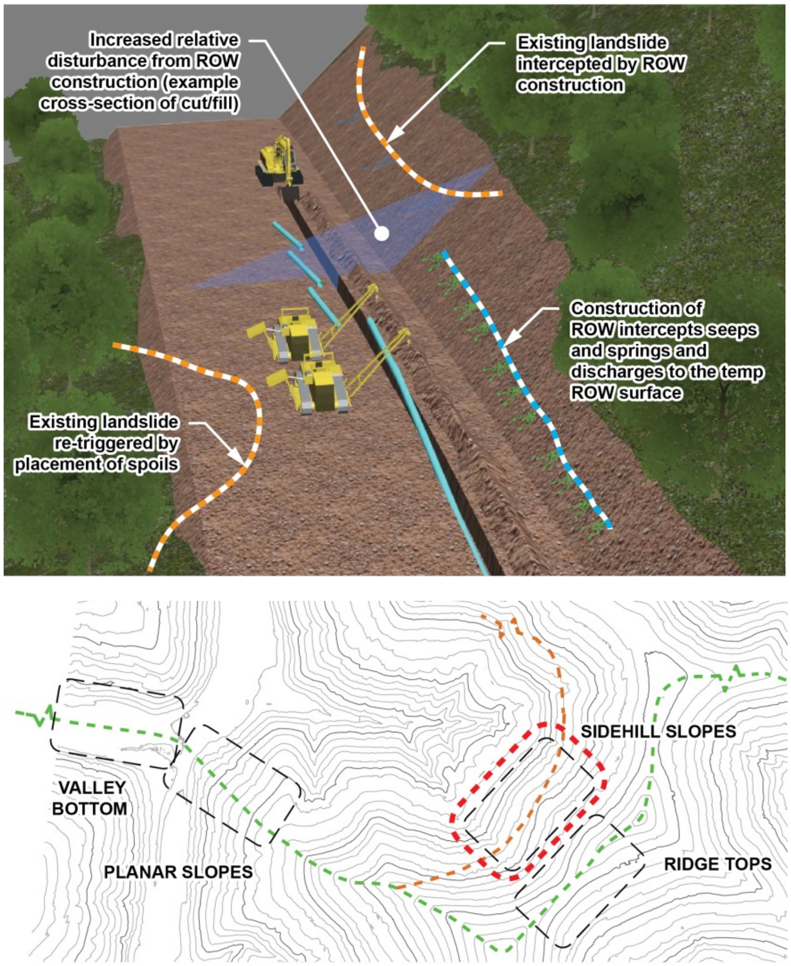

Figure 3-6: Typical Sidehill ROW Construction (and inset showing conceptual location of the construction scenario referenced on Figure 3-2) (Williams 2015)

The deep excavation on the upslope side of the ROW can intercept seeps, springs, surface flow channels and run-off. All of this water is directed down onto the temporary ROW surface during construction, and this temporary ROW surface can direct seepage in the post restoration scenario. Construction of the temporary ROW surface will dictate how surface and subsurface sources of water will interact with the restored construction backfill as the ROW transitions into the operations life cycle phase. Where surface and subsurface sources of water are not addressed (i.e. mitigated) during the construction and restoration of the ROW, these sources of water can discharge into the ROW backfill materials and result in saturated and unstable conditions, which is frequently the governing factor in land movement along the ROW post construction (and post restoration of the ROW).

Mitigation efforts should account for the way the ROW was constructed, including the configuration, size and methods used to build the temporary ROW surface. Mitigation efforts also should account for where the source of water may be originating, namely along the historical temporary ROW surface, which could be very different from the post restoration ROW surface.

3.2.5 Temporary ROW Surface Intercepts Surface and Subsurface Water

The construction of the temporary ROW surface will dictate how surface and subsurface sources of water interact with the restored ROW construction backfill. Seepage flows or springs that followed preferential bedded surfaces typical of the local geology and benched topography express themselves at locations along the ground surface, where these locations are representative of conditions before ROW construction and ground disturbance. That seepage at the ground surface then follows the slope away, depending on the pre-constructed topography at the site. When the temporary ROW surface is constructed, the seepage flows follow along the same geologic bedding and benched topography, but are now expressed along the new surface where the upslope excavation of the temporary ROW surface intercepts the flow paths (Figure 3-7). The constructed temporary ROW surface acts as a preferential flow path, following along the steep cut slope on the uphill side and then along the bottom flat width of the temporary ROW surface.

Backfill and restoration of the ROW uses spoil materials that cannot re-establish the previous bedded geology and corresponding seepage flow characteristics. The backfill is inherently different than the pre-disturbed condition, even if placed with compaction and matching the pre-disturbed contours. Placed backfill tends to saturate when water is added from surface or subsurface sources. After the temporary ROW is backfilled and restored, the temporary excavated ROW surface continues to intercept seepage flows expressed along the steep cut slope, or from seepage through the backfill, and continues to act as a preferential flow path. The new location where the seepage flow discharges along the temporary ROW surface is typically beneath the backfilled materials and at the point where the outboard side of the temporary ROW surface daylights at the ground surface. This new discharge point is farther downslope from where it previously discharged along the pre-project ground.

Mitigation installed at the point where seeps and springs are observed in the post-restoration condition does not directly address the source of the flows, allows the backfill to continue saturating, and increases the potential for landslides, erosion and slope failure of the ROW backfill materials. To be most effective, the mitigation needs to be installed at the location where seepage intersects the temporary excavated ROW surface, and where seepage follows and accumulates on the flat portion of the temporary ROW surface and infiltrates into the pipeline trench, and in other areas where the geometry of the temporary ROW surface delivers water in such a way that it can saturate the ROW backfill.

Depending on how long the pipeline trench/ROW is expected to be left open/unrestored, there may be a need to install temporary drains to address intercepted seeps and springs along the upslope temporary ROW surface or in the pipeline trench. These temporary actions would occur during the clearing and grading, and during the trenching phase of work, for typical planar slope, ridge top and sidehill ROW work scenarios. These temporary mitigation measures may need to function for the duration of the construction activities, and may be damaged or need to be re-constructed or modified in response to other pipeline construction activities. The temporary measures would then be repaired or re-built or additional mitigation measures installed for the final restoration of the ROW. For the final mitigation measures to be effective, they must be installed at the source of the water as described above and not where water is expressed on the ground surface of the restored ROW.

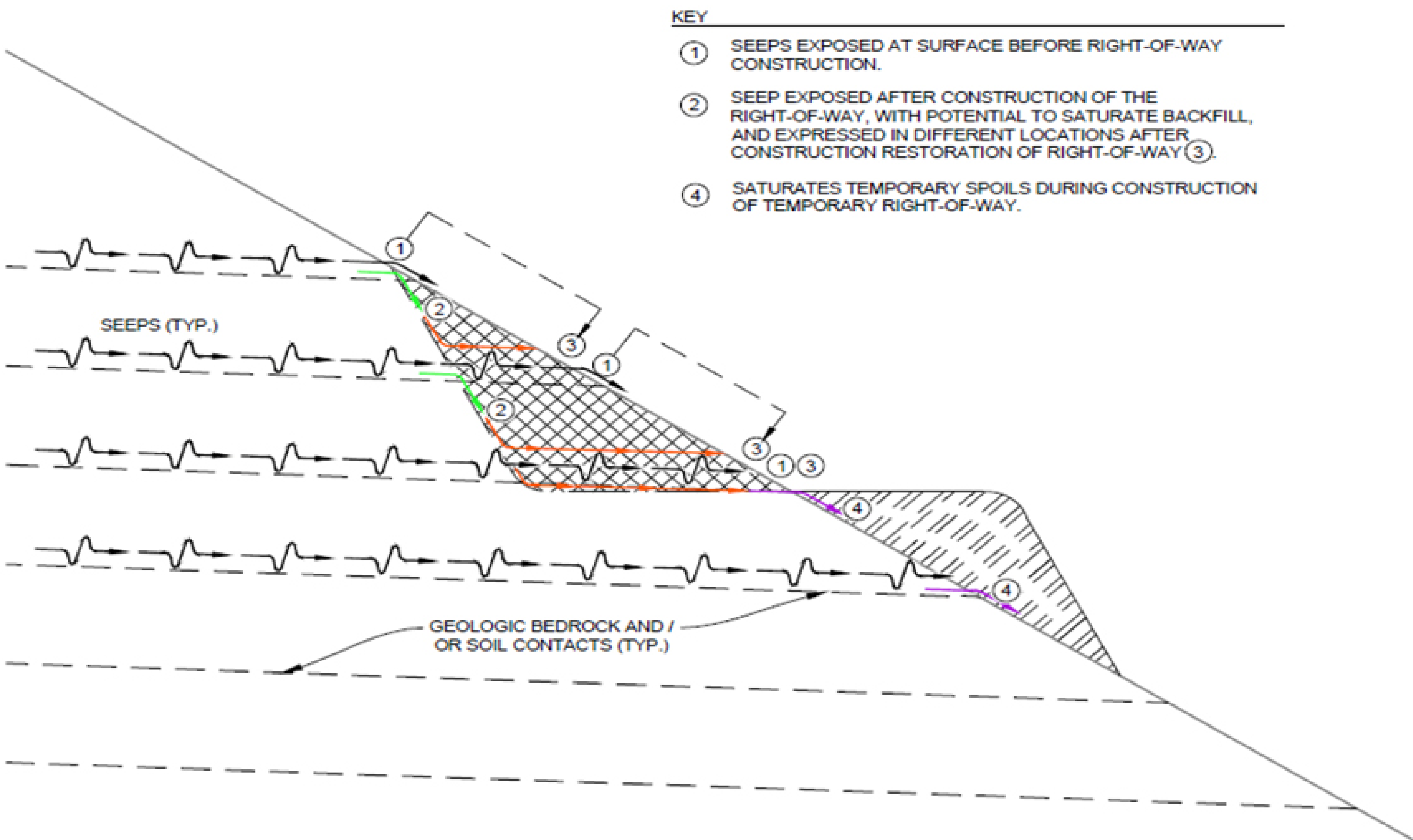

Figure 3-7: Temporary ROW Surface Interaction with Seeps and Springs (Williams 2015)

3.2.6 Comparison of Relative ROW Disturbance in Sidehill Scenarios

A comparison of the typical sections showing the relative disturbance areas for each of the previously discussed ROW construction scenarios (see Figures 3-3, 3-4, 3-5, and 3-6) is shown in Figure 3-8. The comparison highlights the relative increase in excavation volume and corresponding relative increased footprint for the disturbed areas of the ROW in the sidehill scenario. These areas should be identified early in the project design and planning processes, and minimized to the greatest extent possible. Where they cannot be avoided, operators should implement mitigation measures that best fit the site conditions in order to address potential sources of water and to stabilize the ROW backfill materials.

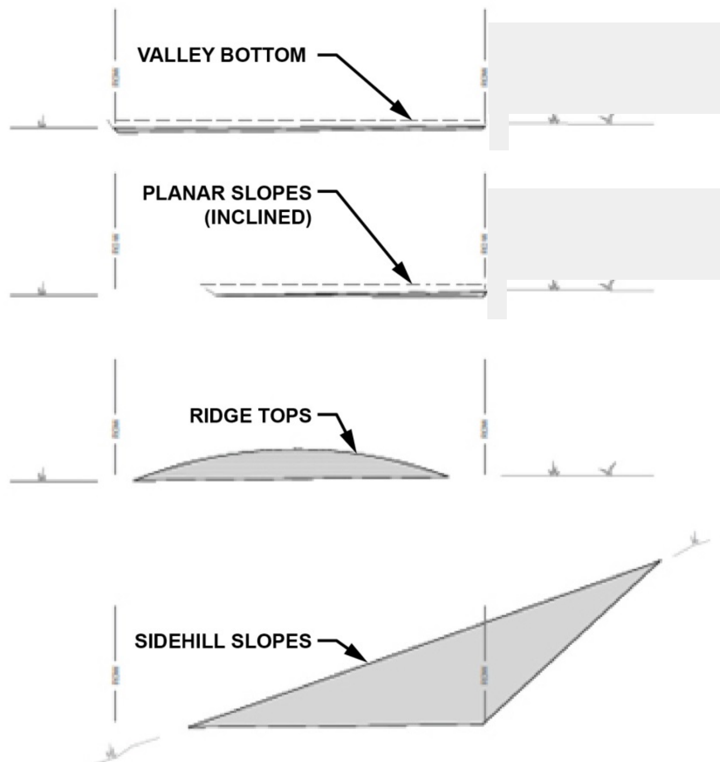

Figure 3-8: Conceptual Comparison of Relative Disturbance Areas (Williams 2015)

3.3 Sequencing Mitigation with Construction

Installing mitigation for existing or potential landslide or erosion hazards should be implemented to incorporate the temporary constructed ROW surface. Depending on how long the ROW is expected to be left open, there may be a need to install drains to address intercepted seeps and springs along the upslope temporary ROW surface or in the pipeline trench. These actions would occur during the clearing and grading, and the trenching phases of work (Figure 3-1) for typical planar slope, ridge top and sidehill ROW work scenarios. These temporary mitigation measures may need to function for the duration of the construction activities, and may be damaged or modified, requiring final mitigation measures to be installed in the restoration phase of the work.

The restoration phase of pipeline construction involves final backfill, finish grading and installation of final erosion control measures (i.e. slope breakers, erosion control fabric, mulching, tracking, vegetation, etc.). Final land movement mitigation measures must be installed at this time but may require building new drains or re-establishing the temporary drains installed in the clearing and grading or trenching phases of work. For these final mitigation measures to be effective, they must be installed at the source of the water, not at the surface of the already backfilled ROW and should be coordinated with the other phases of pipeline construction.

3.4 General Guidance Using Typical Scenarios for Landslide Mitigation

Development of conceptual recommendations for landslide and erosion mitigation can be organized into "Typical Scenarios" that are consistent with pipeline construction, and related to how the ROW is built. General examples are described in the previous section for valley bottom, planar slopes, ridge top and sidehill scenarios. This section provides a general overview on conceptual mitigation approaches for landslide and erosion hazards using Typical Scenarios as a basis for developing conceptual level plans and specifying mitigation measures (i.e. Typical Details). Guidance on which Typical Details are applicable for specified Typical Scenarios is addressed in Section 4.0 of this document.

This approach allows for rapid development of site-specific conceptual mitigation plans during project design and planning and supports review and planning for project budgets and bidding. The approach also allows for development of conceptual mitigation plans concurrent with pipeline installation as conditions are encountered during construction.

The following provides a general summary of the Typical Scenarios discussed herein and related to landslide hazards:

- Sidehill in Stable Trench (Appendix A-1, Sheet 1710) – The pipeline is oriented perpendicular to the orientation of the landslide in a sidehill configuration (Figure 3-9). In this scenario, the pipeline is installed in a "stable trench," indicating the pipeline is below the landslide failure plane, in unyielding native soil and/or bedrock materials. This is a preferred scenario. It mitigates the threat to the pipeline by avoiding the hazard and staying deep enough to allow any land movement to occur independent of the pipeline. However, mitigation often is still necessary to prevent land movement and disturbance on and off the ROW.
- Sidehill in Un-Stable Trench (Appendix A-1, Sheet 1720) - The pipeline is also oriented perpendicular to the orientation of the landslide in a sidehill configuration (Figure 3-9). In this scenario, the pipeline is installed in a potentially "unstable trench," indicating the pipeline is within the landslide mass (i.e. above the failure plane) in active landslide materials. This scenario is frequently associated with active ROW backfill materials, as well as native landslide movement. The accumulated strain can be greater where the pipeline passes across the lateral or vertical limits of a landslide, or, at the lateral boundaries of the landslide with the surrounding stable ground where shear stresses tend to be concentrated. This is not the preferred scenario. It represents an increased potential threat to the integrity of the pipeline.
- Planar in Stable Trench (Appendix A-1, Sheet 1730) - The pipeline is oriented longitudinal to the orientation of the landslide along a planar slope (Figure 3-10). In this scenario, the pipeline is installed in a "stable trench," indicating the pipeline is below the landslide failure plane in unyielding native soil and/or bedrock materials. This is a preferred scenario. It mitigates the threat to the pipeline by avoiding the hazard and staying deep enough to allow any land movement to occur independent of the pipeline. However, mitigation often is still necessary to prevent land movement and disturbance on and off the ROW.
- Planar in Un-Stable Trench (Appendix A-1, Sheet 1740) - The pipeline is oriented longitudinal to the orientation of the landslide along a planar slope (Figure 3-10). In this scenario, the pipeline is installed in a potentially "unstable trench," indicating the pipeline is within the landslide mass (i.e. above the failure plane) in active landslide materials. This scenario is frequently associated with active ROW backfill materials, as well as native landslide movement. The accumulated strain can be greater where the pipe passes across the lateral or vertical limits (vertical displacement is common

in this scenario) of a landslide, at the lateral or vertical boundaries of the landslide with the surrounding stable ground where shear stresses tend to be concentrated. This is not the preferred scenario. It represents an increased potential threat to the integrity of the pipeline.

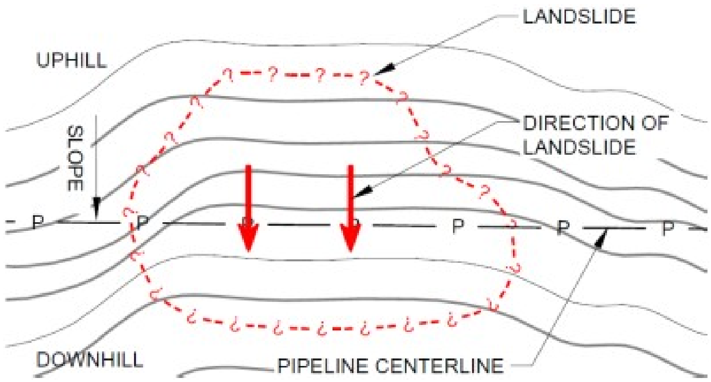

Figure 3-9: Conceptual Schematic for Sidehill Landslide (Williams 2015)

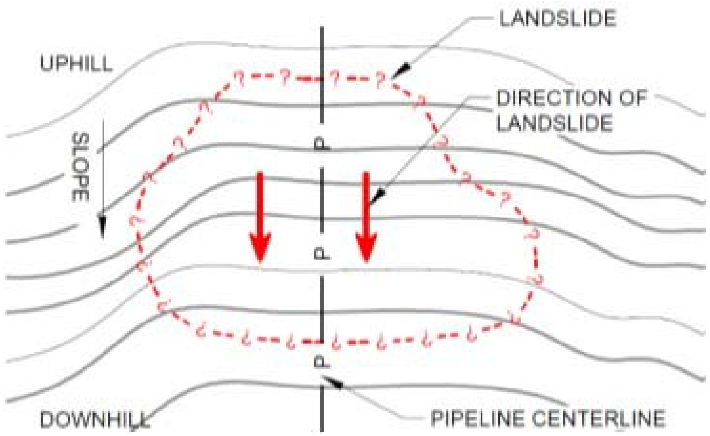

Figure 3-10: Conceptual Schematic for Planar Landslide (Williams 2015)

3.4.1 General Approach for Mitigation of Land Movement using Typical Scenarios

The following outlines the general approach for mitigating land movement for Side Slope and Planar Slope Typical Scenarios (as outlined and discussed above):

1. The final configuration of any ROW restoration measures should be determined based on the conditions encountered at the time of construction, and may change or vary and require additional measures to mitigate hazardous landslide conditions that are identified during the work. The volumes, grade, elevations and quantities will vary depending on the site conditions encountered.
2. Landslides at any given site should be evaluated on a case-by-case basis and should incorporate the site-specific conditions. Mitigation recommendations should be specific to each site and should incorporate appropriate site investigations and assessment, review, mapping, characterization and delineation of site-specific landslide features in order to understand the site-specific processes and dynamics of the landslide at that site.

3. If possible, look to re-route and avoid the landslide site. If re-routes are not possible, then consider additional mitigation measures.
4. Investigate the landslide site to confirm depth to failure zone, extents and limits of the landslide mass, etc. This may be accomplished by: site-specific sub-surface drilling; geophysical surveys; use of LiDAR to map surficial landslide features; digging test-pits; manual probes; or through excavations of the temporary ROW surface. Although sub-surface investigations are often preferred, the timing, access or site conditions may not allow specialized equipment access, and it is common for investigation activities to include test-pit or other localized excavation methods (using rubber-tire or tracked excavators) to quickly map out landslide conditions and confirm depths of the active landslide zone and the corresponding depth to bedrock.
5. If possible, install the pipeline trench in stable bedrock or unyielding and intact native soils.
6. Where the depth to stable bedrock or stable native soils is too deep, or it is not feasible to install the pipeline at that depth, then the following measures should be considered:
    a. Install a deformable backfill around the pipeline (PRCI 2009), which allows for improved drainage along the pipeline trench, and allows the backfill to deform around the pipeline in response to continued land movement and thereby attenuates for accumulated strain in the pipeline;
    b. Install monitoring on the pipeline to track potential increases in strain in the pipeline (i.e. strain gauges);
    c. Install other monitoring at the site to track potential land movement (i.e. geodetic monitoring, regular visual monitoring, inclinometers, piezometers, extensometers, etc.);
    d. Install enhanced drainage measures in the trench to mitigate for subsurface flows and target identified sources of water that may be discharging to the site;
    e. Modify surface water draining to the site to mitigate for discharges from streams, creeks, runs, gullies or other sources of surface run-off that may be contributing water to the site and exacerbating land movement;
    f. Install trench breakers and slope breakers to mitigate for trench seepage and to divert intercepted trench flows along the surface to safe discharge points;
    g. Reduce the loading on the site by removing and/or reducing the excess backfill materials to off-site locations. Spoil placement should be carefully planned to avoid triggering land movement in other locations;
    h. Compact backfill materials at the site to achieve optimal moisture content and to provide increased strength. Added compaction can increase strength and stability of the backfill and reduce infiltration of water into the backfill, thereby further mitigating for potential for land movement;
    i. Wet backfill materials may require drying the soils using special additives to allow the materials to be re-used and worked at the site. Over-saturated materials may require extensive time and space to dry. Use of lime-kiln dust or cement-kiln additives may be needed (pending environmental requirements);
    j. Where local materials cannot be re-used, use of a small angular (i.e. free-draining) rock backfill for ROW restoration (not in the pipeline trench) may be installed. Rock materials allow for reconstruction of slopes and grades in wet conditions and can be placed to establish desired grading and re-contouring at the site. Rock backfill can also be re-used and re-placed during future maintenance activities; and,

k. Where needed, install shear trenches in planar and oblique sidehill scenarios where continued land movement is expected and targeted relief of differential ground movement is possible.

7. Complete an as-built survey to identify and map out the installed mitigation measures at the site, including documentation, drawings, and database information as discussed earlier.
8. Develop a site monitoring plan to track potential changes at the site.

Refer also to the corresponding Typical Scenario sheets in Appendix A-1.

3.4.2 General Approach for Mitigation of Land Movement using Typical Details

The following outlines general guidance for mitigation efforts. This section is limited to describing general categories for mitigation measures (i.e. subsurface drainage, surface drainage, grading, etc.), more detailed guidance and discussion is provided in the Applied Guidance Section 4.0.

3.4.2.1 Subsurface Drainage

The mitigation of subsurface water is one of the most important components of any plan for a specific site. As previously discussed, any subsurface drainage improvements should focus on how the ROW was constructed and install drains to address changes in the subsurface expression and discharge characteristics relative to the temporary ROW surface, and not just the surface expression of flows in the post-restoration ROW surface.

Targeted drainage measures can be configured to fit site-specific conditions. There should be flexibility in how the drainage is designed and installed in order to allow for incorporating the measures into the construction sequence. This may require temporary drains during the initial grading and trenching, and then final drains with completion of the trenching and lowering of the pipeline, and during the restoration phase of work.

Examples of subsurface drainage measures include (but are not limited to):

- French drains that incorporate drain rock with perforated collection pipes to capture and convey water in the trench or other targeted areas;
- Enhanced drains using drain rock with perforated collection and tightline conveyance pipes that can be designed to target certain areas and increase the efficiency and performance of capturing and conveying water. These can be used in the trench or at other areas to mitigate for water;
- Targeted seep drains using drain rock, piping, and/or other materials to build collection and conveyance drains at identified sources of water in the ROW cut or trench. These are often combined with other installed drainage systems to evacuate the water; and,
- Bleeder drains, which cut notches in the outboard trench wall along the bottom of the trench at low spots or intervals along sloping trenches. These drains allow accumulated seepage from sources of water or conveyance along the trench to evacuate the ROW backfill, and not “pool” in the trench or backfill material. They are often constructed using drain rock and may include piping and trench breakers to facilitate flow. They may require added excavation to find a slope-to-drain grade through local high ground.
- Trench breakers are often coordinated with drainage improvements to specifically to address seepage along the trench line, and also coordinated with surface drainage management (i.e. slope breakers), more discussion is included below.

All these variations on drains allow for the collection and evacuation of subsurface seepage, and may be modified and/or combined to fit site conditions.

3.4.2.2 Surface Drains, Runoff Improvements, and Channels

Surface water run-off to a site can contribute flows in relatively small constant incremental discharges, and have larger volume and duration peak discharges during storm events. While many landslide and erosion sites fail in response to storm events, often the contributing factor to failure is the constant and incremental small discharge (i.e. base flows) to a site. Therefore surface drainage plans may have to accommodate a range of flow conditions.

Surface drainage measures may include (but are not limited to):

- Collection and diversion channels, ditches, brow ditches, berms, slope breakers (discussed in more detail below), swales, etc. that intercept and convey base flows and mitigate for saturation of the ROW backfill or other targeted landslide prone terrain at a site;
- Runoff improvements by grading the ROW and surrounding ground to manage or enhance run-off away from the site, or control/manage how surface and subsurface flows are captured or possibly infiltrate into the ROW backfill. This may include changing slopes and cut-fill to mitigate for concentration of aggregate surface runoff, and is often coordinated with installation of slope breakers (discussed in more detail below);
- Armored channels with drain pipes allow for conveyance of high flows and protect against erosion (i.e. the armoring) during peak events while the drain pipes in the channel pick up the lower seepage base flows that would otherwise be slowed and tend to infiltrate in oversized armor rock rather than; and,
- Armored channels in steep ground allow for collection and conveyance of surface runoff and other point sources of water (i.e. seeps, springs, etc.) that may be prone to erosion. Armoring may include riprap materials, sack-crete lining and/or re-construction of steep trench and ROW backfill in bedrock conditions, integrating local erosion resistant geologic units (i.e. bedrock) in the channel, etc.

3.4.2.3 Grading, Backfill Improvements, and Surface Treatments

Any site-specific mitigation plan will include some form of grading and surface mitigation slope work. Examples include:

- Grading to reduce the overburden on the site and thereby minimize or reduce driving forces on a potential landslide;
- Maintaining a stable outboard wedge of soil or bedrock material along the downslope side of ROW to maintain a stable trench;
- Compaction of backfill materials during ROW restoration;
- Drying, moisture conditioning, use of soil additives to soils during ROW backfill and restoration work to improve construction feasibility and stability of materials;
- Removing unsuitable soils when they cannot be used in the backfill or cannot be dried sufficiently;
- Using free-draining rock backfill (typically small to medium sized angular riprap) to replace unsuitable soil materials and re-build ROW slopes, to fit variable slope geometries, to provide a stable backfill configuration at a range of low to high angle slopes, and able to be reused during future maintenance/operation activities, etc.;
- Using sack-crete materials to re-build localized trench backfill, ROW slopes, transitions between soil and bedrock units, and ROW backfill, which can be often integrated with drainage improvements to mitigate for sources of surface or subsurface water;
- Tracking or other surface erosion control treatments for disturbed final ground surfaces;
- Re- vegetation;

- Installing erosion control fabric, silt socks, silt logs, “coir” products, and/or other erosion control devices; and
- Placement of rock armoring, typically using medium to large-sized riprap rock materials, on steep or erosion prone slopes to stabilize and address potential surface erosion, integrate with transitions from soil to bedrock units, or re-build localized over-steepened ROW slopes.

3.4.2.4 Breakers

The use of trench and slope breakers for ROW restoration is a critical component to any restoration or mitigation plan, and should be considered a minimum component to typical mitigation planning, design and construction efforts.

3.4.2.4.1 Trench Breakers

Trench breakers are typically installed at spacing and dimensions that fit slope conditions. Steeper slopes require tighter spacing, and vice-versa for flatter slopes. Consideration should be given to the grade of the slope versus the grade of the pipeline trench, whereby steep slopes with flat pipeline trench grades (e.g. steep planar slopes with pipeline alignment at oblique or sidehill orientation) would allow for wider spacing of breakers, and steep slopes with corresponding steep pipeline trench grades (e.g. steep planar where the pipeline follows the slope down the fall line resulting in similar grades) slopes would require closer spacing of breakers. Technical guidance on the specific placement and spacing of trench breakers is lacking, leaving much to the discretion of the designer, and relying on professional experience for placement configuration and spacing.

Sandbag breakers are recommended for targeted landslide and erosion hazard sites where special geotechnical and hydrotechnical engineering and geologic hazard mitigation efforts are needed. Other materials may be considered in more typical pipeline construction scenarios where hazards do not exist. The use of sandbags to construct breakers allows for a close fit around the pipeline without creating a rigid and potentially load transferring connection to the pipeline, allows for some seepage of water through the breaker structure in a slow and controlled manner that passively dissipates accumulated seepage behind the breaker over time, and can adapted to fit and conform to variable trench geometries during construction and can adjust to changes in the trench geometry over time, while still maintaining their function.

Foam breakers are generally not recommended for landslide or erosion mitigation work at targeted sites, and in particular to mitigate for potential accumulation of trench seepage or drainage issues. Potential drawbacks of using foam breakers include: foam material creates a dam in the trench that holds back and accumulates seepage resulting in saturation of the backfill; they tend to ‘grab’ the pipeline and create a positive connection that can potentially transfer loading from the surrounding soil backfill through the breaker to the pipeline; they are typically placed without a key along the trench walls; they are rigid and do not conform well to changes in trench geometry over time which can result in cracks and gaps around the sides and bottom (where there is no key); and they can form cracks and break as the backfill changes over time which may negate their intended function and can also focus seepage flows and result in piping failures. If foam breakers are used, additional drains should be added to the individual breakers, as well as between multiple breakers, to collect and evacuate accumulations of seepage.

3.4.2.4.2 Slope Breakers

Slope breakers are typically coordinated with trench breakers, such that trench seepage is temporarily (i.e. in the short-term) intercepted by trench breakers and discharged to the ground surface (i.e. seepage builds up behind the trench breaker over a short period of time) until it ‘daylights’ at the ground surface), where slope breakers placed just downslope of the trench breakers divert the water to the side of the ROW into a stable and erosion protected area. Slope breakers should also be coordinated with permanent and temporary access roads, to avoid concentration from multiple sources of water on the ROW or at locations along the edge of the ROW.

Slope breakers are typically constructed using the local ROW soils to form low berms (i.e. water bars) that reach across the disturbed ROW surface. Steep ground or limited supply of local materials to build slope breakers may require constructing them using sand bags, sack-crete, or even rock materials in order to develop the intended function. In planar (i.e. generally flat) sloping ground, slope breakers are typically configured as linear sloping berms with an upslope-side ditch that conveys surface flows, that are placed in parallel configurations down the slope at uniform or variable spacing to fit the slope grades (i.e. steeper grades have closer spacing, and flatter grades have increased spacing). Breakers are typically oriented to discharge surface flows off the ROW, not back onto the ROW, and to avoid discharging flows onto downslope breakers. Where discharges cannot be directed off the ROW, then an armored channel or other conveyance may be needed to carry flows (down the slope) to a suitable discharge location. The upslope-side of the breaker may be armored with riprap, erosion control cloth, vegetated, or even include drains to address seeps or increased runoff. The discharge point at the down-gradient end of the breaker may have a small erosion resistant pad of armor rock or method of erosion protection, bedrock, or may discharge to stable native vegetation. In variable ground conditions, the slope breaker configurations may include alternating the orientation to discharge on opposite sides of the ROW, overlap individual breakers to cover changes in ground topography in order to manage runoff, or create “chevron” shaped breakers that conform to variable topographic conditions. The final geometry and configuration often requires site-specific review and planning to be fit for purpose.

Sack-crete or similar materials are frequently used to build slope breakers, re-build the ROW where slope breakers are needed, or to stabilize trench and ROW backfill in steep ground conditions. As such, they can come in many forms and shapes to fit variable site conditions. These structures are typically built using individually stacked bags of sack-crete to form a structure that fits varying ground conditions. They are often used to re-establish, re-contour or stabilize trench backfill in bedrock conditions where the finer grained trench padding, bedding and backfill is used through cuts into bedrock. Because sack-crete breakers are essentially impermeable, these structures require additional drainage measures to collect and evacuate potential accumulation of trench and ROW backfill seepage flows. This is typically required to address the modified trench excavation in bedrock conditions, which can create focused trench seepage where it was previously not occurring (i.e. used to be bedrock or similar impervious material, and now has a trench with pervious backfill). Adding drainage measures to the trench should be an essential part of the planning, design, and construction effort.

3.4.2.5 Monitoring

Monitoring is a critical component of any site plan, and may be needed after installing mitigation measures. The monitoring plan for a given site must be developed based on the site specific requirements. Typical components include:

- Periodic visits and reconnaissance at sites;
- Geodetic monitoring points (i.e. survey bench marks) to track potential ground movement;
- Slope inclinometers to track ground movement at depth;
- Standpipe piezometers to track changes in groundwater conditions; and
- Strain gauges installed on the pipeline to measure and track potential accumulation of strain in the pipeline.

Monitoring may also include aerial mapping to track changes in ground conditions using remote sensing methods for a targeted site or at a larger pipeline system scale.

3.4.2.6 Stress Relief Excavations

Where landslide movement results in lateral and vertical displacement of the ground around a pipeline, the movement can result in strain accumulation in the pipeline. The accumulated strain can be greater where the pipeline passes across the lateral or vertical limits of a landslide, or at the boundaries of the landslide with the surrounding stable ground. These locations are where landslide shear stresses tend to be concentrated.

An option for mitigating the accumulated strain in the pipeline in this scenario includes excavating the trench backfill material and surrounding local soil within the landslide mass, and extending some distance beyond the transition zone into the stable ground. The removal of the backfill and nearby soil allows the pipeline to physically rebound to a pre-deformation geometry that eliminates, or significantly reduces, the accumulated strain in the pipeline. This is commonly referred to as “stress relief excavation,” or also “strain relief excavation.” There may be more complex interactions of the soil mass within and outside the landslide mass that result in combinations of horizontal and vertical displacements. These more complex relationships of ground movement must be assessed and determined on a case-by-case basis, and are specific to the site conditions. The landslide and pipeline interactions are addressed in simple terms herein, for the purpose of describing the concept of this mitigation option. Additional planning and design is needed to implement this type of mitigation action.

The following discussion does not address operational or safety planning for a given site. These requirements are assumed to be addressed by the owner/operator to fit the site-specific requirements.

Stress relief excavations typically start in the middle of the landslide mass and extend in one or both directions toward the lateral landslide limits, and to some point into the immobile ground beyond the landslide limits where rebound of the pipeline is no longer observed. This is the ideal situation but certainly not the only way to complete this work. The implementation plan for stress relief excavations may need to be modified to fit site conditions, in particular to allow for access and practical mobilization of equipment and project resources, as well as to maintain a safe working site. Access to complete the work is a common challenge; most landslide sites are located in difficult terrain and may have limited access once the excavation has been started.

For example, starting the stress relief excavation on one side of the landslide and moving through it and into the other side may eliminate access to the start point, or may remove ROW materials, or place spoils in a way that makes it difficult to return to the start point if additional excavations along the pipeline are needed again at the start point. Careful planning is needed to coordinate the construction work with the planned mitigation requirements, as well as for related monitoring efforts, to best fit the purpose and site conditions.

Stress relief excavations are commonly implemented as an immediate response action shortly after pipeline displacement is identified, in order to re-establish a baseline condition; and subsequent stress relief excavations may be implemented as a recurring operational activity over time, which may span years or decades. Trench drainage improvements are commonly installed at the same time the stress relief excavations are completed (and the trench and ROW are backfilled).

The use of stress relief excavations as a mitigation technique over the long term typically includes monitoring. Monitoring for stress relief excavation efforts can include a range of methods to address slope (i.e., landslide) movement, and the effects on the pipeline, such as:

- Periodic site reconnaissance (visual monitoring) of the landslide;
- Geodetic surveys of slope monitoring points placed on and surrounding the landslide;
- In-situ monitoring of landslide deformation (i.e. slope inclinometers);
- Tracking of local ground water levels (i.e. piezometers) installed in the landslide; and

- Strain gauges installed directly on the pipeline to measure and record potential accumulation of strain in the pipeline.

The use of strain gauges is critical and recommended as a minimum monitoring tool in conjunction with stress relief excavations. This allows the owner/operator to track potential accumulation of strain in the pipeline, and determine when additional stress relief excavations are needed. It also allows for the monitoring of strain reduction during stress relief excavation.

The accumulation of strain in the pipeline can be attenuated (i.e. for an increment of ground movement around the pipeline, a corresponding reduced amount of movement that actually displaces the pipeline) by installing select “deformable” backfill. The select, deformable backfill allows for some movement of the backfill relative to the pipeline as the ground around it moves, before the movement begins to impact the pipeline. The use of deformable backfill does not preclude continued stress relief excavations, or other site mitigation work. It does typically extend the time between successive stress relief excavation efforts.

The amount of attenuation of ground movement by the select backfill is not expected to be a one-to-one relationship. The typical performance goal is only to reduce relative displacement of the pipeline, and the actual amount of reduced displacement should be tracked through monitoring and addressed through maintenance activities, as needed. Select deformable backfill is typically a loosely placed, granular, clean sand-type material with little or no fines (i.e., < 5 percent fines). The select deformable backfill is placed in a sloped wall trench all around the pipeline, allowing for more material along the horizontal and/or vertical direction and orientation of the expected ground movement. Typical dimensions for deformable backfill relative to the pipeline should match, at a minimum the expected horizontal and/or vertical ground displacement. The properties of the select backfill also have enhanced drainage performance, which may be incorporated into the overall mitigation planning and design for the site, and are addressed in detail in subsequent sections herein.

4.0 APPLIED MITIGATION GUIDANCE

The following sections provide applied mitigation guidance for the Typical Scenarios listed below, along with corresponding discussion and guidance on supporting Typical Details (i.e. individual mitigation measures) for mitigation of landslide and erosion hazards (Williams 2015). The following Typical Scenarios are addressed:

- Side Slopes, sub classified normal (Appendix A-1, Sheet 1110) and oblique (Appendix A-1, Sheet 1120) orientation to pipeline;
- Ridge Tops (Appendix A-1, Sheet 1130);
- Inclined Ridges (Appendix A-1, Sheet 1140);
- Planar Slopes (Appendix A-1, Sheets 1150 and 1160);
- Convergent Topography (Appendix A-1, Sheet 1170);
- Shallow Bedrock (Appendix A-1, Sheet 1500);
- Areas of Fill Soil (Appendix A-1, Sheet 1600); and
- Landslides (Appendix A-1, Sheets 1710, 1720, 1730, and 1740).

These Typical Scenarios help to define the geotechnical and hydrotechnical engineering and geologic hazard processes corresponding to each defined scenario, providing a practical framework for describing the hazards or threats that may be impacting the pipeline at a particular location. They support and guide informed decisions on conceptual design, selection and planning of individual mitigation measures needed at a site.

Each Typical Scenario includes a cross-section or topographic representation to help graphically describe the scenario and a library of corresponding Typical Details that are applicable to the defined scenario. The Typical Detail sheets look like “fly-sheets” or “cut sheets” and depict a single mitigation measure (i.e. silt fence, or compaction, or a targeted drain feature, etc.). This approach allows for easily adding or updating the library of measures, while maintaining the governing framework for defining and characterizing the applicable hazards and threats to the pipeline. The intent is not to use or implement all the Typical Details at any given site, but to offer options for solutions that should be selected based on the applicable site conditions.

The intent of the combined Typical Scenario and Typical Details package is to provide a conceptual framework for describing the site-specific hazards and applicable mitigation measures to address those hazards. The final selection of individual mitigation measures for any given site, and the proposed locations and extents where those measures should be installed, must be confirmed through site specific observations, investigations and studies, and should include careful consideration of construction processes. This information is typically combined with a site-specific topographic based plan (i.e. contour or site survey data), in order to provide coordinate locations and extents for specific mitigation measures relative to the topographic locations, or shown relative to site-specific cross-sections and profiles.

4.1 Side Slope Conditions

The portions of a pipeline route that cross side slopes may encounter more geotechnically sensitive areas versus routing straight up/down the fall line of a slope or along a ridge, because the route will likely cross more existing native landslides or landslide-susceptible slopes, intercept more catchment areas delivering run-off to the ROW, and intercept more potential near-surface seepage and groundwater. In addition, side slope areas typically require the construction of wide, benched work areas where the upslope side of the construction ROW is cut into the hillslope, the excavated material from which is then placed as temporary fill on the downslope side of the ROW. The cut into native slopes and placement of fill on native slopes can have a destabilizing effect on the native ground.

Side slopes have been further categorized herein as either 'side slope normal' or 'side slope oblique' based on the orientation of the proposed pipeline relative to the hillslope. Side slope normal describes areas where the proposed path of the pipeline and/or construction ROW and work zones are generally oriented parallel to the contours. Side slope oblique describes areas where the proposed path of the pipeline and construction ROW and work zones are generally oriented oblique (i.e. at an angle) to either the fall line or the contour of the slope. Special consideration is needed in side slope oblique areas because the surface water and groundwater being intercepted by the ROW and/or pipeline trench will be directed toward, and channelized by, the pipeline trench. Trench fill blowouts commonly occur in side slope oblique conditions if a sufficient amount of water is intercepted by the pipeline trench and adequate measures are not installed to slow and redirect surface and trench water flow. Generally, steep side slope conditions with shallow groundwater or surface water present are the most likely areas to experience landslides, trench backfill blowouts, and surface erosion.

4.1.1 Engineering/construction recommendations for side slope normal

In a side-slope normal scenario (Appendix A-1, Sheet 1110), the pipeline trench typically has a flat or shallow gradient, running along the contour of the slope. The construction disturbance, temporary excavation surface, and trench in a side-slope normal scenario intercept runoff and drainage. The accumulated seepage can cause the native soil and/or fill to become saturated. The result is unstable backfill that can be destabilized, and may retrogress outside the easement work area and may initiate or reactivate existing adjacent native landslides. Restoration measures in this scenario need to focus on reducing surface and near-surface flow to the trench and backfill. The accumulated seepage also must be drained from the backfill and trench in a practical and efficient way. The restoration measures may need to extend outside the actual ROW footprint to mitigate the possibility of initiating broader slope instability.

Typical conceptual restoration measures used in side slope normal conditions may include:

1. Generally re-contour the restored ROW to re-establish pre-construction contours (Appendix A-2, Sheet 2G), except where targeted site assessments recommend reducing backfill over unstable or landslide areas (Appendix A-2, Sheet 2H).
2. Grade the temporary ROW construction surface (Appendix A-2, Sheet 2A) so that it drains away from the inside of the cut. The objective is to minimize the potential for infiltrated water to accumulate, or tend to move along the transition from the disturbed ROW areas and the undisturbed temporary ROW surface (i.e. the native ground). An additional objective is to avoid a situation where the excavated colluvium and residual soils are stockpiled in a manner that traps water, causing the excavated soils to become saturated prior to backfilling the ROW. Temporary construction surfaces need to be incorporated into the final site drainage configuration to limit potential for saturation of the backfill and native soils.
3. Grade the temporary ROW surface and depth of the pipeline trench to allow for a stable outboard wedge of soils/rock material adjacent to the pipeline trench (to the out-slope side), see Appendix A-2, Sheet 2B. This maintains a protective stable section of ground on the outboard slope side of the pipeline trench that mitigates for potential raveling, degradation, landslide or other slope instability or erosion processes that may impact the pipeline.
4. Cut bleeder trenches (Appendix A-2, Sheet 1D) into the downslope side of the pipeline trench at an approximate 100-foot spacing, or to match the local topography. Bleeders should be cut down to the bottom of the pipeline trench excavation, and then slope to drain out through native soil or rock (i.e. not in fill) and discharge on stable ground. Bleeders can be enhanced by adding geotextile wrapped drain rock, and/or drainage pipe (i.e. French drains). The objective of bleeder trenches is to provide drainage relief points at regular intervals, so that as seepage accumulates, it finds an outlet from the trench.

5. Install brow ditches (Appendix A-2, Sheet 6B) excavated into the ground, slope breakers (Appendix A-2, Sheets 5A and 5B), a combination of built-up and excavated water bars and armored channels with drain pipes (Appendix A-2, Sheets 1F, 1H and 1E) along the upslope side of the ROW to intercept and divert surface run-off to stable locations away from the side slope areas. The need and layout of these depends on the topography, for instance if there is no stable location to discharge the intercepted water. In this case, rely more on other measures.
6. Where surface run-off from one or more slope breakers, or other surface or near surface water sources needs to be conveyed down steep slopes that may be subject to erosion, consider using armored channels with an apron at the discharge (Appendix A-2, Sheet 1F and 1E), or in steep terrain the armored channel and more robust drainage piping may be needed (Appendix A-2, Sheet 1H and 1E).
7. Compact the backfill (Appendix A-2, Sheet 2C) during side slope ROW reconstruction. This adds strength to the backfill to make it more stable, and reduces infiltration of water. Achieving compaction in steep and rugged terrain is difficult. Recommended methods include use of sheep's-foot rollers pulled behind a dozer, a self-propelled sheep's-foot compactor or sheep's-foot roller attached to an excavator arm.
8. Where the local soils are not suitable for backfill and/or compaction, for example due to the sensitive nature of the local fine-grained soils or excessive moisture content, it may be necessary to haul the unsuitable material off the site. These materials should not be stockpiled or spoiled in areas that may initiate or exacerbate landslides (Appendix A-2, Sheet 2E). Replace with a free-draining, angular, clean, small sized (i.e. min 4 to 8 inch) rock backfill (Appendix A-2, Sheets 2F and 3D). This kind of rock backfill can stand up at steep angles, does not hold water, is very stable, and adjusts to future changes in the site and ground conditions (i.e. settlement, continued slip movement, etc.). Drying soils (Appendix A-2, Sheet 2D) used as backfill materials can be achieved by spreading the soil in windrows and actively working the windrows until the soil achieves a suitable moisture content. Low humidity and warm temperatures are needed to make this work. An alternative is the use of lime or cement kiln dust, or a similar product, as an additive to wet soils to help facilitate more optimal moisture content. Lime or cement kiln dust is added and mixed with targeted soils, following the manufacturers recommendations, until a suitable soil condition is achieved. Use of the lime or cement kiln dust allows for working in wetter conditions. Mixing rates and methods need to be calibrated to site conditions and may require experimenting to find the right blend for implementation.
9. Install a French drain (Appendix A-2, Sheets 1A and 1E) along the inside catch of the constructed temporary ROW surface at the transition from disturbed soils (i.e. where the backfill starts) and the undisturbed native soils. Drains should discharge at stable locations downslope of the backfill areas so that it does not recharge the backfill.
10. Install drains (Appendix A-2, Sheet 1C and 1E) where seeps or other subsurface water sources are identified during temporary ROW construction.
11. Install slope breakers or other surface diversion berms to intercept surface run-off, or combine slope breakers/berms with armored channels to control run-off (Appendix A-2, Sheets 1E, 1F, 5A, 5B, 5C, and/or 6D).
12. Special consideration is needed to construct and restore drainage measures for existing, permanent and temporary access roads on a site-specific basis. Access roads may collect runoff from upslope areas, increasing the contributing basin area draining to any given site, and deliver water to the ROW, the pipeline trench or to other areas of concern. Use drainage measures such as slope breakers, water bars, grading to improve drainage, French drains, enhanced drains, armoring, armored ditches with drain pipes, rock fill, etc. (Appendix A-2, Sheet 5D) to manage and mitigate drainage issues.

13. Cover disturbed area with erosion control fabric (Appendix A-2, Sheet 3C) or other functional erosion resistant ground covering to mitigate over the short-term until the local vegetation can take over and establish itself. In especially unstable and steep slope conditions, erosion control products such as armor rock may be needed (Appendix A-1, Sheet 3D).
14. Track disturbed slopes (Appendix A-2, Sheet 3A) and re-vegetate all disturbed areas to provide long-term surface stabilization (i.e. replace the short-term erosion control fabric protection).

4.1.2 Engineering/construction recommendations for side slope oblique

In side-slope oblique scenarios (Appendix A-1, Sheet 1120), the same conditions apply as in the previous discussions for side slope normal scenarios, but intercepted seepage flows can be accelerated by the sloping gradient of the trench as it tracks along the side slope at the oblique angle. The higher seepage velocities result in an increased potential for instability and erosion issues (both “piping erosion” and surface erosion). All the recommended typical conceptual restoration measures for normal side slope conditions apply (as described above in 4.1.1), with the addition of the following to address the oblique conditions:

1. Drainage pipes in the pipeline trench are needed to mitigate for the increased gradient and seepage velocities resulting from the sloping trench (i.e. due to the oblique orientation of the trench along the side slope). The bleeder trenches used in side slope normal scenarios may not provide enough drainage relief, and on sloped ground may actually discharge back into the trench. Drainage pipes can be configured as French drains (Appendix A-2, Sheets 1A and 1E) for normal or low flow conditions, with discharge points at the edge of the ROW on stable ground and with erosion pads. Where excessive seepage along the trench may be a problem, then the piping configuration should be modified to include perforated drain pipes that collect water and feed into solid-smooth-interior-walled tightline pipes that convey it away (i.e. enhanced drains, Appendix A-2, Sheets 1B and 1E).
2. Install trench breakers (Appendix A-2, Sheet 4A), preferably using sandbags, at spacing and locations corresponding to the trench slope (not necessarily the ground slope, which may be much steeper). Where foam materials are used for the trench breakers, there should be drainage measures incorporated into breakers that mitigate for accumulation of seepage on the upslope side of the breaker, allowing it to drain through the breaker.

Modifications or alternatives to the above described measures that are feasible and maintain the function and intent as described and offer practical alternatives are encouraged.

4.2 Ridge Tops

Ridge tops (Appendix A-1, Sheet 1130) are defined as areas where the proposed path of the pipeline and/or construction ROW and work zones are located longitudinally (i.e. running along the ridge) along hilltops with average slopes that are shallow, generally not exceeding about 15 percent grade. Ridge tops are the preferable route for a pipeline because they avoid stream crossings, have little or no contributing catchment delivering water (i.e. minimizes seepage and drainage issues) and they avoid many of the sensitive geotechnical areas that will be encountered on side slopes and planar slopes. Landslides rarely occur at ridge tops. However, native landslides may be present on the side slopes on either side of the ridge top. If the pipeline or work areas deviate from the ridge top, or cross up and over it, then side slope conditions and landslide conditions may be encountered. Depth to bedrock is commonly shallow at ridge tops and may be encountered within the design pipeline depth.

4.2.1 Engineering/construction recommendations for ridge tops:

In ridge top scenarios, the backfill has less potential for becoming saturated and can drain to stable ground along either side of the ridge, reducing the potential for focusing seepage flows. Typical conceptual restoration measures used in ridge top conditions may include:

1. Generally re-contour the restored ROW to re-establish pre-construction contours (Appendix A-2, Sheet 2G), except where site assessments recommend reducing backfill over unstable or landslide areas (Appendix A-2, Sheet 2H).
2. Grade the temporary ROW construction surface (Appendix A-2, Sheet 2A) so that it drains away from the inside of the cut. The objective is to minimize the potential for infiltrated water to accumulate, or tend to move along the transition from the disturbed ROW areas and the undisturbed temporary ROW surface (i.e. the native ground). An additional objective is to avoid a situation where the excavated colluvium and residual soils are stockpiled in a manner that traps water, causing the excavated soils to become saturated prior to backfilling the ROW. Temporary construction surfaces need to be incorporated into the final site drainage configuration to limit potential for saturation of the backfill and native soils.
3. Grade the temporary ROW surface and depth of the pipeline trench to allow for a stable outboard wedge of soils/rock material adjacent to the pipeline trench (to the out-slope side, Appendix A-2, Sheet 2B). This maintains a protective stable section of ground on the outboard slope side of the pipeline trench that mitigates for potential raveling, degradation, landslide, or other slope instability or erosion processes that may impact the pipeline. On ridge tops, this may be on both sides of the pipeline trench.
4. Drying soils (Appendix A-2, Sheet 2D) used as backfill materials can be achieved by spreading the soil in windrows and actively working the windrows until the soil achieves a suitable moisture content. Low humidity and warm temperatures are needed to make this work. An alternative is the use of lime or cement kiln dust, or a similar product, as an additive to wet soils to help facilitate more optimal moisture content. Lime or cement kiln dust is added and mixed with targeted soils, following the manufacturers recommendations, until a suitable soil condition is achieved. Use of lime or cement kiln dust allows for working in wetter conditions. Mixing rates and methods need to be calibrated to site conditions and may require experimenting to find the right blend for implementation.
5. Compact the backfill during side slope ROW reconstruction. This adds strength to the backfill to make it more stable, and reduces infiltration of water.
6. Where the local soils are not suitable for backfill and compaction, for example due to the sensitive nature of the local fine-grained soils or excessive moisture content, it may be necessary to haul that unsuitable material off the site. These materials should not be stockpiled or spoiled in areas that may initiate or exacerbate landslides (Appendix A-2, Sheet 2E). Replace with a free-draining, angular, clean, small-sized (i.e. min 4- to 8-inch) rock backfill (Appendix A-2, Sheets 2F and 3D). This kind of rock backfill can stand up at steep angles, does not hold water, is very stable and will adjust to future changes in ground conditions (i.e. settlement, continued slip movement, etc.).
7. Special consideration is needed to construct and restore drainage measures for existing, permanent, and temporary access roads, on a site specific basis. Access roads may collect runoff from upslope areas, thereby increasing the contributing basin area draining to any given site, and deliver water to the ROW, the pipeline trench, or to other areas of concern. Use drainage measures, as described in this study, to manage and/or mitigate drainage issues, such as slope breakers, water bars, grading to improve drainage, French drains, enhanced drains, armoring, armored ditches with drain pipes, rock fill, etc. (Appendix A-2, Sheet 5D).

8. Cover disturbed area with erosion control fabric (Appendix A-2, Sheet 3C), or other functional erosion resistant ground coverings to mitigate over the short-term until the local vegetation can take over and establish itself.
9. Track disturbed slopes (Appendix A-2, Sheet 3A) and re-vegetate all disturbed areas to provide long-term surface stabilization (i.e. replace the short-term erosion control fabric protection).

Modifications or alternatives to the above described measures that are feasible and maintain the function and intent as described and offer practical alternatives are encouraged.

4.3 Inclined Ridges

Inclined ridges (Appendix A-1, Sheet 1140) are defined herein as areas where ridge tops have average slopes that generally exceed about 15 percent grade. Special construction planning and equipment may be needed to operate in these rugged and steep conditions. Inclined ridges commonly cross alternating zones of shallow bedrock and thick soils as a result of local geologic conditions. Native landslides are less-likely to be crossed where the pipeline follows an inclined ridge, and stream crossings are not likely. However, landslides originating in post-construction ROW backfill may occur if the nature and the placement method of the backfill are not adequate to achieve stability, especially if the post construction ROW grade is similar to the steep and often stepped topography of the adjacent native slopes. Near-surface groundwater may be encountered at cuts, especially where a cut is made into the interlayered, water- bearing bedrock units. If the pipeline and/or work areas deviate from the inclined ridge crest, side slope conditions may be encountered.

4.3.1 Engineering/construction recommendations for inclined ridges:

For inclined ridge top scenarios, similar to the ridge top scenario, there is less potential for the backfill to become saturated. Typically, water can drain to stable ground along either side of the ridge, reducing the potential for focusing seepage flows. As such, the recommendations described previously for ridge tops are the same. What the inclined condition creates is a gradient for seepage flows, requiring mitigation to slow and manage seepage flows along the trench. Typical conceptual measures used in inclined ridge conditions may include:

1. Generally re-contour the restored ROW to re-establish pre-construction contours (Appendix A-2, Sheet 2G), except where site assessment recommends reducing backfill over unstable or landslide areas (Appendix A-2, Sheet 2H).
2. Grade the temporary ROW construction surface (Appendix A-2, Sheet 2A) so that it drains away from the inside of the cut. The objective is to minimize the potential for infiltrated water to accumulate or tend to move along the transition from the disturbed ROW areas and the undisturbed temporary ROW surface (i.e. the native ground). An additional objective is to avoid a situation where the excavated colluvium and residual soils are stockpiled in a manner that traps water, causing the excavated soils to become saturated prior to backfilling the ROW. Temporary construction surfaces need to be incorporated into the final site drainage configuration to limit the potential for saturation of the backfill and native soils.
3. Grade the temporary ROW surface and depth of the pipeline trench to allow for a stable outboard wedge of soils/rock material adjacent to the pipeline trench (to the out-slope side, Appendix A-2, Sheet 2B). This maintains a protective stable section of ground on the outboard slope side of the pipeline trench that mitigates for potential raveling, degradation, landslide, or other slope instability or erosion processes that may impact the pipeline. On ridge tops, this may be on both sides of the pipeline trench.
4. Drying soils (Appendix A-2, Sheet 2D) used as backfill materials can be achieved by spreading the soil in windrows and actively working the windrows until the soil achieves a suitable moisture content. Low humidity and warm temperatures are needed to make this work. An alternative is the use of lime or cement kiln dust, or a

similar product, as an additive to wet soils to help facilitate more optimal moisture content. Lime or cement kiln dust is added and mixed with targeted soils, following the manufacturers recommendations, until a suitable soil condition is achieved. Use of lime or cement kiln dust allows for working in wetter conditions. Mixing rates and methods need to be calibrated to site conditions and may require experimenting to find the right blend for implementation.

5. Compact the backfill during side slope ROW reconstruction. This adds strength to the backfill to make it more stable, and reduces infiltration of water.

6. Where the local soils are not suitable for backfill and/or compaction, for example due to the sensitive nature of the local fine-grained soils or excessive moisture content, it may be necessary to haul that unsuitable material off the site. These materials should not be stockpiled or spoiled in areas that may initiate or exacerbate landslides (Appendix A-2, Sheet 2E). Replace with a free-draining, angular, clean, small-sized (i.e. min 4- to 8-inch) rock backfill (Appendix A-2, Sheets 2F and 3D). This kind of rock backfill can stand up at steep angles, does not hold water, is very stable, and will adjust to future changes in ground conditions (i.e. settlement, continued slip movement, etc.).

7. Install drains (Appendix A-2, Sheets 1C and 1E) where seeps or other subsurface water sources are identified during the temporary ROW construction.

8. Where surface run-off from one or more slope breakers or other water sources needs to be conveyed down steep slopes that may be subject to erosion, consider using armored channels with an apron at the discharge (Appendix A-2, Sheet 1F and 1E). For steep terrain the armored channel and more robust drainage piping may be needed (Appendix A-2, Sheet 1H and 1E).

9. Drainage pipes in the pipeline trench are needed to mitigate for the increased gradient and seepage velocities resulting from the sloping ridge top. Drainage pipes can be configured as French drains (Appendix A-2, Sheets 1A and 1E) in low seepage flow conditions, with discharge points at the edge of the ROW on stable ground and/or with erosion pads. Where excessive seepage along the trench may be a problem, then the piping configuration should be modified to include perforated pipes that collect water and feed into solid-smooth-interior-walled tightline pipes that convey it away (i.e. enhanced drains, Appendix A-2, Sheets 1B and 1E).

10. Install Slope breakers (a.k.a. water bars) along the ROW at spacing and orientations that intercept and direct surface run-off to stable and (preferably) vegetated areas along and off the ROW. Slope breaker spacing is typically governed by slope angle and/or the presence of trench breakers (Appendix A-2, Sheet 5A). In steep slope conditions, a slope breaker should be placed just below a trench breaker, so that seepage that is pushed to the surface by the trench breaker is then captured by the slope breaker and diverted off the ROW. Final spacing and placement of breakers should incorporate site specific information. Where excessive run-off may need to be mitigated, then slope breakers can be discharged to an armored ditch or diversion channel (Appendix A-2, Sheets 5C, 6D, 1F and 1E).

11. Install trench breakers (Appendix A-2, Sheet 4A), preferably using sandbags, at spacing and locations corresponding to the trench slope (not necessarily the ground slope, which may be much steeper). Where foam materials are used for the breakers, there should be drainage measures incorporated into breakers that mitigate for accumulation of seepage on the upslope side of the breaker, allowing it to drain through the breaker.

12. Install sack-crete breakers (Appendix A-2, Sheet 4C) in areas where the trench and slopes are steep and the breaker is needed to retain and/or stabilize the trench backfill. These structures may be configured to provide a foundation for imported backfill, retain backfill in the trench itself on steep terrain, or to stabilize larger portions

of the ROW area or larger trench and slope backfill areas. Because these structures can be large and encompass an extended length of the pipeline, install a sleeve interface (geotextile fabric, rock-shield, etc.) between the pipeline and the structure to provide a slip separation, and to avoid transfer of loading from the trench backfill through the structure to the pipeline (Appendix A-2, Sheet 4D).

13. Where the pipeline alignment passes through benched terrain, mitigate for complex backfill and drainage conditions by using rock fill, sack-crete breakers, enhanced drainage, or other measures, as needed (Appendix A-2, Sheet 10A). Benched topography can be very complex and may require site specific review to develop a practical and constructible mitigation and restoration package.
14. Special consideration is needed to construct and/or restore drainage measures for existing, permanent, and temporary access roads, on a site specific basis. Access roads may collect runoff from upslope areas, thereby increasing the contributing basin area draining to any given site, and deliver water to the ROW, the pipeline trench, or to other areas of concern. Use drainage measures, as described in this study, to manage and/or mitigate drainage issues, such as slope breakers, water bars, grading to improve drainage, French drains, enhanced drains, armoring, armored ditches with drain pipes, rock fill, etc. (Appendix A-2, Sheet 5D).
15. Cover disturbed area with erosion control fabric (Appendix A-2, Sheet 3C), or other functional erosion resistant ground coverings to mitigate over the short-term until the local vegetation can take over and establish itself.
16. Track disturbed slopes (Appendix A-2, Sheet 3A) and re-vegetate all disturbed areas to provide long-term surface stabilization (i.e. replace the short-term erosion control fabric protection).

Modifications or alternatives to the above described measures that are feasible and maintain the function and intent as described and offer practical alternatives are encouraged.

4.4 Planar Slopes

A planar slope (Appendix A-1, Sheet 1150) is defined as a slope where the proposed path of the pipeline and/or construction ROW and work zones generally follow the fall line down a slope, and includes limited grading to construct the temporary ROW. Refer to Appendix A-1, Sheet 1160 (Planar Slopes Deep Excavation) where deeper or more extensive excavations are needed to grade through variable topography along the slope. Where the pipeline alignment crosses at an angle along the slope, the condition is referred to as side slope (normal or oblique), refer to previous discussion in Section 4.1. Planar slopes commonly have alternating zones of shallow bedrock and thick soils as a result of local geologic conditions and may have stepped topography. Landslides may be present on planar slopes, but the destabilizing effect caused by pipeline construction may be less because the cut runs parallel to the direction of landslide movement, as opposed to side slope conditions where the cut is made perpendicular and across a landslide. Landslides originating in post-construction ROW may occur if the nature and the placement method of the backfill are not adequate to achieve stability, especially if the post construction ROW grade mimics the steep and often stepped topography of the adjacent native slopes. Surface run-off is common on planar slopes, accumulating on the ROW surface and increasing in volume with increasing length of slopes, such that all the run-off is delivered at the bottom of the slope. Near- surface groundwater may be encountered at cuts, especially where a cut is made into any water-bearing bedrock units.

4.4.1 Engineering/construction recommendations for planar slopes

Installing the pipeline down planar slopes typically connects the alignment between ridge tops and lower elevation flat terrain. Construction on planar slopes is common but may include long sections of ROW with steep gradients. The following recommended measures assume that clearing and grading of the temporary ROW surface is generally limited to removal of vegetation and topsoil, and grading for a continuous vertical profile with little or no lateral side-cuts or excavation leveling latitudinal to the pipeline alignment (i.e. following down the fall line of the slope). Where lateral excavations are necessary, recommendations from the side slope scenarios should be considered. Bedrock steps and benches are a common topographic feature along planar slopes. Cutting through the ridges of these steps is often required to build the ROW and excavate the trench, and site specific plans may be required. These present some unique challenges for both short and long-term restoration. Typical conceptual restoration measures used in planar slope conditions may include:

1. Generally re-contour the restored ROW to re-establish pre-construction contours (Appendix A-2, Sheet 2G), except where site assessments recommend reducing backfill over unstable or landslide areas (Appendix A-2, Sheet 2H).
2. Grade the temporary ROW construction surface (Appendix A-2, Sheet 2A) so that it drains positively away from the inside of the cut. The objective is to minimize the potential for infiltrated water to accumulate, or tend to move along the transition from the disturbed ROW areas and the undisturbed temporary ROW surface (i.e. the native ground). An additional objective is to avoid a situation where the excavated colluvium and residual soils are stockpiled in a manner that traps water, causing the excavated soils to become saturated prior to backfilling the ROW. Temporary construction surfaces need to be incorporated into the final site drainage configuration to limit potential for saturation of the backfill and/or native soils.
3. Compact the backfill (Appendix A-2, Sheet 2C) during side slope ROW reconstruction. This adds strength to the backfill to make it more stable, and reduces infiltration of water. Achieving compaction in steep and rugged terrain is difficult. Recommended methods include use of sheep's-foot rollers pulled behind a dozer, a self-propelled sheep's-foot compactor, or sheep's-foot roller attached to an excavator arm.
4. Install drains (Appendix A-2, Sheets 1C and 1E) where seeps or other subsurface water sources are identified during the temporary ROW construction.
5. Where deeper excavations along the planar slope are required to construct the temporary ROW, resulting in cut slopes and lowered grades that cannot drain to an outboard natural slope (i.e. laterally confined drainage areas), then install armored channels with drains in shallow excavation areas (Appendix A-2, Sheet 1F or 1H in steep ground), or install French drains (Appendix A-2, Sheet 1A) in deeper excavation areas.
6. Where surface run-off from one or more slope breakers or other water sources needs to be conveyed down steep slopes that may be subject to erosion, consider using armored channels with an apron at the discharge (Appendix A-2, Sheet 1F and 1E). In steep terrain the armored channel and more robust drainage piping may be needed (Appendix A-2, Sheet 1H and 1E).
7. Where the local soils are not suitable for backfill and/or compaction, for example due to the sensitive nature of the local fine-grained soils or excessive moisture content, it may be necessary to haul that unsuitable material off the site. These materials should not be stockpiled or spoiled in areas that may initiate or exacerbate landslides (Appendix A-2, Sheet 2E). Replace with a free-draining, angular, clean, small sized (i.e. min 4- to 8-inch) rock backfill (Appendix A-2, Sheets 2F and 3D). This kind of rock backfill can stand up at steep angles, does not hold water, is very stable, will adjust to future changes in the ground conditions (i.e. settlement, continued slip movement, etc.).
8. Drying soils used as backfill materials can be achieved by spreading the soil in windrows and actively working the windrows until the soil achieves a suitable moisture content (Appendix A-2, Sheet 2D). Low humidity and warm temperatures are needed to make this work. An alternative is the use of lime or cement kiln dust, or a similar product, as an additive to wet soils to help facilitate more optimal moisture content.

Lime or cement kiln dust is added and mixed with targeted soils, following the manufacturers recommendations, until a suitable soil condition is achieved. Use of lime or cement kiln dust allows for working in wetter conditions. Mixing rates and methods need to be calibrated to site conditions and may require experimenting to find the right blend for implementation.

9. In cases where bedrock steps or benches (Appendix A-2, Sheet 10A) have been blasted or ripped to build the ROW and the trench, these spoil materials may be used, crushed, or re-processed to provide a more suitable backfill rock material that can be handled and placed as needed to rebuild and restore the ROW. Restoring rock benches to re-create the pre-project bench geometry may not be possible, and is typically very difficult to achieve. Backfill through rock benches should use angular rock materials to create safe slopes and provide the required cover over the pipeline trench. Use of fine-grained soils in rock cuts should be avoided, and would require additional special drainage measures and possible engineered stabilization of the soil backfill. Use of angular rock fill eliminates these requirements.

10. Drainage pipes in the pipeline trench are needed to mitigate for the increased gradient and seepage velocities resulting from the sloping trench (i.e. due to the oblique orientation of the trench along the side slope). Drainage pipes can be configured as French drains (Appendix A-2, Sheets 1A and 1E) in areas of low seepage flows or at inside cut areas along the temporary ROW constructed surface. Where excessive seepage along the trench may be a problem on steep slopes, the piping configuration should be modified to include perforated corrugated pipes that collect water and feed into solid-smooth-interior-walled tightline pipes that convey it away (i.e. enhanced drains, Appendix A-2, Sheets 1B and 1E). Drainage pipes should have discharge points at the edge of the ROW on stable ground and/or with erosion pads.

11. Install Slope breakers (a.k.a. water bars) along the ROW at spacing and orientations that intercept and direct surface run-off to stable and (preferably) vegetated areas along and off the ROW, away from sensitive areas such as landslides. Slope breaker spacing is typically governed by slope angle and/or the presence of trench breakers (Appendix A- 2, Sheet 5A). In steep slope conditions, a slope breaker should be placed just below a trench breaker, so that seepage that is pushed to the surface by the trench breaker is then captured by the slope breaker and diverted off the ROW, and away from sensitive areas such as landslides. Final spacing and placement of breakers should incorporate site specific information. Where excessive run-off may need to be mitigated, then slope breakers can be discharged to an armored ditch or diversion channel (Appendix A-2, Sheets 5C, 6D, 1F and 1E).

12. Install trench breakers (Appendix A-2, Sheet 4A), preferably using sandbags, at a spacing and location corresponding to the trench slope (not necessarily the ground slope, which may be much steeper). Where foam materials are used for the breakers, there should be drainage measures incorporated into breakers that mitigate for accumulation of seepage on the upslope side of the breaker, allowing it to drain through the breaker.

13. Install sack-crete breakers (Appendix A-2, Sheet 4C) in areas where the trench and slopes are steep and the breaker is needed to retain and/or stabilize the trench backfill. These structures may be configured to provide a foundation for imported backfill, retaining backfill in the trench itself on steep terrain, or to stabilize larger portions of the ROW area or larger trench and slope backfill areas. Because these structures can be large and encompass an extended length of the pipeline, install a sleeve interface (geotextile fabric, rock-shield, etc.) between the pipeline and the structure to provide a slip separation, and to avoid transfer of loading from the trench backfill through the structure to the pipeline (Appendix A-2, Sheet 4D).

14. Special consideration is needed to construct and/or restore drainage measures for existing, permanent, and temporary access roads, on a site specific basis. Access

roads may collect runoff from upslope areas, thereby increasing the contributing basin area draining to any given site, and deliver water to the ROW, the pipeline trench, or to other areas of concern. Use drainage measures, as described in this study, to manage and/or mitigate drainage issues, such as slope breakers, water bars, grading to improve drainage, French drains, enhanced drains, armoring, armored ditches with drain pipes, rock fill, etc. (Appendix A-2, Sheet 5D).

15. Track disturbed slope areas (Appendix A-2, Sheet 3A), cover disturbed area with erosion control fabric (Appendix A-2, Sheet 3C), or use other functional erosion resistant ground coverings to mitigate over the short-term until the local vegetation can take over and establish itself.
16. Re-vegetate all disturbed areas to provide long-term surface stabilization (Appendix A-2, Sheet 3B) (i.e. to replace the erosion control fabric over the long-term).

Modifications or alternatives to the above described measures that are feasible and maintain the function and intent as described and offer practical alternatives are encouraged.

4.5 Convergent Topography

Convergent topography (Appendix A-1, Sheet 1170) is defined qualitatively as converging dish-shaped drainage basins that have steep slopes. In areas of convergent topography both water and hillslope materials (landslides, colluvium) are focused toward a central location that may intersect the ROW and pipeline trench. Areas of convergent topography are typically source areas for landslides due to increases in water, colluvium and frequently thicker units of residual soils. Depth to bedrock is typically greater in these locations. However, local geologic conditions may result in shallow bedrock conditions where erosion or landslides have removed the surface soils.

4.5.1 Engineering/construction recommendations for convergent topography

Typical conceptual restoration measures in these areas are the same as those described for side slope (Appendix A-1, Sheet 1110 and 1120) and planar slope (Appendix A-1, Sheet 1150 and 1160) conditions.

4.6 Shallow Bedrock

Shallow bedrock (Appendix A-1, Sheet 1500) is defined as areas along a proposed alignment that cross steep rugged terrain that may be underlain by generally flat-lying, alternating layers of sedimentary rock that may include (in areas around northern West Virginia) sandstone, siltstone, shale, limestone, and coal. The limestone and sandstone layers are generally stronger and more competent than the weaker shale, siltstone, and coal layers. The sandstone and limestone may not easily rip at the time of trench excavation and may require hammering, chipping, and blasting, depending on the thickness, jointing and weathering state of the rock. The weaker bedrock layers are typically rippable using standard construction methods.

The natural topography in northern West Virginia appears ‘benched’ or ‘stair-stepped’ as a result of differential weathering and erosion of the flat-lying bedrock layers that alternate between competent bedrock (limestone and sandstone) and the less-competent bedrock (shale, siltstone, and coal). The less competent rock layers are also prone to weathering and the steep slopes may have a thin to thick veneer of highly to completely weathered rock at the surface. More competent rock is likely found on steep slopes with the possible presence of cliff bands, and along narrow inclined ridges and narrow ridge tops.

4.6.1 Engineering/construction recommendations for Shallow Bedrock

Typical conceptual restoration measures used in shallow bedrock conditions may include (but is not limited to):

1. Typical bedrock trench conditions in generally flat terrain may have challenges generating enough material for padding/bedding and for backfill, where the spoils are large and angular resulting from the blasting, ripping or chipping excavations. Rock guard materials may be needed to provide additional protection around the pipeline to allow for irregularities in the trench bottom and oversized materials in the backfill (Appendix A-2, Sheet 8A).

2. In typical ground conditions, install trench breakers (Appendix A-2, Sheet 4A), preferably using sandbags, at a spacing and location corresponding to the trench slope (not necessarily the ground slope, which may be much steeper). Sandbag breakers allow normal seepage to slowly migrate through the breaker. Where needed, piping may be added to allow this slow movement of trench seepage water, and avoid excessive accumulations of seepage water on the upslope side of breakers. Where foam materials are used for the breakers, there should be drainage measures incorporated into breakers that mitigates for accumulation of seepage on the upslope side of the breaker, allowing it to drain through the breaker.

3. In steep rock trench conditions, the backfill may become unstable due to locally over-steepened slopes and/or the contribution of seepage water to the trench. In these conditions, sandbag (Appendix A-2, Sheet 4A) or sack-crete (Appendix A-2, Sheet 4C) trench breakers are effective at retaining trench backfill and stabilizing ROW backfill. The use of sack materials allows for building contour forming structures that have the mass and geotechnical properties to retain backfill soils or rock materials in steep conditions. Use of foam breaker materials is not recommended in steep conditions. Drainage piping should be added to breakers in steep conditions to collect and convey and evacuate accumulated seepage flows.

4. Trench breakers in steep rock trench conditions should have a sleeved interface, such as a geotextile fabric or rock shield material, between the breaker and the pipeline that breaks the bond that may develop between the breaker material and the pipeline (Appendix A-2, Sheet 4D). Where a tight and bonded connection between the pipeline and breaker occurs, the load from the backfill may be transferred to the pipeline, resulting in increased stress conditions.

5. Drainage pipes in the pipeline trench are needed to mitigate for the increased gradient and seepage velocities resulting from the sloping trench (i.e. due to the oblique orientation of the trench along the side slope). Drainage pipes can be configured as French drains (Appendix A-2, Sheets 1A and 1E) where seepage flows are low, with discharge points at the edge of the ROW on stable ground and/or with erosion pads. Where excessive seepage along the trench may be a problem, then the piping configuration should be modified to include perforated corrugated pipes that collect water and feed into solid-smooth-interior-walled tightline pipes that convey it away (i.e. enhanced drains, Appendix A-2, Sheet 1B).

6. Cut bleeder trenches (Appendix A-2, Sheet 1D) into the downslope side of the pipeline trench at an approximate 100-foot spacing, or to match the local topography. Bleeders should be cut down to the bottom of the pipe trench excavation, and then slope to drain out through native soil or rock (i.e. not in fill) and discharge on stable ground. Bleeders can be enhanced by adding geotextile wrapped drain rock, and/or drainage pipeline (i.e. French drains). The objective of bleeder trenches is to provide drainage relief points at regular intervals, so that as seepage accumulates, it finds an outlet from the trench.

7. Install slope breakers (a.k.a. water bars) along the ROW at spacing and orientations that intercept and direct surface run-off to stable and (preferably) vegetated areas along and off the ROW. Slope breaker spacing is typically governed by slope angle and the presence of trench breakers (Appendix A-2, Sheets 4A and 4C). In steep slope conditions, a slope breaker should be placed just below a trench breaker, so that seepage that is pushed to the surface by the trench breaker is then captured by the slope breaker and diverted off the ROW. Final spacing and placement of breakers should

incorporate site specific information. Where slope breakers are not possible, then consider using armored ditches with a drain pipe in the bottom to collect and convey surface run-off (Appendix A-2, Sheets 1F and 1E).

8. Install drains (Appendix A-2, Sheets 1C and 1E) where seeps or other subsurface water sources are identified during the temporary ROW construction.
9. Special consideration is needed to construct and/or restore drainage measures for existing, permanent, and temporary access roads, on a site specific basis. Access roads may collect runoff from upslope areas, thereby increasing the contributing basin area draining to any given site, and deliver water to the ROW, the pipeline trench or to other areas of concern. Use drainage measures, as described in this report, to manage and mitigate drainage issues, such as slope breakers, water bars, grading to improve drainage, French drains, enhanced drains, armoring, armored ditches with drain pipes, rock fill, etc. (Appendix A-2, Sheet 5D).
10. Where the pipeline alignment passes through benched terrain, mitigate for complex backfill and drainage conditions by using rock fill, sack-crete breakers, enhanced drainage or other measures, as needed (Appendix A-2, Sheet 10A). Bench topography can be very complex and may require site specific review to develop a practical and constructible mitigation and restoration package.

Modifications or alternatives to the above described measures that are feasible and maintain the function and intent as described and offer practical alternatives are encouraged

4.7 Areas of Fill Soils

Fill areas are non-standard sites where a significant amount of soil has been placed as a result of other construction-related, mining or other land modification not related to pipeline construction. (Appendix A-1, Sheet 1600). Smaller fills for road and residential/private development work are not addresses herein, because of their relative small size and corresponding relatively small potential for a hazard that may threaten a pipeline. The focus of this Typical Scenario is on larger scale fill areas, where the potential for a threat to the pipeline is increased, and the scale of the fill requires added planning and consideration. Common areas where fill is identified include existing drill pads and pipeline facility pads, valley fills where spoils have been placed as part of mining activities, large road fills, etc. These areas could be susceptible to landslides and erosion if the fill has any or all of the following characteristics:

- Not adequately drained;
- Not suitable material (silt/clay-rich, logs, debris);
- Improperly compacted; and,
- Wet at the time it was placed.

In the case of historical mining activities, the nature, characteristics, and extent of the fill, spoils, or modifications ground conditions can often be researched through publically available mapping information or through coordination with applicable mining companies.

4.7.1 Engineering/construction recommendations for Areas of Fill Soils

In general, it is difficult to provide recommendations for mitigating fill areas, without having relevant site-specific information and considering site specific conditions. As such, fill areas should be addressed on a case-by-case basis, and typically require SME input on the type and nature of the fill; and typically require site specific investigations, analysis, engineering, and corresponding specialized mitigation measures. While fill areas are recognized as an important hazard to be considered, this issue is only addressed in a general sense herein.

4.8 Landslides

Geotechnically sensitive slopes and landslides may be destabilized as a result of pipeline construction when material previously acting to buttress the hillslope is removed along the cut side of the ROW. At these locations, landslides may retrogress and cause damage to property that is upslope of, and outside of, the work area. In addition, landslide-related displaced ground originating at a cut may slide into the work zone and into the pipeline trench creating potential pipeline integrity issues, worker safety issues, and/or work disruptions during construction. Likewise, temporary fill (i.e. spoils and stockpiles) placed on the downslope side of the work area may act as a surcharge load and consequently destabilize existing hillslopes and/or landslides located within and outside of the work zone. A new landslide created by construction activities or an existing landslide that is reactivated by construction activities may involve ground movement that extends tens of feet to hundreds of feet away from or downslope of the work zone and may be difficult and costly to mitigate once the slope begins moving.

In addition to the destabilizing effect of cutting into, or placing soil stockpiles on, existing geotechnically sensitive slopes, landslides may also be initiated in the ROW backfill where existing road ditches, access roads, surface run-off, pipeline trenches, drainage swales, or ephemeral stream channels are crossed by the ROW. In these locations, where multiple sources of water converge at or on the ROW, the surface water is concentrated and the backfill becomes saturated, loses strength, and may become unstable on the slope. Likewise, if near-surface groundwater that was intercepted at a cut is not adequately controlled, it can saturate the ROW backfill and may cause a landslide on the post-construction ROW. Mitigation strategies should therefore be developed for landslide sites that are crossed by the pipeline or fall within the ROW construction limits in order to address short-term construction impacts and long-term operation of the ROW and pipeline.

4.8.1 General Engineering/construction recommendations for Landslides

Identified landslides along a proposed pipeline alignment should be characterized, the potential hazard assessed, and the pipeline constructability through the landslide should be evaluated. In some cases, detailed mitigation recommendations may be required, based on site specific assessments, investigations, and review.

The following provides a brief summary of typical conceptual mitigation measures that may be employed at a landslide site, recognizing that any recommendations should incorporate site specific information:

1. Backfill around the pipeline using select “deformable” materials that allow for some movement of the backfill relative to the pipeline as the ground around it moves, before the movement begins to impact the pipeline, thereby attenuating accumulation of strain in the pipeline resulting from differential ground movement. Deformable backfill is typically a loose granular sand material with little or no fines. The deformable backfill is placed in a sloped wall trench all around the pipeline, allowing for more material along the direction and orientation (i.e. horizontal and vertical) of landslide movement relative to the pipeline. Typical dimensions for deformable backfill relative to the pipeline should match the expected horizontal and/or vertical ground displacement. A filter fabric layer should be included around the backfill to limit the migration of local fine-grained soils into the imported backfill materials (Appendix A-2, Sheet 12B). The properties of the select backfill also have enhanced drainage performance, which can further mitigate landslide hazards, addressed in the following points.
2. Generally re-contour the restored ROW to re-establish pre-construction contours (Appendix A-2, Sheet 2G), except where site assessments recommend reducing backfill over unstable or landslide areas (Appendix A-2, Sheet 2H).
3. Cut bleeder trenches (drains) (Appendix A-2, Sheet 1D) into the downslope side of the pipeline trench at approximately 100-foot spacing, or to match the local topography. Bleeders should be cut down to the bottom of the pipeline trench excavation, and then

slope to drain out through native soil or rock (i.e. not in fill) and discharge on stable ground. Bleeders can be enhanced by adding geotextile wrapped drain rock, and/or drainage pipeline (i.e. French drains). The objective of bleeder trenches is to provide drainage relief points at regular intervals, so that as seepage accumulates, it finds an outlet from the trench.

4. Install brow ditches (Appendix A-2, Sheet 6B) excavated into the ground, slope breakers (Appendix A-2, Sheets 5A and 5B), a combination of built-up and excavated water bars and/or armored channels with drain pipes (Appendix A-2, Sheets 1F, 1H - in steep terrain and 1E) along the upslope side of the ROW to intercept and divert surface run-off to stable locations away from the side slope areas. The need and layout of these depends on the topography. If there is no stable location to discharge the intercepted water, then rely more on other measures.

5. Where surface run-off from one or more slope breakers or other water sources needs to be conveyed down steep slopes that may be subject to erosion, consider using armored channels with an apron at the discharge (Appendix A-2, Sheet 1F and 1E). In steep terrain the armored channel and more robust drainage piping may be needed (Appendix A-2, Sheet 1H and 1E).

6. Grade the temporary ROW construction surface (Appendix A-2, Sheet 2A) so that it drains away from the inside of the cut. The objective is to minimize the potential for infiltrated water to accumulate, or tend to move along the transition from the disturbed ROW areas and the undisturbed temporary ROW surface (i.e. the native ground). An additional objective is to avoid a situation where the excavated colluvium and residual soils are stockpiled in a manner that traps water, causing the excavated soils to become saturated prior to backfilling the ROW. Temporary construction surfaces need to be incorporated into the final site drainage configuration to limit potential for saturation of the backfill and/or native soils.

7. Grade the temporary ROW surface and depth of the pipeline trench to allow for a stable outboard wedge of soils/rock material adjacent to the pipeline trench (to the out-slope side, Appendix A-2, Sheet 2B). This maintains a protective stable section of ground on the outboard slope side of the pipeline trench that mitigates for potential raveling, degradation, landslide, or other slope instability or erosion processes that may impact the pipeline.

8. Compact the backfill (Appendix A-2, Sheet 2C) during side slope ROW reconstruction. This adds strength to the backfill to make it more stable, and reduces infiltration of water. Achieving compaction in steep and rugged terrain is difficult. Recommended methods include use of sheep's-foot rollers pulled behind a dozer, a self-propelled sheep's-foot compactor, or sheep's-foot roller attached to an excavator arm.

9. Drying soils (Appendix A-2, Sheet 2D) used as backfill materials can be achieved by spreading the soil in windrows and actively working the windrows until the soil achieves a suitable moisture content. Low humidity and warm temperatures are needed to make this work. An alternative is the use of lime or cement kiln dust, or a similar product, as an additive to wet soils to help facilitate more optimal moisture content. Lime or cement kiln dust is added and mixed with targeted soils, following the manufacturers recommendations, until a suitable soil condition is achieved. Use of lime or cement kiln dust allows for working in wetter conditions. Mixing rates and methods need to be calibrated to site conditions and may require experimenting to find the right blend for implementation.

10. Haul materials off-site where the local soils are not suitable for backfill and compaction due to the sensitive nature of the local fine-grained soils or excessive moisture content. These materials should not be stockpiled or spoiled in areas that may initiate or exacerbate landslides (Appendix A-2, Sheet 2E). Replace with a free-draining, angular, clean, small sized (i.e. min 4 to 8 inch) rock backfill (Appendix A-2, Sheets 2F

and 3D). This kind of rock backfill can stand up at steep angles, does not hold water, is very stable, and will adjust to future changes in ground conditions (i.e. settlement, continued slip movement, etc.).

11. Final grading and ROW restoration in the area of the landslide should minimize cover depth over the pipeline (Appendix A-2, Sheet 2H). For instance, replacing deep fill soils over the pipeline in the post-landslide restoration condition may further exacerbate the problem. Cover depth over the deformable backfill should be minimized to the greatest extent possible, to further reduce soil backfill loading on the landslide area. This may require hauling excess spoils away from the site.
12. Drainage pipes in the pipeline trench collect and discharge seepage and near-surface flows within the trench excavation depth. Drainage pipes can be configured as French drains (Appendix A-2, Sheets 1A and 1E) running along the pipeline for low seepage flow conditions, or in specific locations to collect seepage trapped by grading of the temporary ROW or targeted seeps. Where excessive seepage along the trench may be a problem, then the piping configuration should be modified to include perforated corrugated pipes that collect water and feed into solid-smooth-interior-walled tightline pipes that convey it away (i.e. enhanced drains, Appendix A-2, Sheet 1B). Drainage piping can be configured to collect and convey seepage in targeted areas of the landslide, to make for more efficient discharge of flows or even to provide monitoring of specific areas (i.e. isolating piping from targeted areas to track corresponding flows from those areas). Discharge points should be located at the edge of the ROW on stable ground and/or with erosion pads (Appendix A-2, Sheet 1E).
13. Drains may be needed at specific locations to address localized seepage, springs, wet areas, or ponded water areas that influence a landslide (Appendix A-2, Sheet 1C). These may be configured as French drains (Appendix A-2, Sheets 1A and 1E) or other configurations of perforated and solid-wall pipes with sandbags and geotextile wrapped drain rock that are designed and built to address a specific-site condition. Special considerations should incorporate expected changes at the site and the impact of such changes on the pipe(s). For example, placement of collection or conveyance pipes across (i.e. perpendicular) a landslide shear boundary that is expected to move over the long-term may disrupt or break the pipe(s), causing discharge of flows back into the landslide. Piping should be located outside of the landslide boundaries. Where that is not possible, then piping should be parallel to landslide boundary geometries and cross the landslide footprint at the downstream side where water will flow away from the site in the event that piping is disrupted.
14. Where landslides are located on sloping ground, trench breakers (Appendix A-2, Sheet 4A) may enhance mitigation by managing trench seepage flows. Trench breakers for landslide projects should use sandbags. Foam material for breakers on landslide mitigation projects is not recommended. Drainage piping, as discussed previously, should be designed to allow for passage of seepage flows through the breakers, to collect and drain the seepage flows from the trench.
15. Trench dams (Appendix A-2, Sheet 4B) are trench breakers that are intended to interrupt and block seepage flows, and may be required to isolate landslide areas from seepage flows running along the trench. Drainage piping would be required to collect and divert the interrupted seepage flows to a discharge location off the ROW. Trench dams would be constructed of foam, sack-crete, or other impermeable materials. The use of trench dams is rare, as the intended function can typically be accomplished by the use of a traditional breaker, as described previously.
16. Install sack-crete breakers (Appendix A-2, Sheet 4C) in areas where the trench and slopes are steep and the breaker is needed to retain and stabilize the trench backfill. These structures may be configured to provide a foundation for imported backfill, retaining backfill in the trench itself on steep terrain, or to stabilize larger portions of the ROW area or larger trench and slope backfill areas. Because these structures can

be large and encompass an extended length of the pipeline, install a sleeve interface, such as geotextile fabric or rock shield, between the pipeline and the structure to provide a slip separation, and to avoid transfer of loading from the trench backfill through the structure to the pipeline (Appendix A-2, Sheet 4D).

17. Where the pipeline alignment passes through benched terrain, mitigate for complex backfill and drainage conditions by using rock fill, sack-crete breakers, enhanced drainage, or other measures, as needed (Appendix A-2, Sheet 10A). Bench topography can be very complex and may require site specific review to develop a practical and constructible mitigation and restoration package.

18. Install Slope breakers (a.k.a. water bars) along the ROW at spacing and orientations that intercept and direct surface run-off to stable and (preferably) vegetated areas off the ROW. Slope breaker spacing is typically governed by slope angle and/or the presence of trench breakers (Appendix A-2, Sheets 5A and 5B). In steep slope conditions, a slope breaker should be placed just below a trench breaker, so that seepage that is pushed to the surface by the trench breaker is captured by the slope breaker and diverted off the ROW. Final spacing and placement of breakers should incorporate site specific information. Where excessive run-off may need to be mitigated, then slope breakers can be discharged to an armored ditch or diversion channel (Appendix A-2, Sheets 5C, 6D, 1F and 1E).

19. Geodetic monitoring at the site may include various ground surface geodetic monuments installed at the site that allow for subsequent ground-based surveys to track changes in ground or pipeline position (Appendix A-2, Sheet 11A).

20. In scenarios where the pipeline is installed in a landslide and ground movement is expected, strain gauges may be required, depending on the site specific conditions and potential impacts to the pipeline(s) (Appendix A-2, Sheet 11B). Strain gauges monitor the accumulated strain in the pipeline that may be induced by differential ground movement. Strain gauges are attached to the pipe typically at locations where the pipeline crosses the lateral or vertical boundaries of a landslide; that is, at the boundaries of the landslide with the surrounding stable ground. These locations are where landslide shear stresses tend to be concentrated. Depending on the size of the landslide, one or more sets of strain gauges may be installed on the pipeline at other relevant locations. Monitoring of strain gauges at regular time intervals, and/or after identified movement events, may show that threshold stress conditions are achieved, which would trigger response actions including additional stress relief excavations and/or additional site assessment and mitigation work.

21. Additional monitoring instrumentation may be required, depending on site specific studies, including inclinometers (Appendix A-2, Sheets 11C and 11D) or piezometers (Appendix A-2, Sheet 11E).

22. In the event the pipe is installed in a landslide and post construction landslide-related ground movement appears to indicate a threat to the pipeline, then stress relief excavations may be needed. Stress relief excavations remove the soils constraining the pipeline, allowing it to rebound to the non-stress condition (Appendix A-2, Sheet 12A). Excavations start generally in the middle of the landslide and extend in either direction until no rebound is observed, and typically continue for a minimum of another 50 feet. Surveys may be required during the excavation work to track pipeline rebound, and to confirm before-and-after pipeline location and elevation.

23. Where the pipeline is installed in unstable (i.e. landslide) ground, then use deformable backfill (Appendix A-2, Sheet 12B). Additional drainage mitigation measures are typically included with the same backfill, to collect and convey seepage away from the pipeline trench (Appendix A-2, Sheets 1B and 1E). Similarly, a shear trench, also using a deformable sand backfill material, may be needed to maintain separation of the pipeline from moving landslide masses (Appendix A-2, Sheet 12C).

24. Where the pipeline is installed in unstable, (i.e. landslide-prone) ground that cannot partially or totally be mitigated with measures as outlined above, or for other specific reasons it is necessary to take an alternative approach to mitigation of a landslide, then it may be necessary to avoid the unstable area by routing around it (Appendix A-2, Sheet 15A), or to excavate the unstable ground in order to completely remove the localized hazard (Appendix A-2, Sheet 15B). These options should only be employed through close coordination with the Pipeline Operator/Owner.
25. Special consideration is needed to construct and/or restore drainage measures for existing, permanent, and temporary access roads, on a site specific basis. Access roads may collect runoff from upslope areas, increasing the contributing basin area draining to any given site, and deliver water to the ROW, the pipeline trench, or to other areas of concern. Use drainage measures, as described in this study, to manage and/or mitigate drainage issues, such as slope breakers, water bars, grading to improve drainage, French drains, enhanced drains, armoring, armored ditches with drain pipes, rock fill, etc. (Appendix A-2, Sheet 5D).
26. Cover disturbed area with erosion control fabric (Appendix A-2, Sheet 3C), or other functional erosion resistant ground coverings to mitigate over the short-term until the local vegetation can take over and establish itself. In especially unstable and/or steep slope conditions armor rock may be needed (Appendix A-1, Sheet 3D).
27. Track disturbed slopes (Appendix A-2, Sheet 3A) and re-vegetate all disturbed areas to provide long-term surface stabilization (i.e. replace the short-term erosion control fabric protection).
28. Re-vegetate all disturbed areas to provide long-term surface stabilization (Appendix A-2, Sheet 3B) (i.e. to replace the erosion control fabric over the long-term).

Modifications or alternatives to the above described measures that are feasible and maintain the function and intent as described and offer practical alternatives are encouraged.

5.0 UNCERTAINTY IN FUTURE MITIGATION AND REPAIR COSTS

The following discussion on the uncertainty in future mitigation and repair costs is based on work in the Williams OVM system in northern West Virginia for land movement mitigation work completed between 2012 and 2015. These results were developed by evaluating actual costs for work performed on a representative sampling of sites in the period of time stated above, through a probabilistic risk-based assessment. Costs addressed in the assessment included actual landslide and erosion hazard related mitigation costs based on work performed (i.e. costs include equipment, materials, labor, access, permitting, design, environmental, operations, etc.); potential additional mitigation repair cost for future events, and potential long-term (i.e. post-mitigation) costs associated with continued maintenance, monitoring, or continued mitigation efforts associated with a given site (i.e. drainage improvements, stress relief excavations, etc.). It is recognized that recurring landslide and erosion hazards might continue to impact the pipeline and ROW, even where mitigation has previously been completed.

This discussion is intended to illustrate the value added to operation and maintenance efforts through a risk-based evaluation of landslide and erosion related hazards in a pipeline system similar to the subject work in OVM. Using data and analyses for work that incorporates the approach and methods described in this document, the mitigation cost risk (i.e. pre-emptive cost to mitigate or reduce the likelihood of a “failure”) is generally an order of magnitude lower than the un-mitigated cost risk (i.e. cost to correct post “failure”) for the landslide and erosion hazards that can threaten the pipeline and ROW. The results presented herein are representative of the types of landslide and erosion hazards and corresponding mitigation work completed in OVM. Detailed cost information is not presented. These results and information are provided for discussion and relative planning purposes only, and should not be used as a basis for final costing efforts.

Costs are aggregated for landslide and erosion hazards observed in OVM in terms of potential integrity threat to the pipeline and/or ROW. For purposes of discussion, they are grouped in terms of either low-hazard sites, or a combined moderate to high-hazard site classification, as described in Table 5-1. These groupings were selected to demonstrate the relative difference in cost risk observed for maintenance related work (i.e. low-hazard site classifications) with generally lower integrity threat potential, versus increased integrity and threat related scenarios (i.e. moderate to high-hazard site classifications) that would require added review and management level decisions related to operation and maintenance actions.

Table 5-1: General Pipeline Integrity Hazard Description

Definition	Classification
Pipeline crosses through active landslide or erosion hazard; pipeline likely stressed; further movement or expansion of the landslide will likely threaten the pipeline. Direct observed or measured evidence or indirect and circumstantial evidence of an active hazard suggests the pipeline may be under stress, and/or requires actions to mitigate the hazard.	Moderate to High
Shallow landslide or limited erosion hazard located on or near the ROW, or crosses alignment of pipeline in the ROW, pipeline appears to be in stable ground/trench (i.e. below landslide failure surface or erosion extent). Continued hazard activity or possible lateral expansion/retrogression across the pipeline may occur in the future, but will likely not affect the pipeline.	Low

Starting with available costing information (Williams 2015) and supplementing with assessments from SME’s, a risk-based evaluation of potential costs for additional sites (i.e. sites not yet addressed or discovered) was conducted. Results are summarized in Figure 5-1, which shows that potential mitigation costs for low-hazard landslide and erosion hazard sites, as defined in Table 5-1, ranges from approximately \$40,000 to \$160,000, corresponding to the 20th and 80th percentiles, respectively (in 2014

USD). The potential mitigation costs for moderate to high-hazard landslide and erosion hazard sites that might impact and threaten the integrity of the pipeline range from approximately \$180,000 to \$600,000, corresponding to the 20th to 80th percentiles, respectively (in 2014 USD).

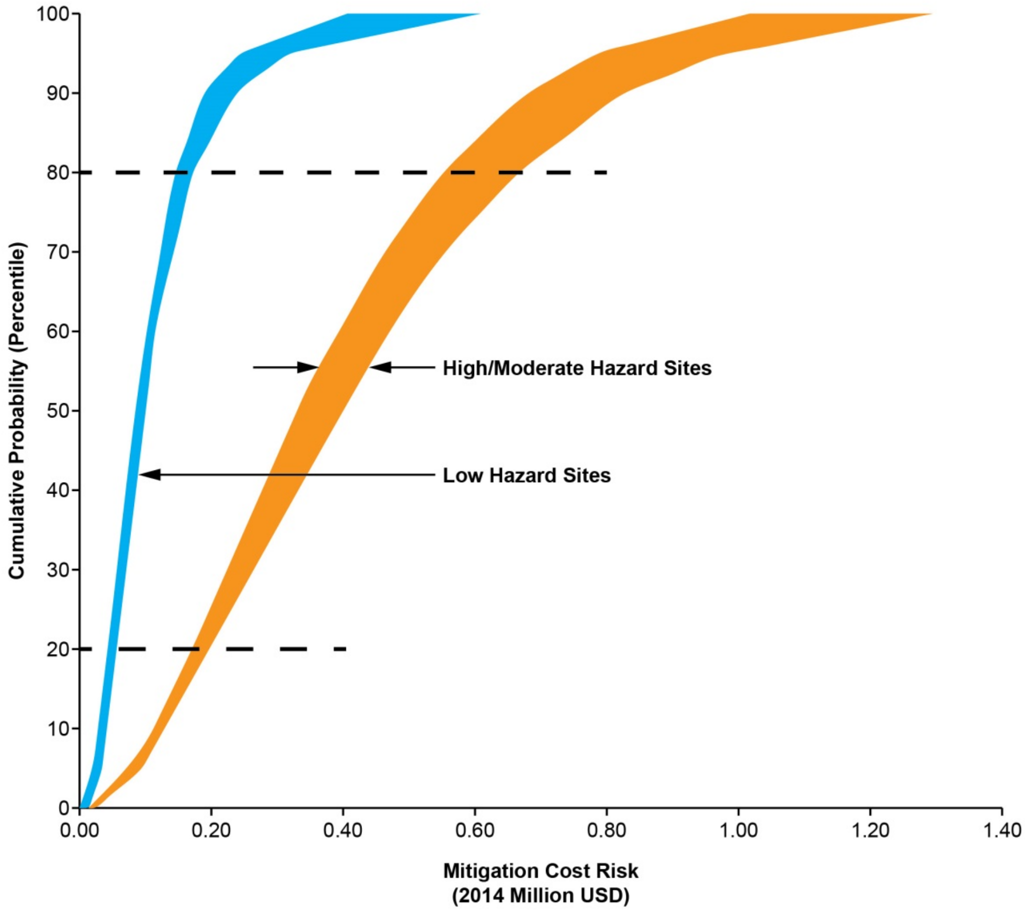

Figure 5-1: Mitigation Cost Risk

The same information was used to quantify the cost risk assuming no mitigation work is completed (i.e. un-mitigated risk). Multiple variables were considered in the assessment of risk, including the potential modes and likelihoods for geologic hazard related failures (i.e. both construction related and native landslide and erosion hazards). Risk related to other types of failures such as defective pipeline materials, pipeline construction defects, and accidents were acknowledged, but not included in this assessment. General categories of variables included: type, size, and proximity of the hazard site, construction cost (including site access) to repair land movement to the pipeline right-of-way assuming methods and approaches as outlined in this study, construction and materials cost to repair damage to the pipelines, the potential for rupture, construction and materials to re-route segments of the pipeline alignment around the site, consideration of future rupture after a site has been mitigated, staffing and overhead costs, loss of revenue associated with pipeline ruptures, cost to remediate hydrocarbon releases from ruptures, and potential environmental impacts.

The results in Figure 5-2 show that potential un-mitigated cost risks for low-hazard landslide and erosion sites, as defined in Table 5-1, are as high as approximately \$800,000, corresponding to the 80th percentile (in 2014 USD); and there is little or no cost risk associated with low-hazard sites below the 50th percentile. This suggests that the cost to mitigate low-hazard sites (at OVM) is likely to be more than the cost to repair a failure. Therefore, a corresponding reduced level of response might be warranted. The moderate to high-hazard sites have an increased potential to impact and/or threaten the integrity of the pipeline, and therefore represent an increased need for response, with an un-mitigated cost risk ranging from approximately \$0.5M to \$7M, corresponding to the 20th and 80th percentile, respectively (in 2014 USD). The greater uncertainty (range) in cost risk reflects a wide potential range in adverse impacts for higher-hazard sites.

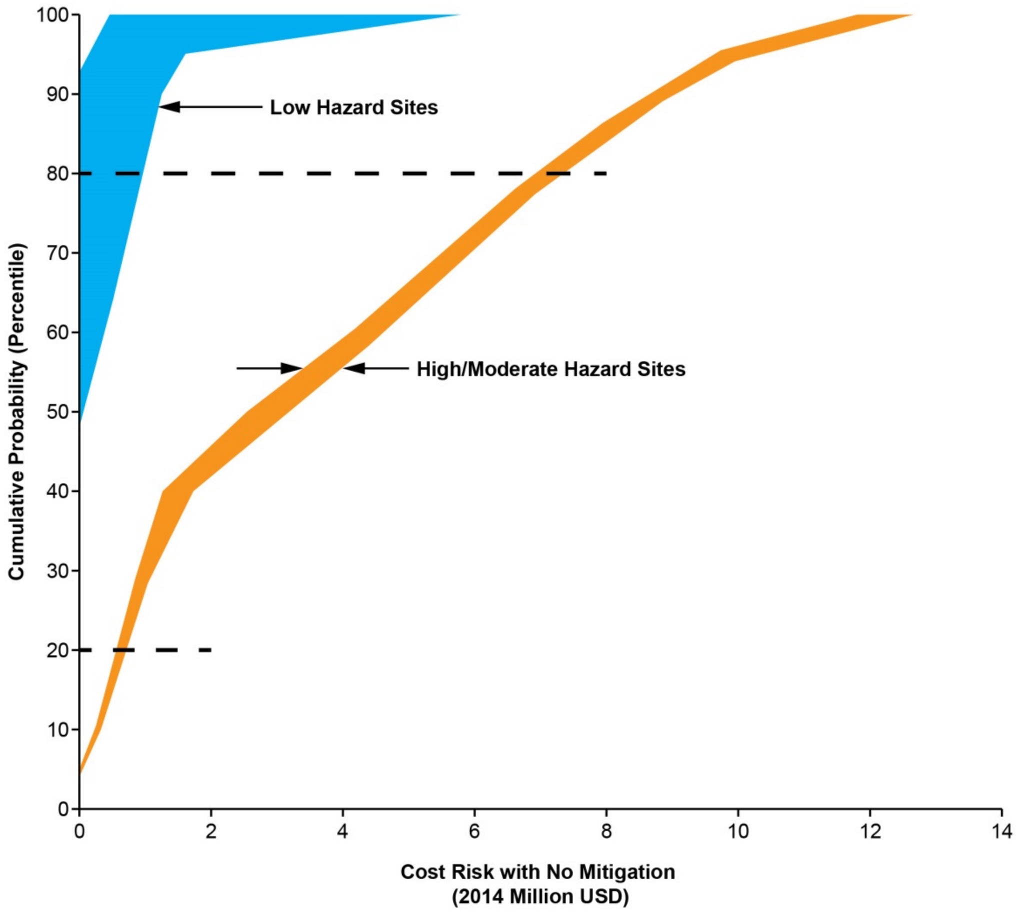

Figure 5-2: Un-mitigated Cost Risk

These cost risk results should be considered within the context of available data (which is representative of generally shallow translational landslides and similar erosion hazards typical of northern West Virginia in OVM and as discussed throughout this study), and the assessments of SME's involved in the risk assessments. Within that context, they show a clear and significant differential in mitigated versus un-mitigated cost risk associated with landslide and erosion hazards.

Mitigation efforts do not preclude continued land movement or continued occurrence of landslides and erosion hazards, but the results suggest that a comprehensive program of proactive mitigation can significantly reduce operator and owner risk in a pipeline system and implementation of a comprehensive system-wide program can provide compounding benefits over time.

6.0 CONCLUSIONS

Landslide and erosion hazards along a proposed pipeline alignment need to be identified, characterized and incorporated into every phase of a project. While careful planning and routing of proposed pipelines is always preferred to avoid potential threats from landslide and erosion hazards, mitigation may be required when hazards cannot be avoided. In some situations, the mitigation may not be intended to provide a long-term permanent mitigation and full elimination of the hazard. Instead, the pipeline ROW is mitigated to an acceptable level of risk (e.g. use of deformable backfill and monitoring to schedule stress relief excavations over time). As such, mitigation measures should take into consideration the risk tolerance of the owner/operator, consider the costs and benefits of long-term and short-term solutions and incorporate construction considerations into the planning and design efforts.

Experience with OVM suggests that in most cases the occurrence of land movement in this region is associated with surface and subsurface water in combination with recent or historical changes in geologic conditions and construction related activities. This combination of contributing conditions is so common that we were able to develop sets of Typical Scenarios and Typical Details which enabled us to create site-specific mitigation designs. During the Scenario and Detail development process, we identified a number of critical items to consider when mitigating land movement on pipeline ROWs. These include:

- The importance of identifying landslide and erosion hazards, and incorporating that information into the design, planning and construction phases of a project. Mitigation efforts should be tailored to address site-specific conditions as well as to balance costs with practicality of installation, operation and mitigation of risk. Note, the identification and characterization of landslide and erosion hazards represents a science all by itself, and is not directly addressed herein. This document focuses on the mitigation efforts related to these hazards;
- The critical role of route selection in identifying and avoiding hazards that may impact pipelines and ROWs. Careful planning and routing is always preferred to avoid or minimize potential threats from landslide and erosion hazards, but mitigation is usually required when such hazards cannot be avoided;
- The need to incorporate site-specific mitigation measures into the project planning process, to address threats to the pipeline and the ROW. The cause of any given landslide or erosion hazard is commonly the result of several contributing factors. Defining the governing geologic hazard and geotechnical/hydrotechnical engineering processes that are contributing to the land movement is critical in supporting the selection, planning, and design of an effective mitigation plan. Ultimately, the owner/operator must decide on the acceptable level of risk for any given mitigation package;
- The association between land movement and surface and subsurface water in combination with changes in the local ground conditions from recent or historical changes in geologic conditions and/or construction-related activities. Examples of mitigation options that address these conditions include re-grading the ROW surface to improve site conditions, modifying local surface drainage, conveyance of sub-surface drainage, modified ROW backfill materials, deformable backfill in the pipeline trench, removal of unstable soil and replacement with engineered performance materials, ground surface erosion protection, slope breakers, trench breakers, special pipeline coatings and protective sleeve-wraps, modified ROW configurations, monitoring and special pipeline design. These options are typically used in combination to develop a strategy for addressing the identified hazards at any given site;
- Structural measures are also available to address unstable slopes, such as retaining walls, soldier piles, sheet piles, wire mesh systems, mechanically stabilized earth systems and other mechanical structures. These options can be costly, have special equipment and access requirements in order to install in steep slope conditions, may limit future access or

expansion in constrained ROW corridors, and may also have special long-term maintenance requirements;

- Reducing ground disturbance through minimized ROW footprints, appropriately sized and applicable equipment, and planning construction during optimal seasonal conditions (i.e. dry versus wet) can minimize mitigation requirements;
- Consideration of the landslide and erosion processes, and the origin of the source(s) of water relative to the constructed pipeline ROW. In particular, mitigation measure selection should consider the disturbed temporary ground surface from the initial grading of the ROW and subsequent construction work and not just the finished and restored ROW surface;
- Organizing mitigation options into a framework of Typical Scenarios and supporting Typical Details that are consistent with how the ROW is built (i.e. ridge top, planar slopes, side slope, etc.). This allows for rapid development of conceptual site-specific mitigation plans during project planning and design;
- Designing to mitigate for all or only portions of targeted threats from land movement, thereby allowing the owner/operator to decide and select the level of mitigated risk, and allowing time for the owner/operator to plan, assess and make risk-based decisions on how to best manage the asset.

The most effective mitigation strategy requires recognition of the multiple factors governing a site, and may require long-term performance monitoring before full mitigation can be achieved. In some situations, the mitigation may not be intended to provide a long-term permanent mitigation and full elimination of the hazard. Instead, the pipeline ROW is mitigated to an acceptable level of risk. As such, mitigation measures should be tailored to address the site specific and potentially variable conditions, consider the risk tolerance of the owner/operator, consider the costs and benefits of long-term and short-term solutions, and incorporate construction considerations into the planning and design efforts and integrate with the construction process.

While mitigation efforts will not prevent every landslide or all erosion hazards, comparison of mitigated versus un-mitigated cost risk suggest that a comprehensive program of proactive mitigation and implementation on a system-wide scale can significantly reduce overall risk in a pipeline system, and can provide compounding benefits over time.

7.0 REFERENCES

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8.0 DEFINITIONS

The following provides brief definitions of selected terminology either addressed or related to the topics discussed herein, in order to support discussions of these topics. The reader is encouraged to research any listed definition when more details or specific information is needed. These definitions are based on our experience working in the oil and gas industry, or other sources of pipeline related expertise (Hosmanek 1984):

Armoring – installing small diameter, angular, riprap materials; use of geotextile or other biodegradable materials; or installation of vegetation; to protect against erosion of soils on temporary ROW surfaces or on the final restored ROW surface. Often installed in conjunction with conveyance of surface flows, in defined conveyance channels; or to protect steep slope areas from unraveling in response to runoff.

Bleeder drain – a drainage mitigation method that uses a gravity drainage pathway excavated at the low spot in a pipeline trench, that conveys seepage flows away from the trench, and may use drain rock backfill wrapped in filter fabric to create the drainage pathway (e.g. french drain). Typically installed in sidehill conditions where the pipeline gradient is flat.

Cost Risk – in this context, uncertain costs resulting from potential future landslide or erosion failures and the related potential impacts (e.g., costs of emergency response, environmental clean-up and fines, lost revenue, planning, design, engineering, and construction efforts to correct failure, etc.). Unmitigated cost risk reflects the uncertain cost impacts associated with sites that have not been mitigated (as defined elsewhere) in an attempt to reduce the likelihood and/or consequences of a failure. Mitigation cost reflects the cost to mitigate a hazard (as discussed elsewhere) in an attempt to reduce the probability and/or impacts associated with failure (i.e., to reduce the unmitigated cost risk).

Cover depth – the measurement from top of a pipeline to ground level along the ROW.

Convergent topography – convergent U-shaped or closed drainage basins that have steep slopes, and focus surface run-off back onto a focused area at the bottom of the valley or corresponding toe of the slope(s). This results in increased and concentrated surface and near sub-surface flows and sources of water.

Cut and Fill – the cut down high ground and/or fill in low ground to achieve a uniform or design grade.

Deformable backfill - Backfill around the pipeline using select “deformable” materials that allow for some movement of the pipeline through the backfill (i.e. the lower strength loose backfill fails and deforms around the pipeline more readily than native undisturbed higher strength soils) in response to continued land movement, thereby attenuating accumulation of stress in the pipeline resulting from displacement of the pipeline by landslide movement. Deformable backfill is typically a loose granular sand material with little or no fines. The deformable backfill is placed in a sloped wall trench all around the pipeline, in dimensions that match the expected displacement, and allowing for select material along the direction and orientation (i.e. horizontal and/or vertical) of landslide movement relative to the pipeline.

Easement – a right that one individual or company has to access land typically representing the ROW footprint; may be differentiated by temporary construction related easements versus permanent ownership.

Enhanced drain – a drainage mitigation method that uses a combination of perforated pipes to collect seepage and sub-surface water, and solid-wall pipes to convey the collected seepage away. The perforated pipe segments are typically limited to 50-100 foot lengths, and surrounded by free-draining gravel or sand with geotextile filter fabric; the conveyance pipes can be backfilled with native soils, and typically have an erosion pad at the discharge.

Erosion – grain-by-grain movement of soil and/or rock resulting from gravity or flowing water.

French drain – a drainage mitigation method that uses a perforated pipe surrounded by free-draining gravel or sand with geotextile filter fabric to capture and convey seepage originating typically in shallow depth subsurface applications.

Geology – the science that deals with the dynamics and physical history of the Earth's materials, and the processes that act on it, and that change it.

Geodetic Monitoring – Survey points at identified locations, typically completed over a period of time to track and monitor changes in position of that point; installed at landslide sites to track changes in ground position and/or elevation.

Geotechnical Engineering – the science and engineering addressing the Earth's materials with a focus on geotechnics, soil and rock mechanics, slope stability, subsurface conditions, soil interactions, etc.

Grading – the process of providing a smooth and even work area to facilitate the movement of equipment onto and along the ROW; entails cutting and filling of native ground to achieve a temporary ROW surface.

Hazard – in the context of this document; includes geologic, geotechnical, or hydrotechnical processes and conditions that can threaten the pipeline or ROW.

Hydrotechnical Engineering – the science and engineering addressing the earth's materials with a focus on hydrotechnics, hydrology, hydraulics, fluvial geomorphology, erosion, scour, surface and near sub-surface water, soil and water interactions, etc.

Inclinometer – a monitoring instrument used to measure and monitor changes in horizontal displacements along a borehole resulting from subsurface ground movement, particularly associated with landslide activity.

Land movement – generally describes horizontal and/or vertical changes in ground conditions resulting from landslide and/or erosion processes.

Landslide – mass movement of soil and/or rock down a slope from the effects of gravity.

Mitigation – in the context of this document; the planning, design, engineering, or construction efforts that are implemented or intended to reduce risk associated with an identified hazard.

Normal – orientation of a pipeline alignment that generally follows sidehill with the contours and perpendicular (i.e. normal) to the fall-line (i.e. alignment straight down) of the slope.

Oblique – orientation of a pipeline alignment at an angle to the fall-line (i.e. the alignment that goes straight down the slope) as it traverses down (on planar) or along (sidehill) slopes.

Padding – screened or sifted soils placed in a trench to prevent the pipeline from damage caused by rocky or coarse grained trench backfill,

Piezometer – a monitoring instrument installed in a well or casing to track and monitor subsurface ground water levels.

Pipeline – a system of connected lengths of pipe, usually buried, that is used for transporting liquid or gaseous products. The pipeline can be used as a conveyor or a temporary storage container.

Planar slopes – construction of pipeline alignment and/or ROW in sloping terrain that is generally flat (i.e. planar) when facing down the slope; there may be some vertical variation in the planar slope, transitioning through localized changes in flatter or steeper planar segments as the alignment traverses up/down a slope. The catchment area (i.e. the basin area that can capture rainfall) that drains to the disturbed ROW in this scenario is generally limited to the actual disturbed ROW itself, and may increase if the pipeline ROW is oblique to the fall-line of the slope as it traverses down the planar slope.

Ridge top – construction of pipeline ROW along the highest elevation ground that follows ridges; this scenario minimizes the catchment area (i.e. the basin area that can capture rainfall) that drains to the disturbed ROW. Steeper grades of ridge top areas are referred to as ‘inclined ridge tops’.

Right-of-Way (ROW) – the legal right of passage over public land and privately owned property; also the way or area over which the right exists. The width of the ROW varies according to contract specification and individual easements, but is generally between 50-150 feet.

Routing – the planning and decision making process for selecting a pipeline alignment.

ROW Restoration – in pipeline construction, the process of returning the ROW to its original condition, or better, after the pipeline has been installed in the trench. ROW restoration may depend on legal stipulation in the contract with the pipeline owner, and in agreements with individual land owners.

Sack-crete – individual sacks filled with concrete (in total) or mixed with fine grained soils, and used to build breakers or other slope stabilization structures in the trench or ROW. Typically used in steep slope, or rock conditions. Allows for constructing complex structures that conform to irregular ground surfaces, but requires directed manual labor to place each individual unit. Where concrete is mixed into sack fill, the sacks will be soft and flexible at initial placement, and then eventually set and harden as they become hydrated, resulting in a rigid structure over time.

Shear trench – placement of select (e.g. loose, granular, sand materials) backfill in targeted locations with the intent of creating a zone that will intentionally fail (i.e. shear) in response to land movement.

Side slope (a.k.a. side hill) – construction of pipeline alignment and/or ROW that follows with the contours (i.e. parallel), or follows at an angle (i.e. oblique) to the contours; essentially running along planar sloping ground, such that there is sloping ground coming to the pipeline ROW from the up-hill side, and sloping ground running away from the ROW to the down-hill side; this scenario maximizes the catchment area (i.e. the basin area that can capture rainfall) that drains to the disturbed ROW.

Slope breaker (a.k.a. water bar) – installed on disturbed ROW areas to intercept and manage surface runoff flows, typically functions like a water bar, and constructed using local materials in typical ROW construction and soil conditions; except in special conditions where slope geometry or limited availability requires constructing them using imported, engineered, or other specialized materials and/or configurations (e.g. in very steep or rock conditions). Slope breakers reduce concentration of surface runoff along disturbed ROW areas, by intercepting and diverting runoff to stable discharge areas along the ROW edge. Slope breaker spacing is typically coordinated with trench breakers, such that trench seepage is temporarily intercepted by trench breakers and directed to the ground surface (i.e. seepage builds up behind the trench breaker over a short period of time until it 'daylights' at the ground surface), where slope breakers placed just downslope divert the water to the side of the ROW. Slope breakers should be coordinated with permanent and temporary access roads, to avoid aggregated (i.e. multiple) discharges of water in the same concentrated ROW locations.

SME – Subject Matter Expert (SME), and professional expert in a targeted geologic, engineering, environmental, scientific, construction, or other field of expertise.

Spoil – excavated soils that are temporarily placed along the constructed ROW, or in some situations moved away from the site where they were excavated to a separate location.

Spread – the necessary equipment and crew needed to build a pipeline, or to build a targeted segment of a pipeline. Modern spreads, which are like moving assembly lines made up of teams of crews focused on individual specialties of pipeline construction, can consist of hundreds of pieces of equipment and supporting operators and other resources.

Strain gauge – a strain monitoring instrument attached directly to the pipeline that measures longitudinal strain changes and accumulated strain in the pipeline.

Stress relief excavation – removal of the trench backfill and surrounding soil within a landslide mass that displace (horizontally and/or vertically) the pipeline. This is to remove the landslide stresses, and mitigate the accumulated strain in the pipeline caused by the landslide stresses. The resulting excavation actions allow the pipeline to physically rebound to a pre-displacement geometry in the trench that eliminates, or significantly reduces, the accumulated strain in the pipeline. Note there may be more complex interactions of the soil mass within and outside the landslide mass that result in combinations of horizontal and vertical displacements. These complex relationships of ground movement need to be assessed and determined on a case-by-case basis, specific to the site conditions. These interactions are addressed in simple terms herein, for the purpose of describing the concept of this mitigation option, and recognizing that additional planning and design is needed to implement this type of mitigation action.

Targeted drain – a drainage mitigation method that uses a combination of perforated pipes to collect seepage and sub-surface water, solid-wall pipes to convey the collected seepage away, sandbags (or similar functioning units), filter fabric, and grading to manage targeted shallow subsurface seep and spring sources of water. The configuration of a targeted drain often addresses a water source on the upslope (i.e. inboard) side of the temporary ROW surface relative to the pipeline trench, and then must convey flows to the outboard side of the ROW. The geometry, configuration, materials, and construction can vary.

Trench – the excavated trench in which a pipeline is installed, not necessarily including the additional excavations for constructing the ROW.

Trench breaker - installed in pipeline trench to intercept and manage seepage flows along the trench, in order to restore the general seepage characteristics of the trench backfill to be as similar as possible to the adjacent in-situ native materials; typically constructed using sandbags filled with permeable sand/soil mix, sack-crete (in steep and rock conditions) with cement mixed in to form solid placements over time, or foam materials. Drainage pipe is sometimes added to the breakers to collect and convey seepage flows past individual breakers, and/or to the ground surface. Trench breakers are typically installed at spacing and dimensions that fit slope conditions, where steeper slopes require tighter spacing, and vice versa for flatter slopes. Technical guidance on the specific placement and spacing of trench breakers is lacking, leaving much to the discretion of the designer, and relying on experience. Trench breakers are typically coordinated with slope breakers, such that trench seepage is temporarily intercepted by the trench breakers and directed to the ground surface (i.e. seepage builds up behind the trench breaker over a short period of time, until it ‘daylights’ at the ground surface), where slope breakers placed just downslope divert the water to the side of the ROW into stable and/or erosion protected areas.

Valley Bottom - construction of pipeline alignment and/or ROW in generally flat ground following along valley bottom areas.

APPENDIX A-1

Typical Scenarios (14 Sheets)

WILLIAMS OHIO VALLEY MIDSTREAM (OVM)

TYPICAL RIGHT-OF-WAY RESTORATION SCENARIOS

TYPICAL SCENARIOS			
SHEET NO.	TITLE	REV.	DATE
1000	COVER SHEET	0	2/28/2014
1110	SIDE SLOPE (NORMAL)	1	8/11/2014
1120	SIDE SLOPE (OBLIQUE)	1	8/11/2014
1130	RIDGE TOP	1	8/11/2014
1140	INCLINED RIDGE	1	8/11/2014
1150	PLANAR SLOPE (STANDARD)	1	8/11/2014
1160	PLANAR SLOPE (EXCAVATION)	1	8/11/2014
1170	CONVERGENT TOPOGRAPHY	1	8/11/2014
1500	POTENTIAL SHALLOW BEDROCK	1	8/11/2014
1600	AREAS OF FILL GEOTECHNICAL CONCERN	0	2/28/2014
1710	LANDSLIDES - SIDE SLOPE WITH STABLE TRENCH	1	8/11/2014
1720	LANDSLIDES - SIDESLOPE WITH UNSTABLE TRENCH	1	8/11/2014
1730	LANDSLIDES - PLANAR SLOPE WITH STABLE TRENCH	1	8/11/2014
1740	LANDSLIDES - PLANAR SLOPE WITH UNSTABLE TRENCH	1	8/11/2014

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW

NOTES

PROJECT

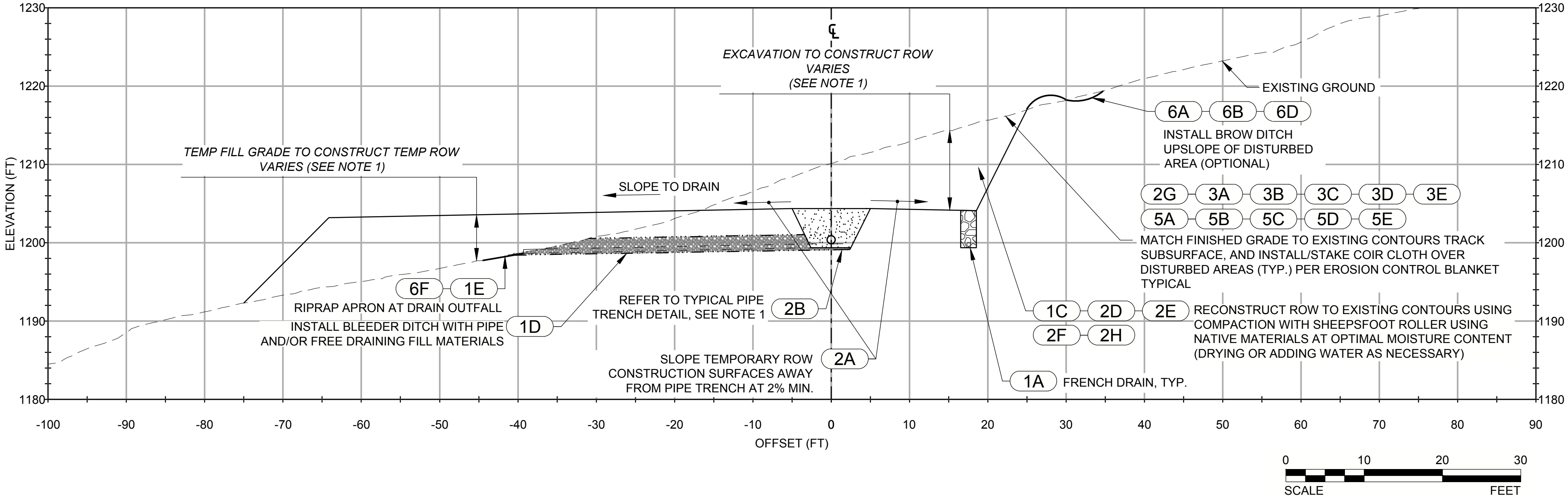
WILLIAMS OVM

TITLE

COVER SHEET

Golder Associates

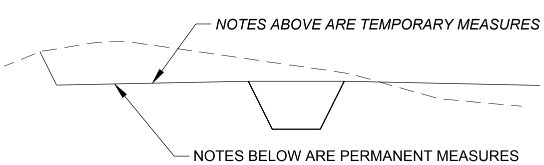
PROJECT No.			
DESIGN	BJV	2014-02-28	SCALE AS SHOWN
CADD	BJV	2014-02-28	SHEET
CHECK	AGM	2014-02-28	**1000**
REVIEW	AQK	2014-02-28	



SUPPORTING TYPICAL DETAILS

- 1A FRENCH DRAIN (SIMPLE), SEE NOTE 3
- 1C TARGETED SEEP DRAINS, SEE NOTE 1
- 1D BLEEDER DRAIN, SEE NOTE 1
- 1E DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1
- 1F ARMORED CHANNEL WITH DRAIN PIPE, SEE NOTE 1
- 1H STEEP CONVEYANCE CHANNEL, AS NEEDED
- 1I CHANGED SEEP CHARACTERISTICS, AS NEEDED
- 1J SINGLE TARGETED SEEP COLLECTOR, AS NEEDED
- 1K ENERGY DISSIPATION BASIN, AS NEEDED
- 2A GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
- 2B GRADING TRENCH WITH OUTBOARD WEDGE, SEE NOTE 1
- 2C COMPACT BACKFILL, SEE NOTE 1
- 2D DRY SOILS AND BACKFILL, SEE NOTE 1
- 2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, SEE NOTE 1
- 2F ROCK BACKFILL (WITH DRAIN), SEE NOTE 1
- 2G GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1
- 2H GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE, SEE NOTE 1
- 3A TRACK DISTURBED SLOPES, SEE NOTE 1
- 3B RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1
- 3C COIR CLOTH ON DISTURBED SLOPES, AS NEEDED
- 3D ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED
- 3E COIR LOGS ON DISTURBED SLOPES, AS NEEDED
- 4G SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED
- 5A SLOPE BREAKERS (TEMP AND PERMANENT), AS NEEDED
- 5B SLOPE BREAKER ARMORED OUTLET, AS NEEDED
- 5C SLOPE BREAKERS WITH DIVERSION CHANNELS, AS NEEDED
- 5D ACCESS ROADS, SEE NOTE 1
- 5E TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED
- 6A COIR-LINED VEGETATED DIVERSION CHANNEL, SEE NOTE 1
- 6B BROW DITCH, SEE NOTE 1
- 6D ARMORED CHANNEL, AS NEEDED
- 6F RIPRAP GRADATIONS, AS NEEDED

LEGEND



NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. TYPICAL SECTION SHOWS SCENARIO WITH VARIED CUT/FILL IN GENERALLY PLANAR GEOMETRY. EXTENT OF CUT/FILL MAY VARY.
4. WHERE THE TEMP ROW SURFACE GRADING DRAINS TO AN IN-BOARD CUT SLOPE, THEN FRENCH DRAINS, OR SHALLOW ARMORED DITCH WITH DRAIN, OR AN ARMORED CHANNEL CONNECTED TO SLOPE BREAKERS IS NEEDED.

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
△						

NOTES

PROJECT

WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO SIDE SLOPE (NORMAL)

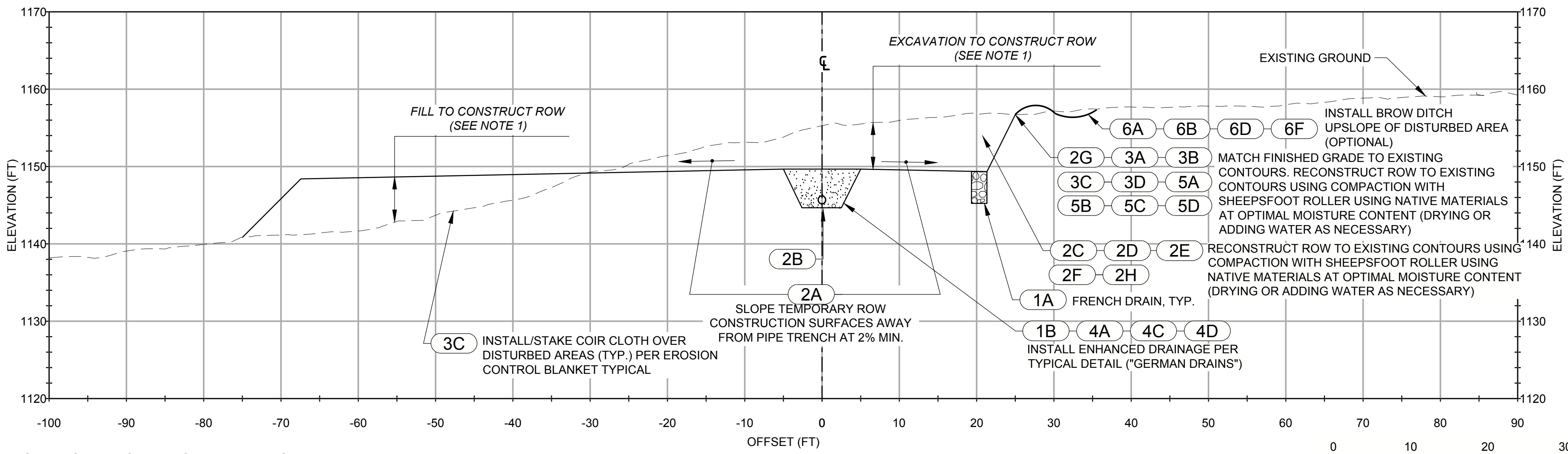
Golder Associates

PROJECT No.		
DESIGN	BJV	2014-08-11
CADD	BJV	2014-08-11
CHECK	AGM	2014-08-11
REVIEW	AQK	2014-08-11

SCALE AS SHOWN

SHEET

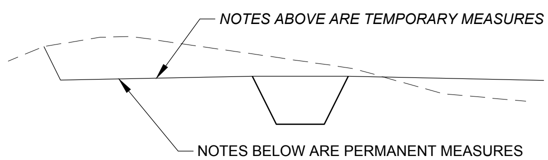
1110



SUPPORTING TYPICAL DETAILS

1A	FRENCH DRAIN (SIMPLE), SEE NOTE 3	2E	REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, SEE NOTE 1	5A	SLOPE BREAKERS (TEMP AND PERMANENT), AS NEEDED
1B	ENHANCED DRAIN (GERMAN DRAIN), SEE NOTE 1	2F	ROCK BACKFILL (WITH DRAIN), SEE NOTE 1	5B	SLOPE BREAKER ARMORED OUTLET, AS NEEDED
1C	TARGETED SEEP DRAINS, SEE NOTE 1	2G	GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1	5C	SLOPE BREAKERS WITH DIVERSION CHANNELS, AS NEEDED
1D	BLEEDER DRAIN, SEE NOTE 1	2H	GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE, SEE NOTE 1	5D	ACCESS ROADS, SEE NOTE 1
1E	DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1	3A	TRACK DISTURBED SLOPES, SEE NOTE 1	5E	TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED
1F	ARMORED CHANNEL WITH DRAIN PIPE, SEE NOTE 1	3B	RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1	6A	COIR-LINED VEGETATED DIVERSION CHANNEL, SEE NOTE 1
1H	STEEP CONVEYANCE CHANNEL, AS NEEDED	3C	COIR CLOTH ON DISTURBED SLOPES, AS NEEDED	6B	BROW DITCH, SEE NOTE 1
1I	CHANGED SEEP CHARACTERISTICS, AS NEEDED	3D	ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED	6D	ARMORED CHANNEL, AS NEEDED
1J	SINGLE TARGETED SEEP COLLECTOR, AS NEEDED	3E	COIR LOGS ON DISTURBED SLOPES, AS NEEDED	6F	RIPRAP GRADATIONS, AS NEEDED
1K	ENERGY DISSIPATION BASIN, AS NEEDED	4A	TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 1		
2A	GRADING TEMPORARY ROW SURFACE, SEE NOTE 1	4C	SACK-CRETE BREAKERS (STRUCTURAL BREAKER), AS NEEDED		
2B	GRADING TRENCH WITH OUTBOARD WEDGE, SEE NOTE 1	4D	SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, SEE NOTE 1		
2C	COMPACT BACKFILL, SEE NOTE 1	4F	TRENCH BREAKER WITH DRAINAGE		
2D	DRY SOILS AND BACKFILL, SEE NOTE 1				

LEGEND



NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. TYPICAL SECTION SHOWS SCENARIO WITH VARIED CUT/FILL IN GENERALLY PLANAR GEOMETRY. EXTENT OF CUT/FILL MAY VARY.
4. WHERE THE TEMP ROW SURFACE GRADING DRAINS TO AN IN-BOARD CUT SLOPE, THEN FRENCH DRAINS, OR SHALLOW ARMORED DITCH WITH DRAIN, OR AN ARMORED CHANNEL CONNECTED TO SLOPE BREAKERS IS NEEDED.

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW

NOTES

PROJECT

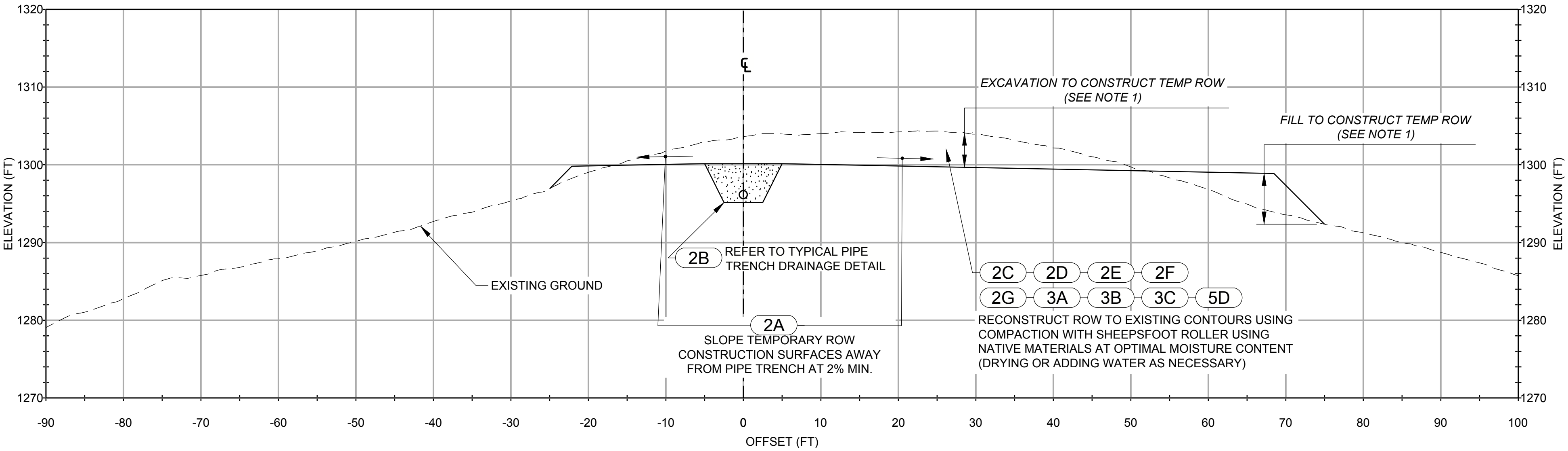
WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO SIDE SLOPE (OBLIQUE)

Golder Associates

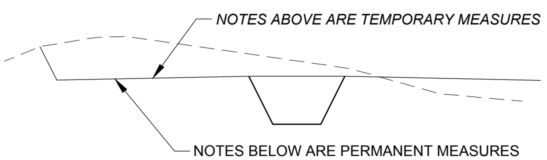
PROJECT No.			
DESIGN	BJV	2014-08-11	SCALE AS SHOWN
CADD	BJV	2014-08-11	SHEET
CHECK	AGM	2014-08-11	1120
REVIEW	AQK	2014-08-11	



SUPPORTING TYPICAL DETAILS

- 2A GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
- 2B GRADING TRENCH WITH OUTBOARD WEDGE, SEE NOTE 1
- 2C COMPACT BACKFILL, SEE NOTE 1
- 2D DRY SOILS AND BACKFILL, SEE NOTE 1
- 2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, SEE NOTE 1
- 2F ROCK BACKFILL (WITH DRAIN), SEE NOTE 1
- 2G GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1
- 3A TRACK DISTURBED SLOPES, SEE NOTE 1
- 3B RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1
- 3C COIR CLOTH ON DISTURBED SLOPES, SEE NOTE 1
- 5D ACCESS ROADS, SEE NOTE 1

LEGEND



NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. SCENARIO SHOWN WHERE RIDGE TOP IS GENERALLY CENTERED, BUT MAY VARY WITH CUT/FILL TO ONE SIDE OR THE OTHER.

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW

NOTES

PROJECT

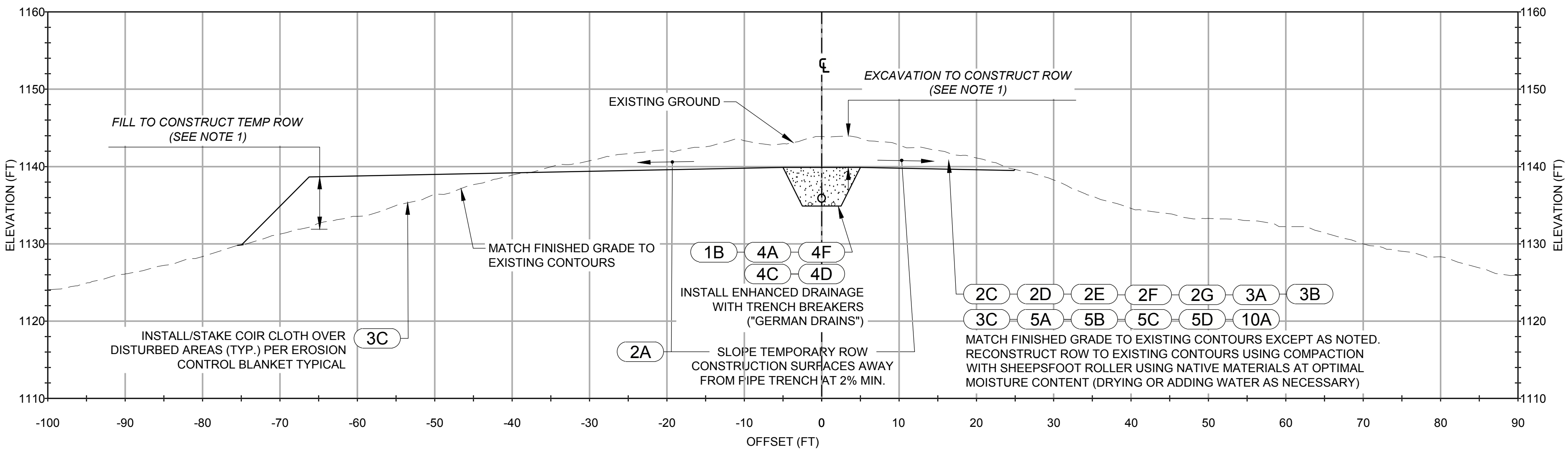
WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO RIDGE TOP

Golder Associates

PROJECT No.			
DESIGN	BJV	2014-08-11	SCALE AS SHOWN
CADD	BJV	2014-08-11	SHEET
CHECK	AGM	2014-08-11	**1130**
REVIEW	AQK	2014-08-11	



SUPPORTING TYPICAL DETAILS

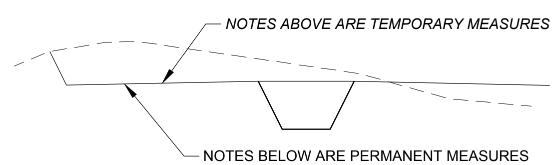
- 1B ENHANCED DRAIN (GERMAN DRAIN), SEE NOTE 1
- 1E DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1
- 2A GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
- 2B GRADING TRENCH WITH OUTBOARD WEDGE, SEE NOTE 1
- 2C COMPACT BACKFILL, SEE NOTE 1
- 2D DRY SOILS AND BACKFILL, SEE NOTE 1
- 2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, SEE NOTE 1
- 2F ROCK BACKFILL (WITH DRAIN), SEE NOTE 1
- 2G GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1
- 3A TRACK DISTURBED SLOPES, SEE NOTE 1
- 3B RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1
- 3C COIR CLOTH ON DISTURBED SLOPES, AS NEEDED
- 4A TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 1
- 4C SACK-CRETE BREAKERS (STRUCTURAL BREAKER), AS NEEDED
- 4D SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, SEE NOTE 1
- 4F TRENCH BREAKER WITH DRAINAGE, SEE NOTE 1
- 5A SLOPE BREAKERS (TEMP AND PERMANENT), SEE NOTE 1
- 5B SLOPE BREAKER ARMORED OUTLET, SEE NOTE 1
- 5C SLOPE BREAKERS WITH DIVERSION CHANNELS, SEE NOTE 1
- 5D ACCESS ROADS, SEE NOTE 1
- 5E TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED
- 10A BENCHES RE-CONSTRUCTION THROUGH NATURAL STEPS, SEE NOTE 1

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. SCENARIO SHOWN WHERE RIDGE TOP IS GENERALLY CENTERED, BUT MAY VARY WITH CUT/FILL TO ONE SIDE OR THE OTHER.

0 10 20 30
SCALE FEET

LEGEND



REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW

NOTES

PROJECT

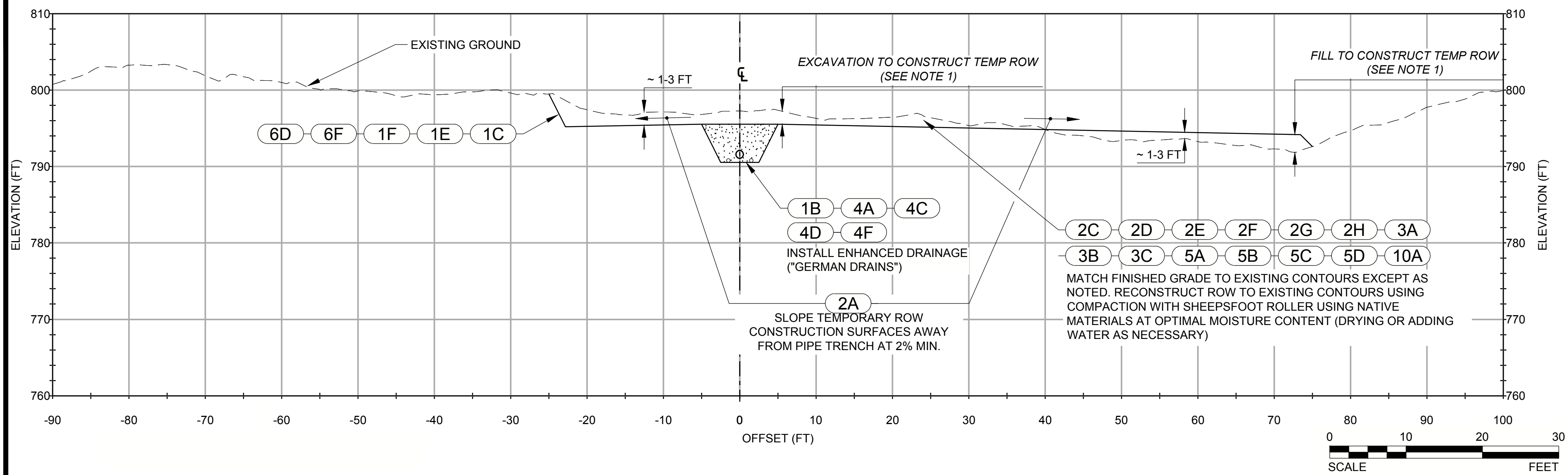
WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO INCLINED RIDGE

Golder Associates

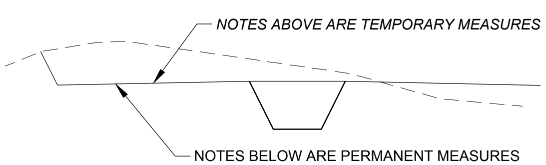
PROJECT No.			SCALE	AS SHOWN
DESIGN	BJV	2014-08-11	SHEET	
CADD	BJV	2014-08-11		1140
CHECK	AGM	2014-08-11		
REVIEW	AQK	2014-08-11		



SUPPORTING TYPICAL DETAILS

- 1B ENHANCED DRAIN (GERMAN DRAIN), IN PIPELINE TRENCH, SEE NOTE 1
- 1C TARGETED SEEP DRAINS, AT INTERSEPTED SEEPS, AS NEEDED
- 1E DRAIN PIPE OUTFALL RIPRAP APRON, AS NEEDED
- 1F ARMORED CHANNEL WITH DRAIN PIPE, AS NEEDED
- 1H STEEP CONVEYANCE CHANNEL, AS NEEDED
- 1I CHANGED SEEP CHARACTERISTICS, AS NEEDED
- 1J SINGLE TARGETED SEEP COLLECTOR, AS NEEDED
- 1K ENERGY DISSIPATION BASIN, AS NEEDED
- 2C COMPACT BACKFILL, AS NEEDED
- 2A GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
- 2D DRY SOILS AND BACKFILL, AS NEEDED
- 2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, AS NEEDED
- 2F ROCK BACKFILL (WITH DRAIN), AS NEEDED
- 2G GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1
- 3A TRACK DISTURBED SLOPES, SEE NOTE 1
- 3B RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1
- 3C COIR CLOTH ON DISTURBED SLOPES, SEE NOTE 1
- 3D ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED
- 3E COIR LOGS ON DISTURBED SLOPES, AS NEEDED
- 4A TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 1
- 4C SACK-CRETE BREAKERS (STRUCTURAL BREAKER), SEE NOTE 1 FOR UNSTABLE FILL
- 4D SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, SEE NOTE 1
- 4F TRENCH BREAKER WITH DRAINAGE, SEE NOTE 1
- 4G SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED
- 5A SLOPE BREAKERS (TEMP AND PERMANENT), SEE NOTE 1
- 5B SLOPE BREAKER ARMORED OUTLET, SEE NOTE 1
- 5C SLOPE BREAKERS WITH DIVERSION CHANNELS, SEE NOTE 1 AND 4
- 5D ACCESS ROADS, SEE NOTE 1
- 5E TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED
- 6D ARMORED CHANNEL, SEE NOTE 4
- 6F RIPRAP GRADATIONS, AS NEEDED
- 10A BENCHES RE-CONSTRUCTION THROUGH NATURAL STEPS, AS NEEDED

LEGEND



NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
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3. TYPICAL SECTION SHOWS SCENARIO WITH VARIED CUT/FILL IN GENERALLY PLANAR GEOMETRY. EXTENT OF CUT/FILL MAY VARY.
4. WHERE THE TEMP ROW SURFACE GRADING DRAINS TO AN IN-BOARD CUT SLOPE, THEN FRENCH DRAINS, OR SHALLOW ARMORED DITCH WITH DRAIN, OR AN ARMORED CHANNEL CONNECTED TO SLOPE BREAKERS IS NEEDED.

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW

NOTES

PROJECT

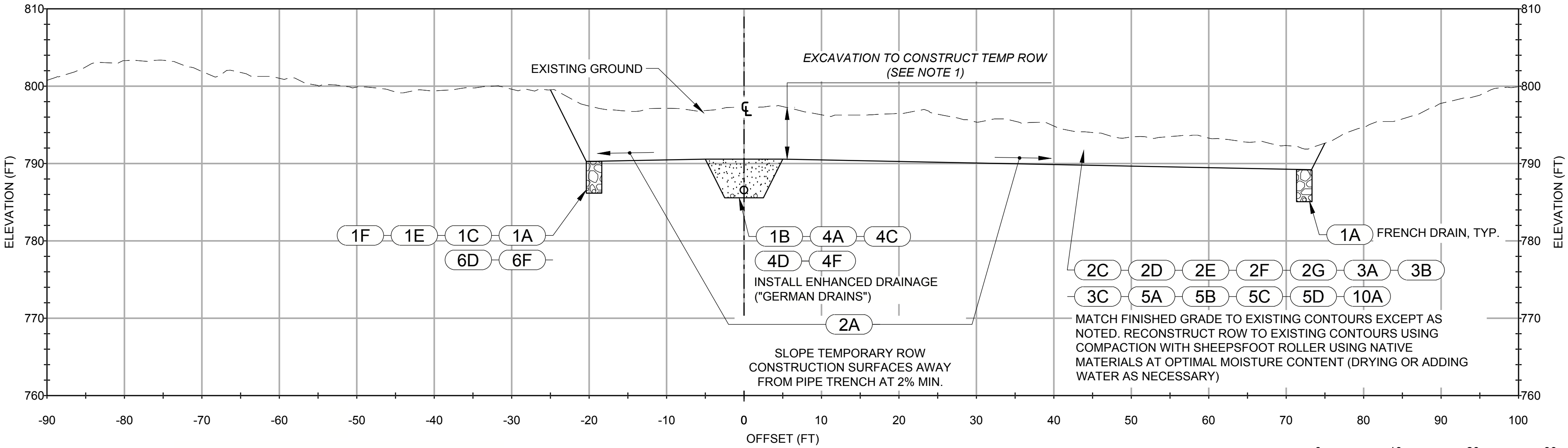
WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO PLANAR SLOPE (STANDARD)

Golder Associates

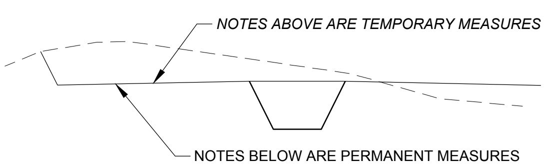
PROJECT No.			.	
DESIGN	BJV	2014-08-11	SCALE	AS SHOWN
CADD	BJV	2014-08-11	SHEET	
CHECK	AGM	2014-08-11	1150	
REVIEW	AQK	2014-08-11		



SUPPORTING TYPICAL DETAILS

- 1A FRENCH DRAIN (SIMPLE), SEE NOTE 4
- 1B ENHANCED DRAIN (GERMAN DRAIN), IN PIPELINE TRENCH, SEE NOTE 1
- 1C TARGETED SEEP DRAINS, AT INTERSEPTED SEEPS, AS NEEDED
- 1E DRAIN PIPE OUTFALL RIPRAP APRON, AS NEEDED
- 1F ARMORED CHANNEL WITH DRAIN PIPE, AS NEEDED
- 1H STEEP CONVEYANCE CHANNEL, AS NEEDED
- 1I CHANGED SEEP CHARACTERISTICS, AS NEEDED
- 1J SINGLE TARGETED SEEP COLLECTOR, AS NEEDED
- 1K ENERGY DISSIPATION BASIN, AS NEEDED
- 2A GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
- 2C COMPACT BACKFILL, AS NEEDED
- 2D DRY SOILS AND BACKFILL, AS NEEDED
- 2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, AS NEEDED
- 2F ROCK BACKFILL (WITH DRAIN), AS NEEDED
- 2G GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1
- 3A TRACK DISTURBED SLOPES, SEE NOTE 1
- 3B RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1
- 3C COIR CLOTH ON DISTURBED SLOPES, SEE NOTE 1
- 3D ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED
- 3E COIR LOGS ON DISTURBED SLOPES, AS NEEDED
- 4A TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 1
- 4C SACK-CRETE BREAKERS (STRUCTURAL BREAKER), SEE NOTE 1 FOR UNSTABLE FILL
- 4D SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, SEE NOTE 1
- 4F TRENCH BREAKER WITH DRAINAGE, SEE NOTE 1
- 4G SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED
- 5A SLOPE BREAKERS (TEMP AND PERMANENT), SEE NOTE 1
- 5B SLOPE BREAKER ARMORED OUTLET, SEE NOTE 1
- 5C SLOPE BREAKERS WITH DIVERSION CHANNELS, SEE NOTE 1 AND 4
- 5D ACCESS ROADS, SEE NOTE 1
- 5E TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED
- 6D ARMORED CHANNEL, SEE NOTE 4
- 6F RIPRAP GRADATIONS AS NEEDED
- 10A BENCHES RE-CONSTRUCTION THROUGH NATURAL STEPS, SEE NOTE 1

LEGEND



NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. TYPICAL SECTION SHOWS SCENARIO WITH VARIED CUT/FILL IN GENERALLY PLANAR GEOMETRY. EXTENT OF CUT/FILL MAY VARY.
4. WHERE THE TEMP ROW SURFACE GRADING DRAINS TO AN IN-BOARD CUT SLOPE, THEN FRENCH DRAINS, OR SHALLOW ARMORED DITCH WITH DRAIN, OR AN ARMORED CHANNEL CONNECTED TO SLOPE BREAKERS IS NEEDED.

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW

NOTES

PROJECT

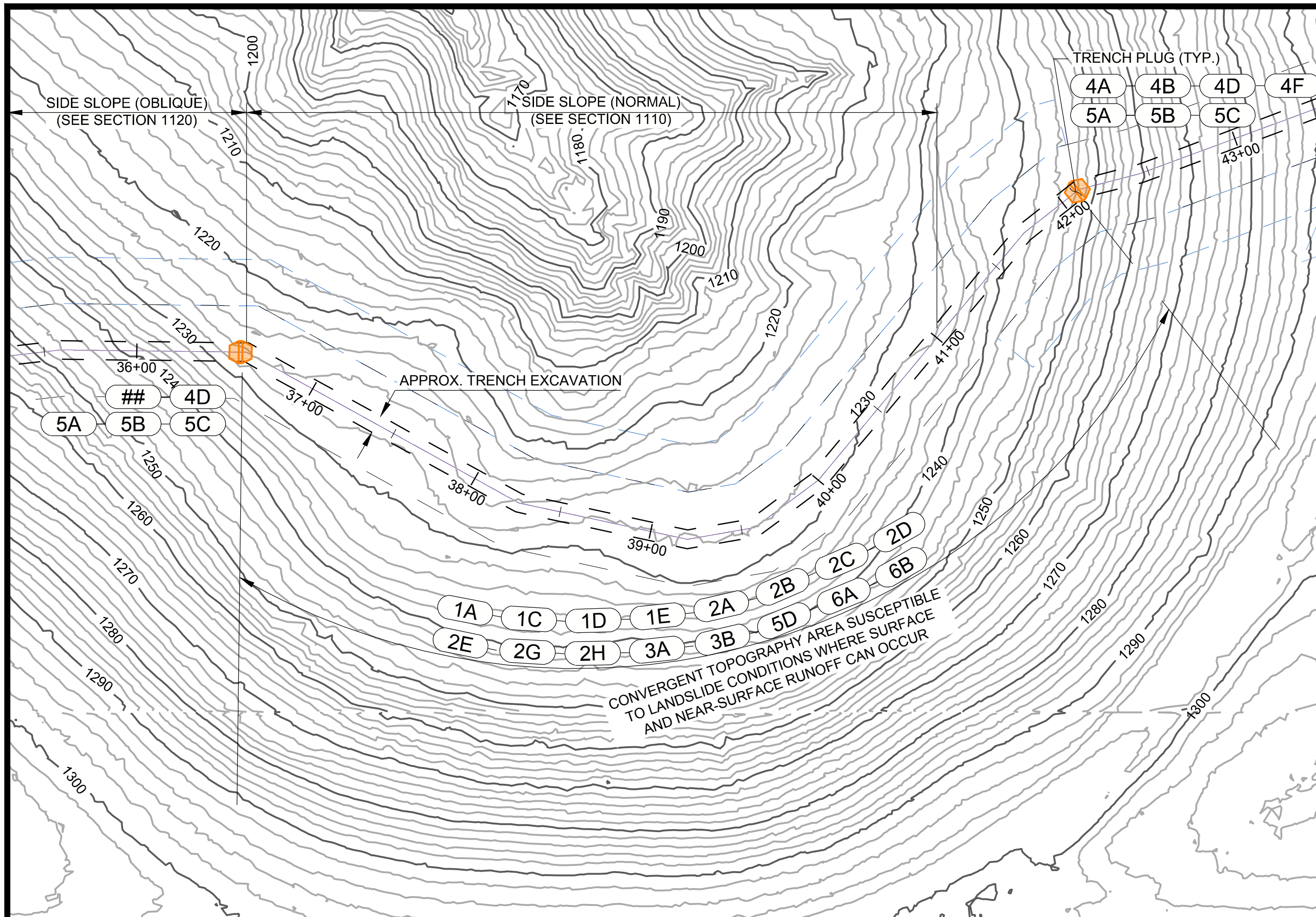
WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO PLANAR SLOPE (DEEP EXCAVATION)

Golder Associates

PROJECT No.			.	
DESIGN	BJV	2014-08-11	SCALE	AS SHOWN
CADD	BJV	2014-08-11	SHEET	
CHECK	AGM	2014-08-11	1160	
REVIEW	AQK	2014-08-11		



0 50 100 150

SCALE FEET

TYPICAL SUPPORTING DETAILS

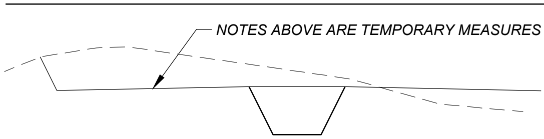
REFER TO SCENARIO SHEETS FOR SIDE SLOPES AND PLANAR SLOPES:

1A	FRENCH DRAIN (SIMPLE), SEE NOTES 1 AND 5
1C	TARGETED SEEP DRAINS, SEE NOTES 1 AND 6
1D	BLEEDER DRAIN, SEE NOTE 1
1E	DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1
1H	STEEP CONVEYANCE CHANNEL, AS NEEDED
1I	CHANGED SEEP CHARACTERISTICS, AS NEEDED
1J	SINGLE TARGETED SEEP COLLECTOR, AS NEEDED
1K	ENERGY DISSIPATION BASIN, AS NEEDED
2A	GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
2B	GRADING TRENCH WITH OUTBOARD WEDGE, SEE NOTE 1
2C	COMPACT BACKFILL, SEE NOTE 1
2D	DRY SOILS AND BACKFILL, SEE NOTE 1
2E	REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, SEE NOTE 1
2G	GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1
2H	GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE, SEE NOTE 1
3A	TRACK DISTURBED SLOPES, SEE NOTE 1
3B	RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1
3C	COIR CLOTH ON DISTURBED SLOPES, SEE NOTE 1
3D	ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED
3E	COIR LOGS ON DISTURBED SLOPES, AS NEEDED
4A	TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 1
4B	TRENCH DAMS (FOAM BAGS OR FINE GRAINED SOILS), SEE NOTE 1
4D	SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, SEE NOTE 1
4F	TRENCH BREAKER WITH DRAINAGE, SEE NOTE 1
4G	SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED

SUPPORTING TYPICAL DETAILS, CONTINUED

5A	SLOPE BREAKERS (TEMP AND PERMANENT), SEE NOTES 1 AND 5
5B	SLOPE BREAKER ARMORED OUTLET, SEE NOTE 1
5C	SLOPE BREAKERS WITH DIVERSION CHANNELS, AS NEEDED
5D	ACCESS ROADS, SEE NOTE 1
6A	COIR-LINED VEGETATED DIVERSION CHANNEL, AS NEEDED
6B	BROW DITCH, AS NEEDED

LEGEND



NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. TYPICAL SECTION SHOWS SCENARIO WITH VARIED CUT/FILL IN GENERALLY PLANAR GEOMETRY. EXTENT OF CUT/FILL MAY VARY.
4. WHERE THE TEMP ROW SURFACE GRADING DRAINS TO AN IN-BOARD CUT SLOPE, THEN FRENCH DRAINS, OR SHALLOW ARMORED DITCH WITH DRAIN, OR AN ARMORED CHANNEL CONNECTED TO SLOPE BREAKERS IS NEEDED.
5. INTERCEPT SEEPAGE FLOWS ALONG TRENCH IN SLOPED TERRAIN APPROACHING AND DEPARTING CONVERGENT AREA. COORDINATE WITH ## AND 5A.
6. FOR AREAS WHERE R.O.W. FOLLOW SLOPE (I.E. CONTOURS WITH SLOPE), AND AT IDENTIFIED SEEP LOCATIONS.

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
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NOTES

PROJECT

WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO CONVERGENT TOPOGRAPHY

Golder Associates

PROJECT No.			
DESIGN	BJV	2014-08-11	SCALE AS SHOWN
CADD	BJV	2014-08-11	SHEET
CHECK	AGM	2014-08-11	1170
REVIEW	AQK	2014-08-11	

SUPPORTING TYPICAL DETAILS

1A	FRENCH DRAIN (SIMPLE), SEE NOTE 1 AND 5
1B	ENHANCED DRAIN (GERMAN DRAIN), SEE NOTE 1 AND 5
1C	TARGETED SEEP DRAINS, SEE NOTE 1
1D	BLEEDER DRAIN, SEE NOTE 1
1E	DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1
1F	ARMORED CHANNEL WITH DRAIN PIPE, SEE NOTE 1
1H	STEEP CONVEYANCE CHANNEL, AS NEEDED
1I	CHANGED SEEP CHARACTERISTICS, SEE NOTE 1
1J	SINGLE TARGETED SEEP COLLECTOR, AS NEEDED
1K	ENERGY DISSIPATION BASIN, AS NEEDED
2C	COMPACT BACKFILL, SEE NOTE 1
2D	DRY SOILS AND BACKFILL, SEE NOTE 1
2E	REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, AS NEEDED
4A	TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTES 1 AND 3
4C	SACK-CRETE BREAKERS (STRUCTURAL BREAKER), SEE NOTE 1 AND 3
4D	SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, AS NEEDED
4F	TRENCH BREAKER WITH DRAINAGE, SEE NOTE 1 AND 3
4G	SACK-CRETE ARMOR WITH BREAKERS, SEE NOTE 1 AND 3
5D	ACCESS ROADS, SEE NOTE 1
8A	ROCK GUARD ON PIPELINE, SEE NOTE 1
10A	BENCHES RE-CONSTRUCTION THROUGH NATURAL STEPS, SEE NOTE 1

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. TRENCH EXCAVATIONS INTO BEDROCK IN SLOPED TERRAIN [PLANAR SLOPES, INCLINED RIDGES, AND SIDESLOPE (OBLIQUE)] WILL REQUIRE TRENCH BREAKERS WITH SUFFICIENT MASS AND GEOTECHNICAL PROPERTIES TO RETAIN BACKFILL SOILS AND/OR ROCK MATERIALS. USE OF FOAM BREAKERS IS NOT RECOMMENDED. SANDBAG OR SACK-CRETE BREAKERS ARE RECOMMENDED.
4. ALTERNATING LAYERS OR WEAKER BEDROCK AND STRONGER BEDROCK MATERIALS OFTEN CREATES A "BENCHED" OR "STAIR-STEPPED" APPEARANCE TO EXISTING HILL SLOPES. MINIMIZE BACKFILL IN THESE SITUATIONS, AND TRANSITION THE SLOPES AT THE ROW BOUNDARIES TO MEET TO EXISTING TERRAIN, BUT MAINTAIN A MORE UNIFORM, POSITIVELY DRAINING SLOPE ACROSS THE ROW. INCORPORATE DRAINAGE MITIGATION WHERE NEEDED SEE NOTE 5. BUILDING BENCHES ALTERNATING WITH FILL ACROSS THE ROW TO MATCH THE EXISTING TOPOGRAPHY IS NOT RECOMMENDED.
5. DRAINAGE IMPROVEMENTS NEEDED TO MITIGATE FOR POSSIBLE SEEPAGE ACCUMULATIONS, OR TO ADDRESS SEEPAGE SCOURS.

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW

NOTES

PROJECT

WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO POTENTIAL SHALLOW BEDROCK

Golder Associates

PROJECT No.			
DESIGN	BJV	2014-08-11	SCALE AS SHOWN
CADD	BJV	2014-08-11	SHEET
CHECK	AGM	2014-08-11	**1500**
REVIEW	AQK	2014-08-11	

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.

3. GEOTECHNICAL STUDY MAY BE REQUIRED TO ADDRESS SITE-SPECIFIC CONDITIONS

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW

NOTES

PROJECT

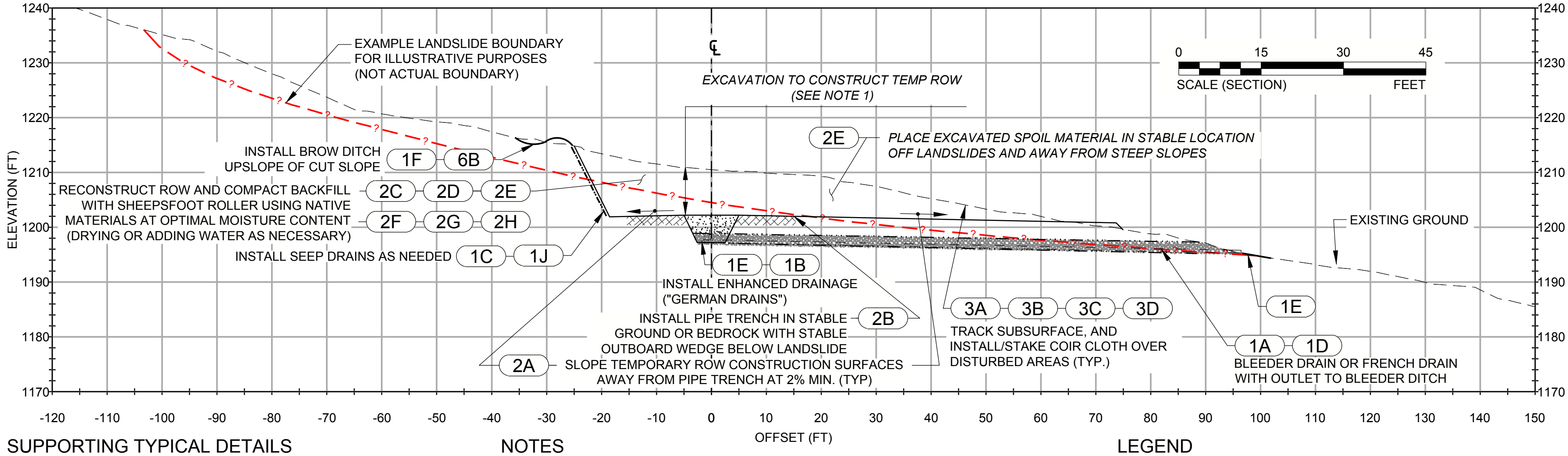
WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO AREAS OF FILL

Golder Associates

PROJECT No.			
DESIGN	BJV	2014-02-28	SCALE AS SHOWN
CADD	BJV	2014-02-28	SHEET
CHECK	AGM	2014-02-28	1600
REVIEW	AQK	2014-02-28	



SUPPORTING TYPICAL DETAILS

- 1A FRENCH DRAIN (SIMPLE), SEE NOTES 1 AND 5
- 1B ENHANCED DRAIN (GERMAN DRAIN), SEE NOTES 1 AND 2
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- 1D BLEEDER DRAIN, SEE NOTE 1
- 1E DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1
- 1F ARMORED CHANNEL WITH DRAIN PIPE, SEE NOTE 1
- 1H STEEP CONVEYANCE CHANNEL, AS NEEDED
- 1I CHANGED SEEP CHARACTERISTICS, AS NEEDED
- 1J SINGLE TARGETED SEEP COLLECTOR, SEE NOTE 1 AND 6
- 1K ENERGY DISSIPATION BASIN, AS NEEDED
- 2A GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
- 2B GRADING TRENCH WITH OUTBOARD WEDGE, SEE NOTE 1
- 2C COMPACT BACKFILL, SEE NOTE 1
- 2D DRY SOILS AND BACKFILL, SEE NOTE 1
- 2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, AS NEEDED
- 2F ROCK BACKFILL (WITH DRAIN), AS NEEDED
- 2G GRADING TO MATCH EXISTING CONTOURS, SEE NOTE 1
- 2H GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE, SEE NOTE 1
- 3A TRACK DISTURBED SLOPES, SEE NOTE 1
- 3B RE-VEGETATE DISTURBED SLOPES, SEE NOTE 1
- 3C COIR CLOTH ON DISTURBED SLOPES, AS NEEDED
- 3D ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED
- 3E COIR LOGS ON DISTURBED SLOPES, AS NEEDED
- 4A TRENCH BREAKERS (FOAM AND SANDBAGS), SEE NOTE 6
- 4B TRENCH DAMS (FOAM BAGS OR FINE GRAINED SOILS), SEE NOTE 6
- 4G SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED
- 5D ACCESS ROADS, SEE NOTE 1
- 5E TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED
- 5F SACK-CRETE WEDGE, AS NEEDED
- 6A COIR-LINED VEGETATED DIVERSION CHANNEL, SEE NOTE 1
- 6B BROW DITCH, SEE NOTE 1

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
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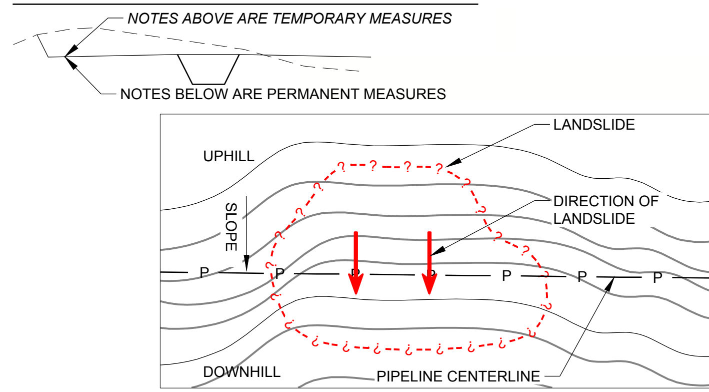
3. LANDSLIDES ("SLIPS") ARE TO BE IDENTIFIED AND EVALUATED ON A CASE-BY-CASE BASIS FOR FOR EACH SITE. MITIGATION RECOMMENDATIONS SPECIFIC TO EACH LANDSLIDE SITE IDENTIFIED SHOULD BE OBTAIN BASED ON SITE-SPECIFIC REVIEW, MAPPING, CHARACTERIZATION, AND DELINEATION OF LANDSLIDE FEATURES.
4. MITIGATION RECOMMENDATIONS MAY CONTAIN THE FOLLOWING IN ADDITION TO OTHER SITE-SPECIFIC RECOMMENDATIONS:
   - A. IF POSSIBLE, REROUTE THE PIPELINE AROUND LANDSLIDE.
   - B. IF NOT POSSIBLE, TEST PIT TO DETERMINE EXTENT OF STABLE/UNSTABLE SOILS. IF POSSIBLE INSTALL PIPELINE TRENCH BENEATH THE LANDSLIDE INTO STABLE MATERIALS, PREFERABLY WITH TRENCH INTO BEDROCK.
   - C. IF PIPE IS NOT IN STABLE GROUND, THEN, INSTALL DEFORMABLE BACKFILL (SAND) WITHIN THE TRENCH AND INSTALL STRAIN GAUGES ON THE PIPE TO MONITOR LONG-TERM STRAIN ACCUMULATION.
   - D. IF POSSIBLE, HAUL EXCESS BACKFILL MATERIALS OFFSITE OR TO ANOTHER STABLE LOCATION AND MINIMIZE BACKFILL OVER THE TRENCH.
   - E. PROVIDE ADDITIONAL AND/OR ENHANCED TRENCH DRAINAGE MEASURES IN TRENCH. DISCHARGE POINTS MUST DRAIN AWAY FROM THE LANDSLIDES ONTO STABLE GROUND.
   - F. SURFACE WATER FLOWS SHOULD BE DIRECTED AWAY FROM LANDSLIDES. INSTALL SLOPE BREAKERS, BROW DITCHES, DIVERSION CHANNELS, DRAINS, ACCESS/ATV ROAD DRAINAGE MEASURES, ETC. AS NEEDED TO DIVERT CONCENTRATED FLOWS OFF THE ROW AND TO NOT POND OR SATURATE SOILS AT LANDSLIDES.
   - G. VERIFY BACKFILL MATERIALS ARE SUITABLE AND COMPACTED AT OPTIMUM MOISTURE CONTENT. ADD WATER OR DRY FILL MATERIALS AS NECESSARY AND, IF NECESSARY, ADD LIME-KILN DUST OR CEMENT-KILN DUST. REPLACE BACKFILL MATERIALS WITH FREE-DRAIING ROCKFILL IF LOCAL SOILS ARE NOT SUITABLE.
   - H. IF NECESSARY, INSTALL TRENCH BREAKERS OR TRENCH DAMS TO INTERRUPT AND BLOCK SEEPAGE FLOWS ALONG THE TRENCH THAT MAY ENTER THE LANDSLIDE AREAS.
   - I. IF NECESSARY, INSTALL SHEAR TRENCH AT ROW BOUNDARY.
   - J. INSTALL GEODETIC MONITORING POINTS (SURVEY BENCHMARKS) AND/OR STAKES.
5. INSTALL DRAINS AT IDENTIFIED SEEPS AND SOURCES OF WATER.
6. TRENCH BREAKERS OR TRENCH DAMS MAY BE REQUIRED AT AREAS JUST OUTSIDE OF LANDSLIDE LIMITS AS WELL AS AT TRANSITIONS FROM SLOPING GROUND TO FLAT GROUND. TRENCH BREAKERS AND TRENCH DAMS ARE USUALLY NOT NEEDED WITHIN LANDSLIDES ON SIDESLOPE - NORMAL.
7. TO-BE-DETERMINED BASED ON THE RECOMMENDATIONS FROM A SITE-SPECIFIC STUDY.

LEGEND



SIDESLOPE ORIENTATION (N.T.S.)

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW

NOTES

PROJECT

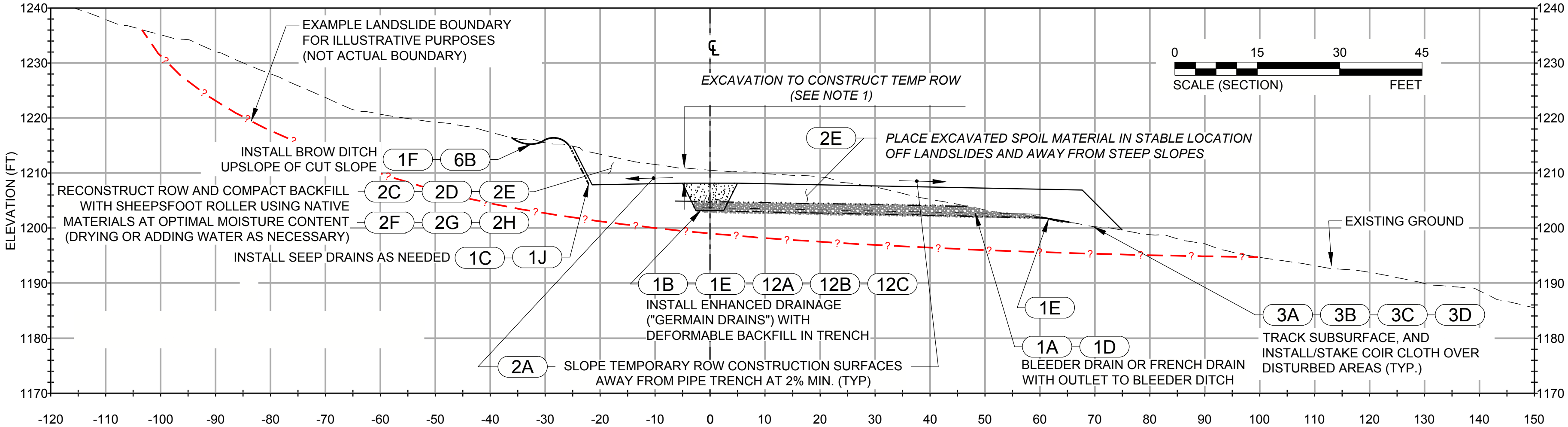
WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO LANDSLIDES SIDE SLOPE WITH STABLE TRENCH

Golder Associates

PROJECT No.			
DESIGN	BJV	2014-08-11	SCALE AS SHOWN
CADD	BJV	2014-08-11	SHEET
CHECK	AGM	2014-08-11	1710
REVIEW	AQK	2014-08-11	



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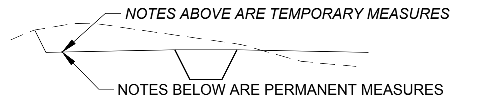

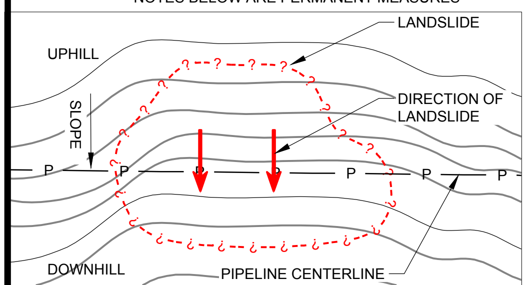

SIDESLOPE ORIENTATION (N.T.S.)

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- 1J SINGLE TARGETED SEEP COLLECTOR, SEE NOTE 1 AND 6
- 1K ENERGY DISSIPATION BASIN, AS NEEDED
- 2A GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
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- 2C COMPACT BACKFILL, SEE NOTE 1
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- 2E REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL, AS NEEDED
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- 3C COIR CLOTH ON DISTURBED SLOPES, AS NEEDED
- 3D ROCK ARMORING ON DISTURBED SLOPES, AS NEEDED
- 3E COIR LOGS ON DISTURBED SLOPES, AS NEEDED
- 4A TRENCH BREAKERS (FOAM AND SANDBAGS),
- 4B TRENCH DAMS (FOAM BAGS OR FINE GRAINED SOILS), SEE NOTE 6
- 4G SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED
- 5D ACCESS ROADS, SEE NOTE 1
- 5E TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED
- 5F SACK-CRETE WEDGE, AS NEEDED
- 6A COIR-LINED VEGETATED DIVERSION CHANNEL, SEE NOTE 1
- 6B BROW DITCH, SEE NOTE 1
- 11A GEODETIC MONITORING, SEE NOTE 7
- 11B STRAIN GAUGE MONITORING, SEE NOTE 7
- 11C SLOPE INCLINOMETER MONITORING, SEE NOTE 7
- 11D SLOPE INCLINOMETER CASING, SEE NOTE 7
- 11E STANDPIPE PIEZOMETER MONITORING, SEE NOTE 7
- 12A STRESS RELIEF EXCAVATIONS, SEE NOTE 1
- 12B SELECT (DEFORMABLE) TRENCH BACKFILL, SEE NOTE 1
- 12C SHEAR TRENCH, SEE NOTES 1 AND 7

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1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
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7. TO-BE-DETERMINED BASED ON THE RECOMMENDATIONS FROM A SITE-SPECIFIC STUDY.

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW

NOTES

PROJECT

WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO LANDSLIDES SIDESLOPE WITH UNSTABLE TRENCH

Golder Associates

PROJECT No.			
DESIGN	BJV	2014-08-11	SCALE AS SHOWN
CADD	BJV	2014-08-11	SHEET
CHECK	AGM	2014-08-11	1720
REVIEW	AQK	2014-08-11	

SUPPORTING TYPICAL DETAILS

- 1A FRENCH DRAIN (SIMPLE), SEE NOTES 1 AND 5
- 1B ENHANCED DRAIN (GERMAN DRAIN), SEE NOTE 1
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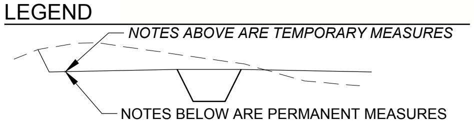
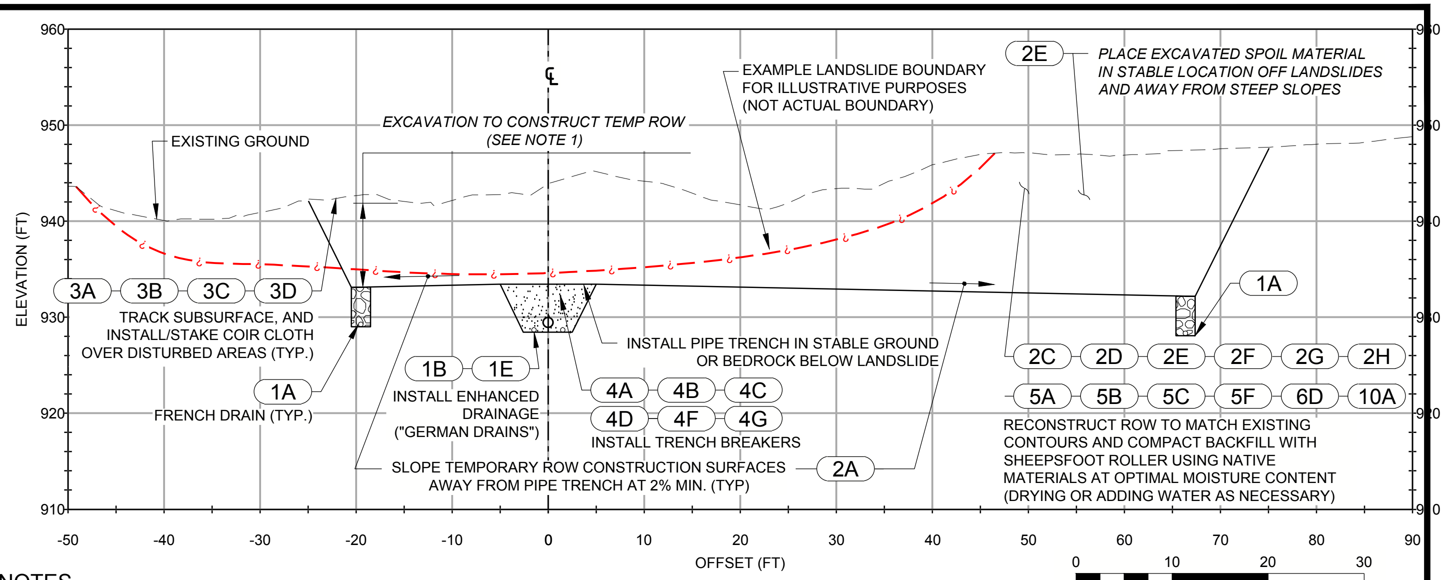
- 4D SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER, SEE NOTE 1
- 4F TRENCH BREAKER WITH DRAINAGE, SEE NOTE 6
- 4G SACK-CRETE ARMOR WITH BREAKERS, AS NEEDED
- 5A SLOPE BREAKERS (TEMP AND PERMANENT), SEE NOTE 1
- 5B SLOPE BREAKER ARMORED OUTLET, SEE NOTE 1
- 5C SLOPE BREAKERS WITH DIVERSION CHANNELS, SEE NOTE 1
- 5D ACCESS ROADS, SEE NOTE 1
- 5E TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED
- 5F SACK-CRETE WEDGE, AS NEEDED
- 6D ARMORED CHANNEL, AS NEEDED
- 10A BENCHES RE-CONSTRUCTION THROUGH NATURAL STEPS, SEE NOTE 1

LEGEND





NOTES

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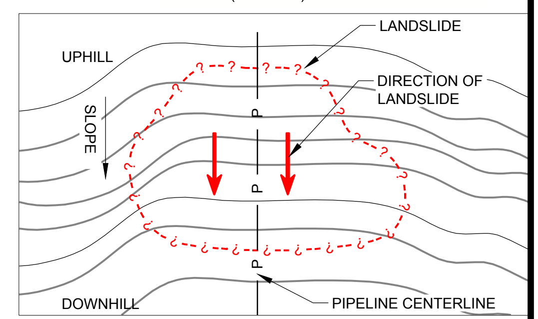

PLANAR SLOPE ORIENTATION (N.T.S.)

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
△	2014-08-11	ISSUED FOR CONSTRUCTION	BJV	BJV	AGM	AQK

NOTES

PROJECT

WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO LANDSLIDES PLANAR SLOPE WITH STABLE TRENCH

Golder Associates

PROJECT No.			
DESIGN	BJV	2014-08-11	SCALE AS SHOWN
CADD	BJV	2014-08-11	SHEET
CHECK	AGM	2014-08-11	1730
REVIEW	AQK	2014-08-11	

SUPPORTING TYPICAL DETAILS

1A	FRENCH DRAIN (SIMPLE), SEE NOTES 1 AND 5
1B	ENHANCED DRAIN (GERMAN DRAIN), SEE NOTE 1
1C	TARGETED SEEP DRAINS, SEE NOTES 1 AND 5
1E	DRAIN PIPE OUTFALL RIPRAP APRON, SEE NOTE 1
1F	ARMORED CHANNEL WITH DRAIN PIPE, SEE NOTE 1
1H	STEEP CONVEYANCE CHANNEL, AS NEEDED
1I	CHANGED SEEP CHARACTERISTICS, AS NEEDED
1J	SINGLE TARGETED SEEP COLLECTOR, SEE NOTE 1 AND 6
1K	ENERGY DISSIPATION BASIN, AS NEEDED
2A	GRADING TEMPORARY ROW SURFACE, SEE NOTE 1
2C	COMPACT BACKFILL, SEE NOTE 1
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5D	ACCESS ROADS, SEE NOTE 1
5E	TEMPORARY SLOPE BREAKER WITH DRAIN PIPE, AS NEEDED
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10A	BENCHES RE-CONSTRUCTION THROUGH NATURAL STEPS, SEE NOTE 1
11A	GEODETIC MONITORING, SEE NOTE 7
11B	STRAIN GAUGE MONITORING, SEE NOTE 7
11C	SLOPE INCLINOMETER MONITORING, SEE NOTE 7
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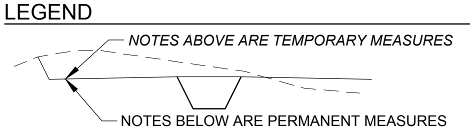
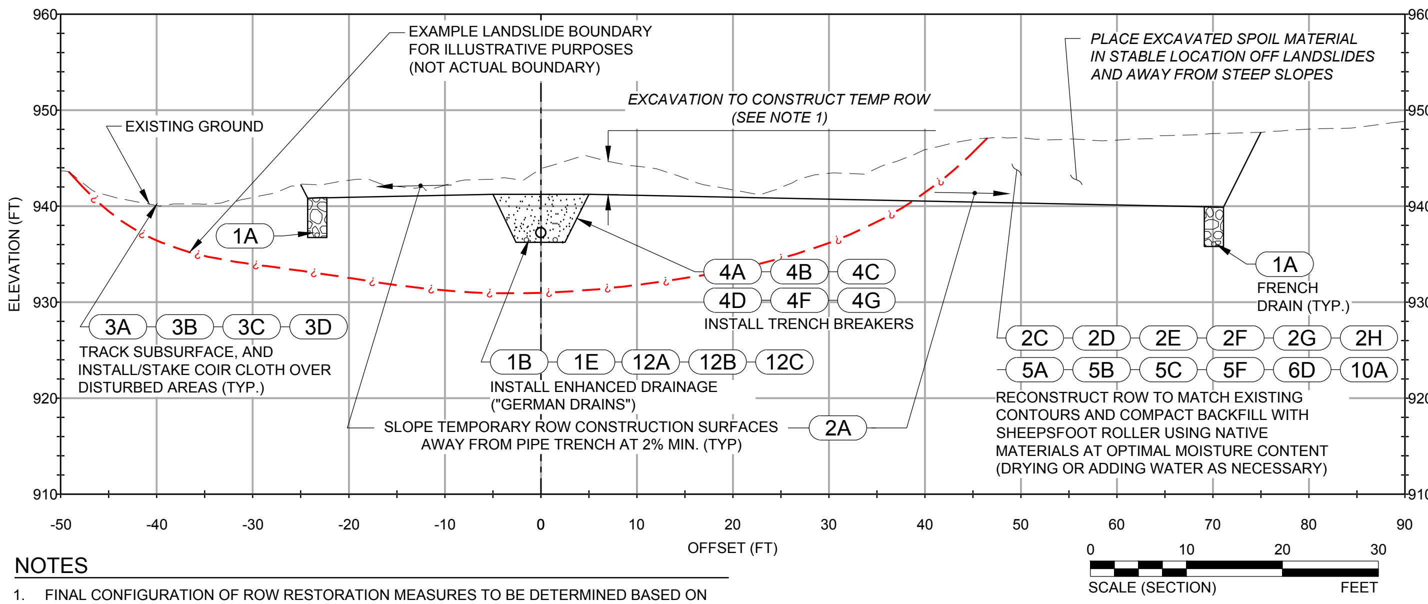
LEGEND





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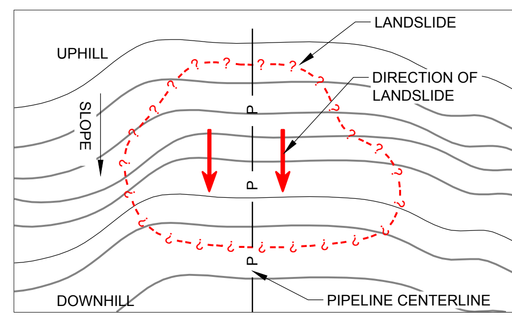
   D. IF POSSIBLE, HAUL EXCESS BACKFILL MATERIALS OFFSITE OR TO ANOTHER STABLE LOCATION AND MINIMIZE BACKFILL OVER THE TRENCH.
   E. PROVIDE ADDITIONAL AND/OR ENHANCED TRENCH DRAINAGE MEASURES IN TRENCH. DISCHARGE POINTS MUST DRAIN AWAY FROM THE LANDSLIDES ONTO STABLE GROUND.
   F. SURFACE WATER FLOWS SHOULD BE DIRECTED AWAY FROM LANDSLIDES. INSTALL SLOPE BREAKERS, BROW DITCHES, DIVERSION CHANNELS, DRAINS, ACCESS/ATV ROAD DRAINAGE MEASURES, ETC. AS NEEDED TO DIVERT CONCENTRATED FLOWS OFF THE ROW AND TO NOT POND OR SATURATE SOILS AT LANDSLIDES.
   G. VERIFY BACKFILL MATERIALS ARE SUITABLE AND COMPACTED AT OPTIMUM MOISTURE CONTENT. ADD WATER OR DRY FILL MATERIALS AS NECESSARY AND, IF NECESSARY, ADD LIME-KILN DUST OR CEMENT-KILN DUST. REPLACE BACKFILL MATERIALS WITH FREE-DRAIING ROCKFILL IF LOCAL SOILS ARE NOT SUITABLE.
   H. IF NECESSARY, INSTALL TRENCH BREAKERS OR TRENCH DAMS TO INTERRUPT AND BLOCK SEEPAGE FLOWS ALONG THE TRENCH THAT MAY ENTER THE LANDSLIDE AREAS.
   I. IF NECESSARY, INSTALL SHEAR TRENCH AT ROW BOUNDARY.
   J. INSTALL GEODETIC MONITORING POINTS (SURVEY BENCHMARKS) AND/OR STAKES.
5. INSTALL DRAINS AT IDENTIFIED SEEPS AND SOURCES OF WATER.
6. TRENCH BREAKERS OR TRENCH DAMS MAY BE REQUIRED JUST OUTSIDE OF LANDSLIDE LIMITS, AT TRANSITIONS, AND WITHIN LANDSLIDES AS NEEDED BASED ON SITE-SPECIFIC RECOMMENDATIONS.
7. TO-BE-DETERMINED BASED ON THE RECOMMENDATIONS FROM A SITE-SPECIFIC STUDY.



PLANAR SLOPE ORIENTATION (N.T.S.)

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
	2014-08-11	ISSUED FOR CONSTRUCTION	BJV	BJV	AGM	AQK

NOTES

PROJECT

WILLIAMS OVM

TITLE

TYPICAL ROW RESTORATION SCENARIO LANDSLIDES PLANAR SLOPE WITH UNSTABLE TRENCH

Golder Associates

PROJECT No.		
DESIGN	BJV	2014-08-11
CADD	BJV	2014-08-11
CHECK	AGM	2014-08-11
REVIEW	AQK	2014-08-11

SCALE AS SHOWN

SHEET 1740

APPENDIX A-2

Typical Details (42 Sheets)

WILLIAMS OHIO VALLEY MIDSTREAM (OVM)

TYPICAL DETAILS

SHEET NO.	TITLE	REV.	DATE
0	COVER SHEET	1	2014-08-07
1A	FRENCH DRAIN (SIMPLE)	0	2014-02-28
1B	ENHANCED DRAIN (GERMAN DRAIN)	0	2014-02-28
1C	TARGETED SEEP DRAINS	1	2014-05-30
1D	BLEEDER DRAIN	0	2014-02-28
1E	DRAIN PIPE OUTFALL RIPRAP APRON	0	2014-02-28
1F	ARMORED CHANNEL WITH DRAIN PIPE	1	2014-05-30
1H	STEEP CONVEYANCE CHANNEL	0	2014-05-30
2A	GRADING TEMPORARY ROW SURFACE	1	2014-05-30
2B	GRADING TRENCH WITH OUTBOARD WEDGE	0	2014-02-28
2C	COMPACT BACKFILL	0	2014-02-28
2D	DRY SOILS AND BACKFILL	0	2014-02-28
2E	REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL	0	2014-02-28
2F	ROCK BACKFILL (WITH DRAIN)	1	2014-05-30
2G	GRADING TO MATCH EXISTING CONTOURS	0	2014-02-28
2H	GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE	0	2014-02-28
3A	TRACK DISTURBED SLOPES	0	2014-02-28
3B	RE-VEGETATE DISTURBED SLOPES	0	2014-02-28
3C	COIR CLOTH ON DISTRUBED SLOPES	0	2014-02-28
3D	ROCK ARMORING ON DISTRUBED SLOPES	0	2014-02-28
4A	TRENCH BREAKERS (FOAM AND SANDBAGS)	0	2014-02-28
4B	TRENCH DAMS (FOAM, BAGS, OR FINE GRAINED SOILS)	0	2014-02-28
4C	SACK-CRETE BREAKERS (STRUCTURAL BREAKER)	1	2014-05-30
4D	SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER	1	2014-05-30
5A	SLOPE BREAKERS (TEMP AND PERMANENT)	0	2014-02-28
5B	SLOPE BREAKER ARMORED OUTLET	0	2014-02-28
5C	SLOPE BREAKERS WITH DIVERSION CHANNELS	0	2014-02-28
5D	ACCESS ROADS	0	2014-02-28
6B	BROW DITCH	0	2014-02-28
6D	ARMORED CHANNEL	0	2014-02-28
8A	ROCK GUARD ON PIPELINE	0	2014-02-28
10A	BENCH RE-CONSTRUCTION THROUGH NATURAL STEPS	0	2014-02-28
11A	GEODETIC MONITORING	0	2014-02-28
11B	STRAIN GAUGE MONITORING	0	2014-02-28
11C	SLOPE INCLINOMETER MONITORING	0	2014-02-28
11D	SLOPE INCLINOMETER CASING	0	2014-02-28

TYPICAL DETAILS

SHEET NO.	TITLE	REV.	DATE
11E	STANDPIPE PIEZOMETER MONITORING	0	2014-02-28
12A	STRESS RELIEF EXCAVATIONS	0	2014-02-28
12B	SELECT (DEFORMABLE) BACKFILL AROUND PIPELINE IN LANDSLIDE	0	2014-02-28
12C	SHEAR TRENCH	0	2014-02-28
15A	AVOIDANCE	1	2014-05-30
15B	EXCAVATION REMOVAL OF HAZARD	1	2014-05-30

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT

Golder Associates

YYYY-MM-DD	2014-08-07
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

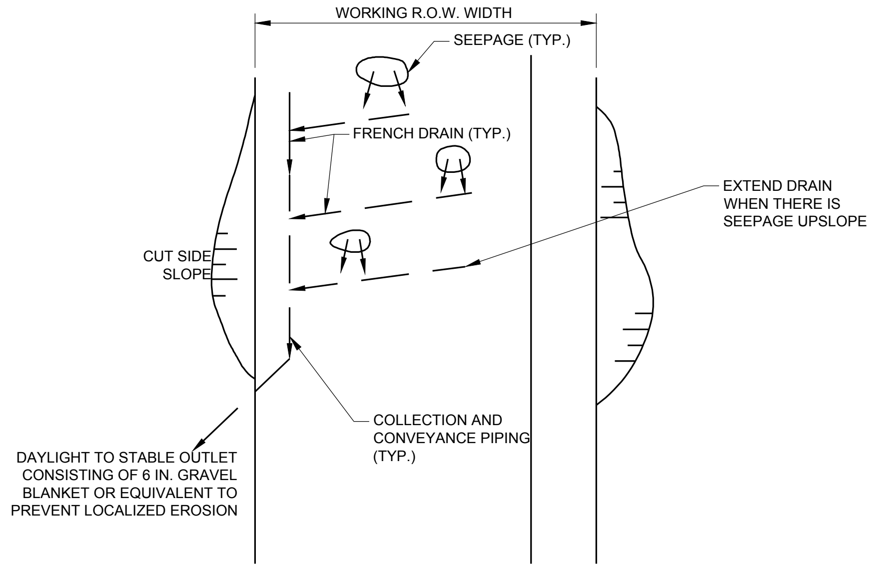
TITLE
COVER SHEET

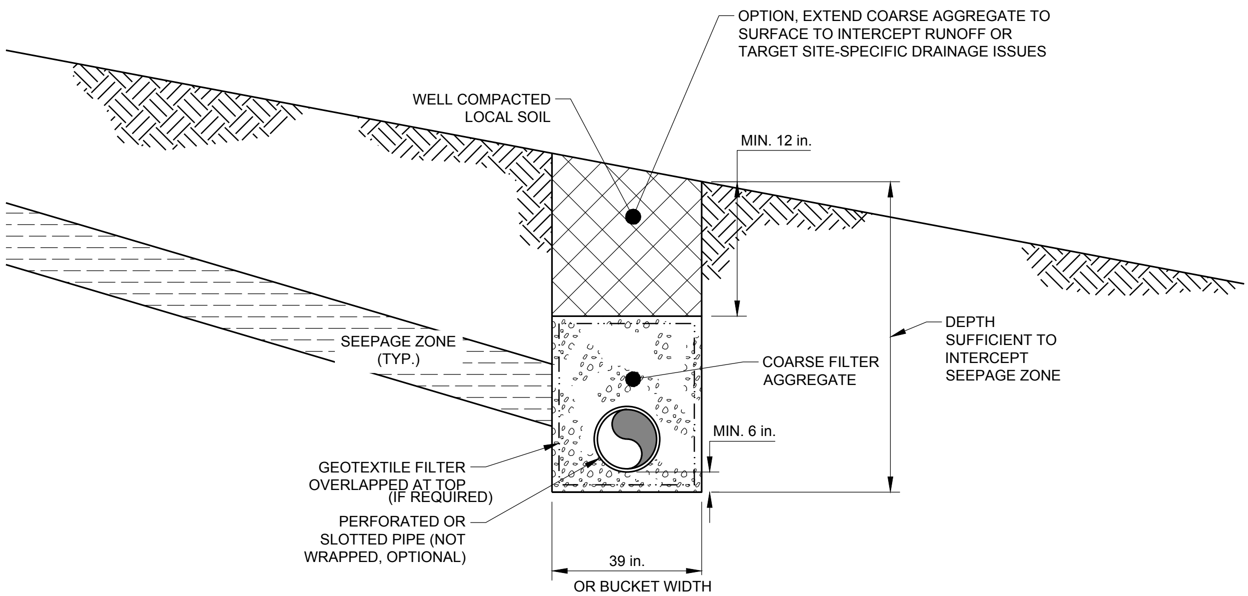
PROJECT No.

ISSUED FOR CONSTRUCTION

Rev. 1

SHEET 0





NOTES:

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

CLIENT
WILLIAMS OVM

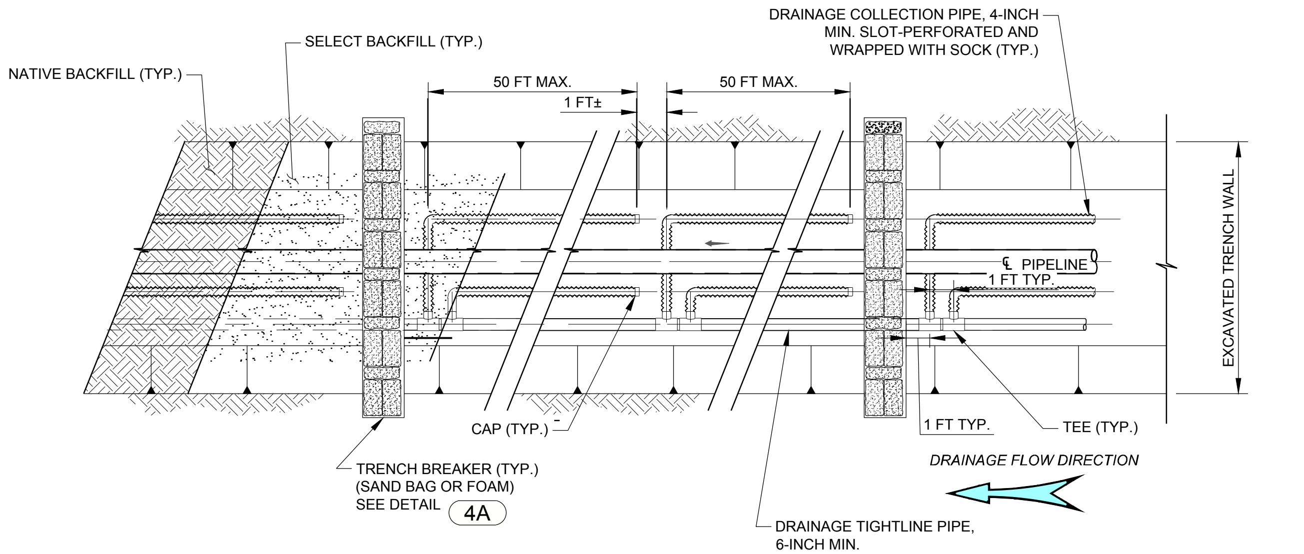
PROJECT
TYPICAL DETAILS

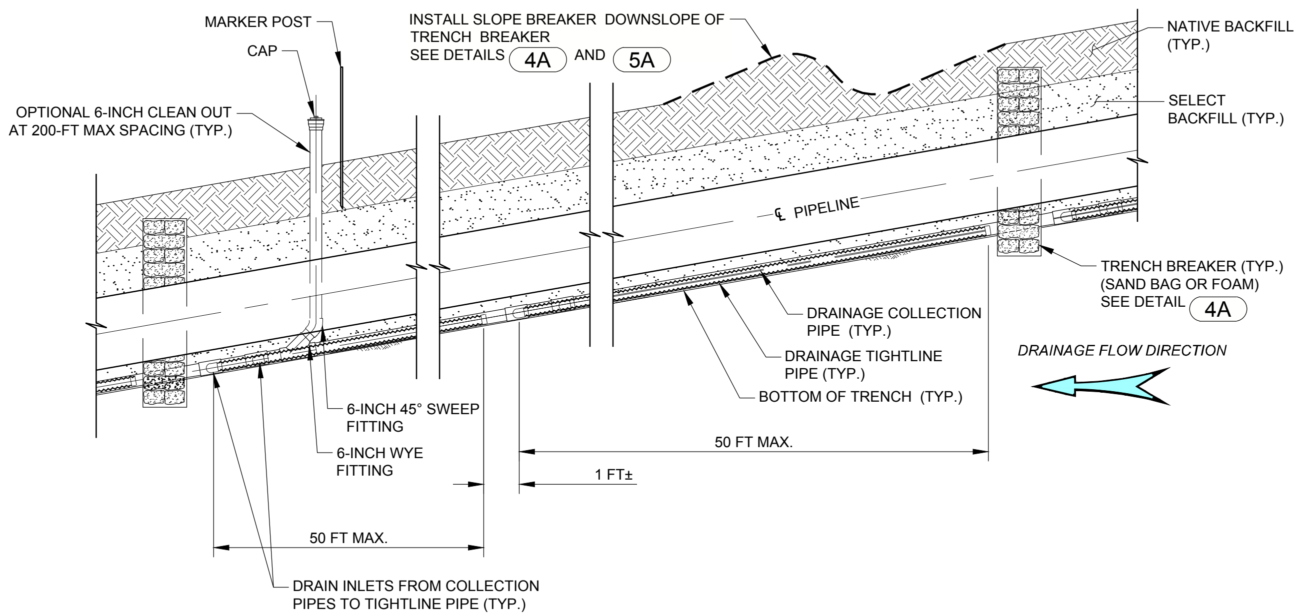
CONSULTANT
Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
FRENCH DRAIN (SIMPLE)

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	1A





CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

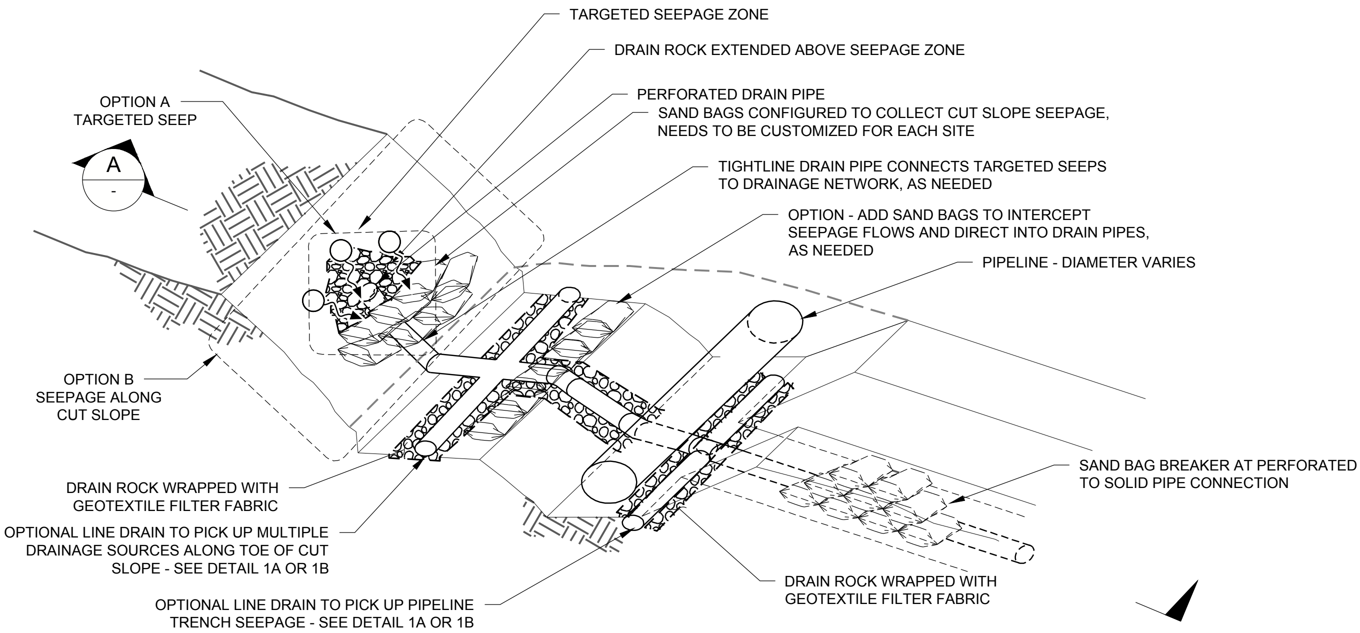
CONSULTANT
Golder Associates

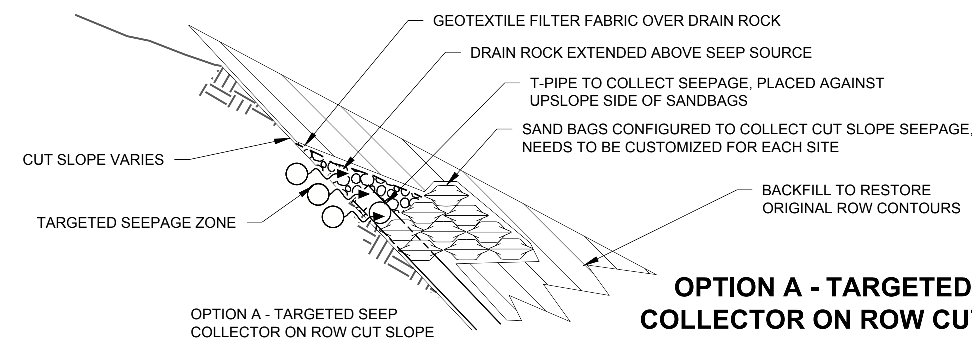
YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
ENHANCED DRAIN (GERMAN DRAIN)

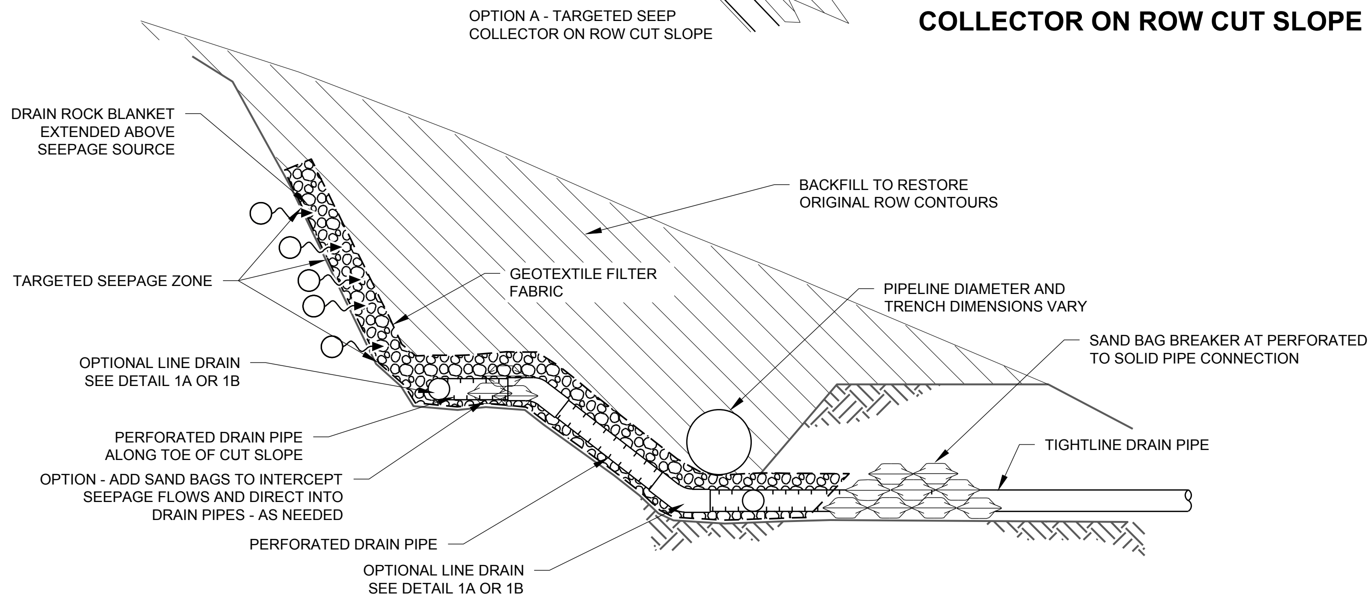
PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	1B

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
0
1 in





OPTION A - TARGETED SEEP COLLECTOR ON ROW CUT SLOPE



A
-

OPTION B - TARGETED SEEP COLLECTOR ON ROW CUT SLOPE

CLIENT
WILLIAMS OVM

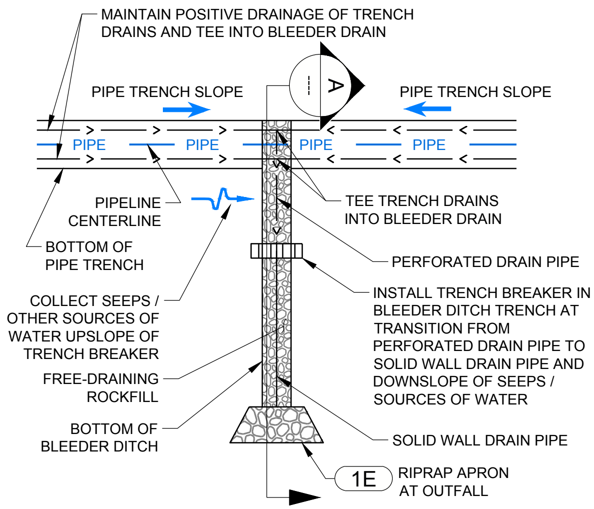
PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

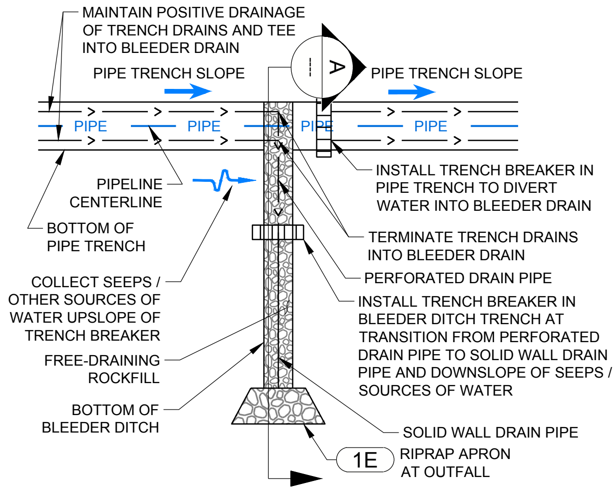
YYYY-MM-DD	2014-05-30
PREPARED	ACF
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
TARGETED SEEP DRAINS

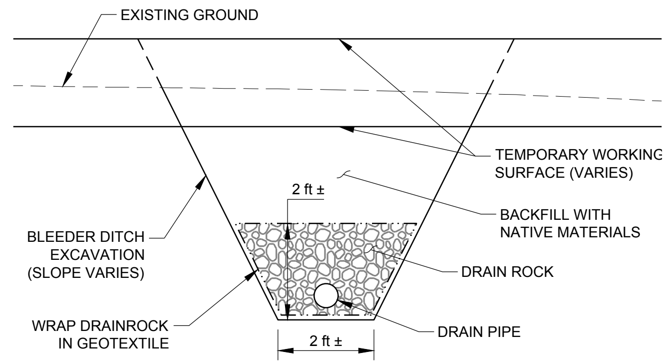
PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	1	1C



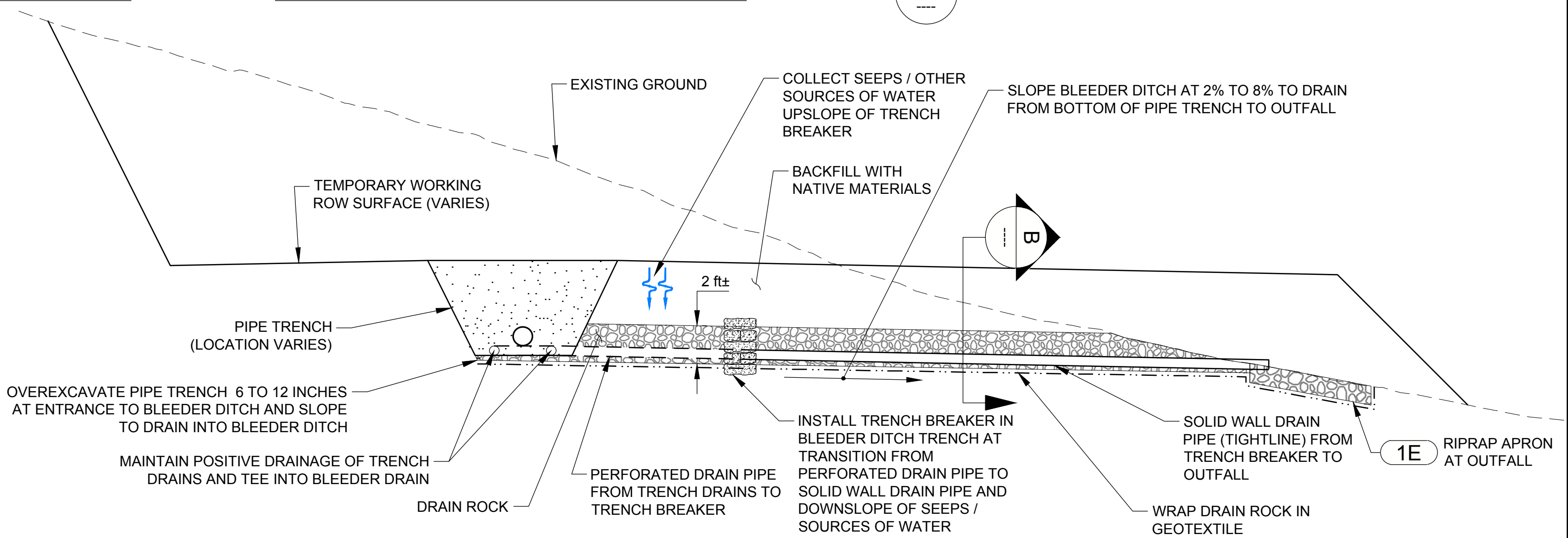
BLEEDER DRAIN WITH FLAT PIPE TRENCH



BLEEDER DRAIN WITH SLOPED PIPE TRENCH



B ---- BLEEDER DRAIN DITCH SECTION



A ---- BLEEDER DRAIN PROFILE

NOTES:

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. INSTALL BLEEDER DITCH IN SIDESLOPE SCENARIOS AT 100 FT INTERVALS, AT LOW POINTS IN THE PIPELINE TRENCH, OR AS NEEDED TO COLLECT SEEPS, SOURCES OF WATER, OR OTHER DRAINS.
3. NATIVE MATERIALS MAY BE USED DOWNSLOPE OF BLEEDER DITCH TRENCH BREAKER INSTEAD OF DRAINFILL PROVIDED THAT NATIVE BACKFILL MATERIALS ARE FREE-DRAINING AND NO SEEPS OR SOURCES OF WATER ARE IDENTIFIED DOWNSLOPE OF THE PIPE TRENCH.
4. LENGTH OF BLEEDER DRAIN WILL VARY AS NEEDED TO MAINTAIN POSITIVE DRAINAGE IN DITCH TO OUTFALL.

CLIENT
WILLIAMS OVM

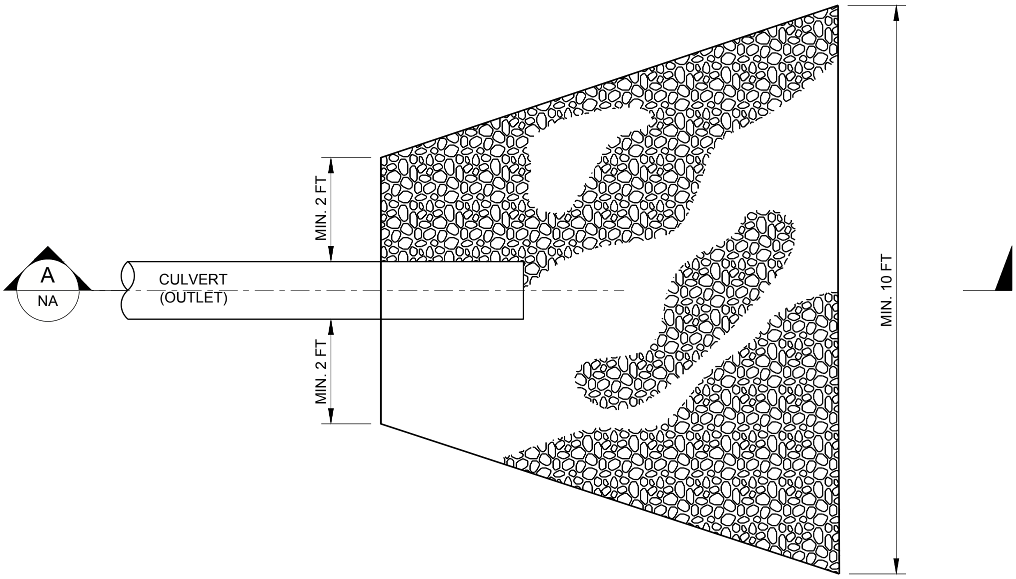
PROJECT
TYPICAL DETAILS

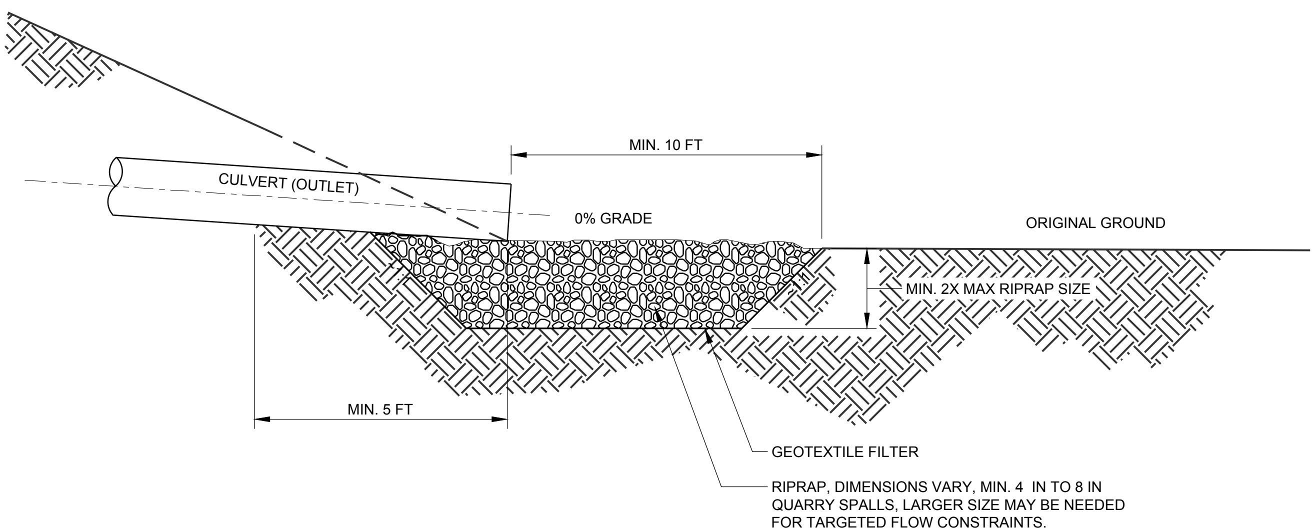
CONSULTANT
Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
BLEEDER DRAIN

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	1D





NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

CLIENT
WILLIAMS OVM

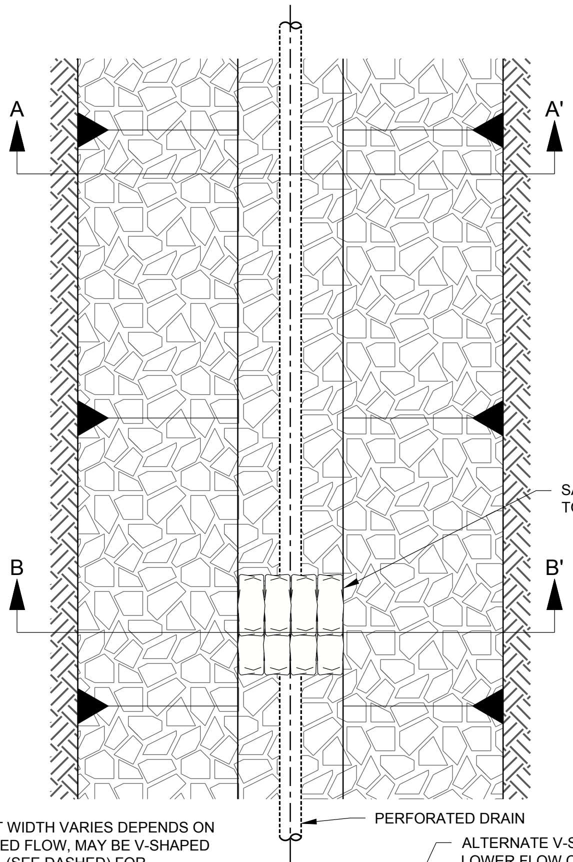
PROJECT
TYPICAL DETAILS

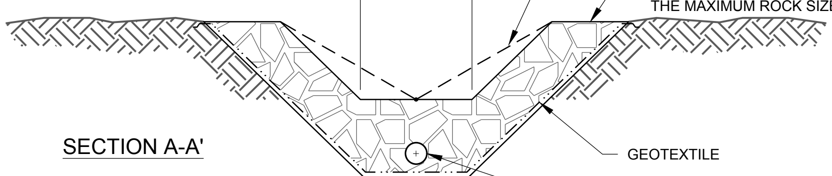
CONSULTANT
Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

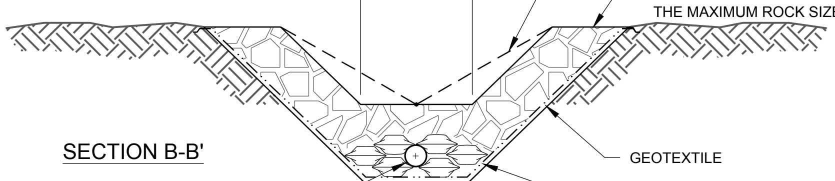
TITLE
DRAIN PIPE OUTFALL RIPRAP APRON

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	1E





SECTION A-A'



SECTION B-B'

NOTES:

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. 100-FT MAX SPACING FOR BREAKERS.

CLIENT
WILLIAMS OVM

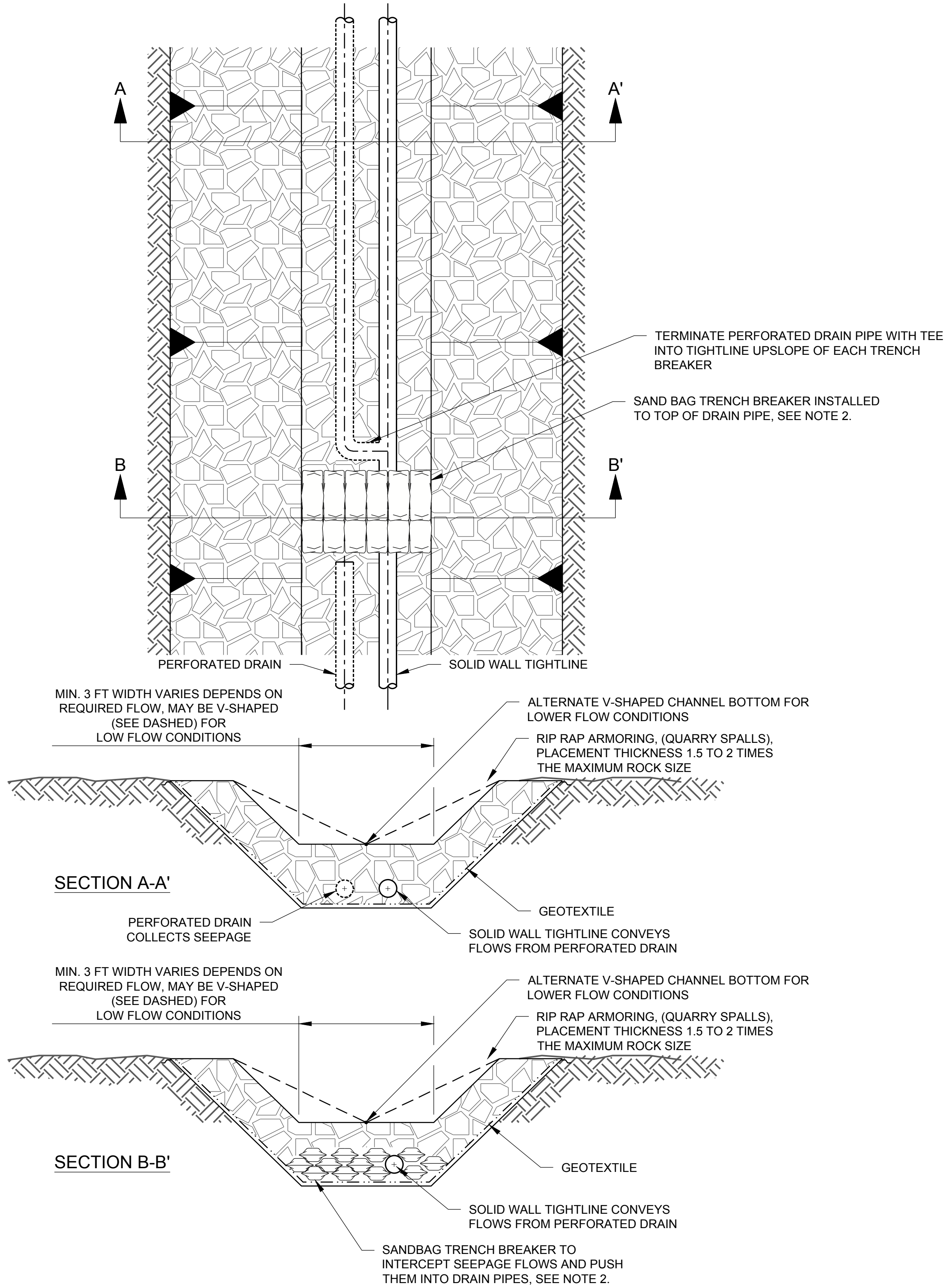
PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

YYYY-MM-DD	2014-05-30
PREPARED	ACF
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
ARMORED CHANNEL WITH DRAIN PIPE

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	1	1F



NOTES:

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. 100-FT MAX SPACING FOR BREAKERS.

CLIENT
WILLIAMS OVM

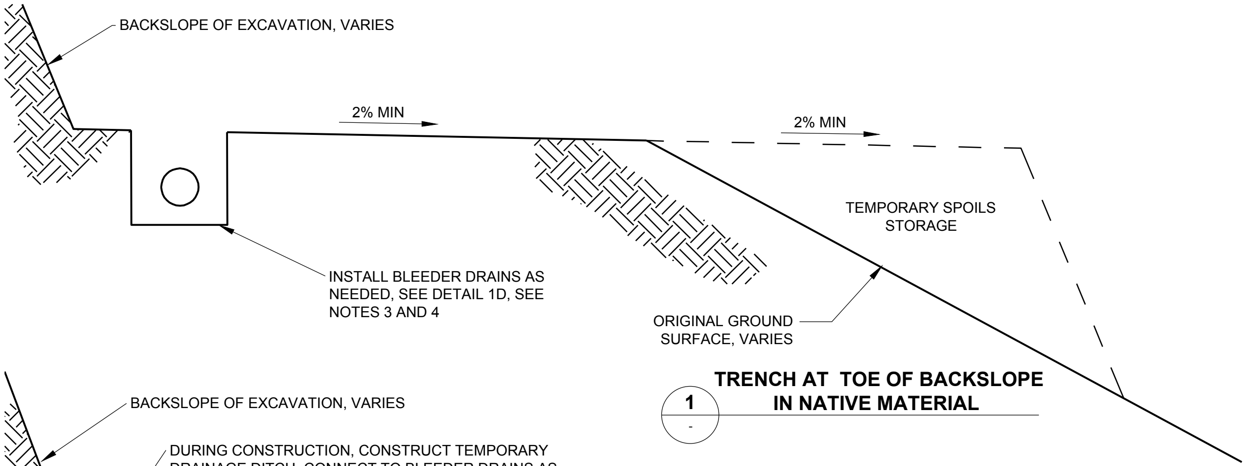
PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

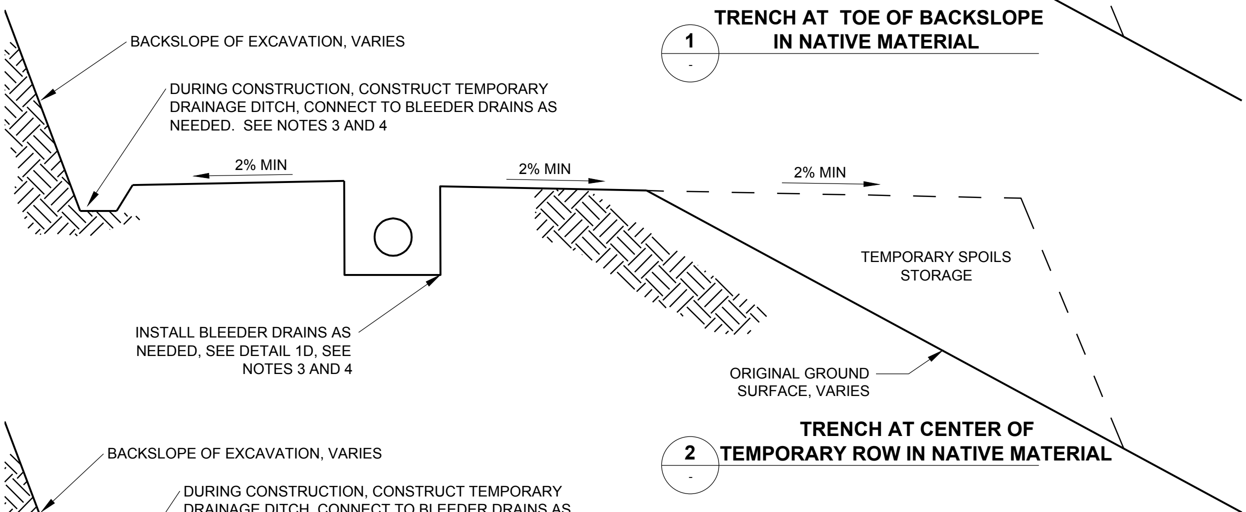
YYYY-MM-DD	2014-05-30
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
STEEP CONVEYANCE CHANNEL

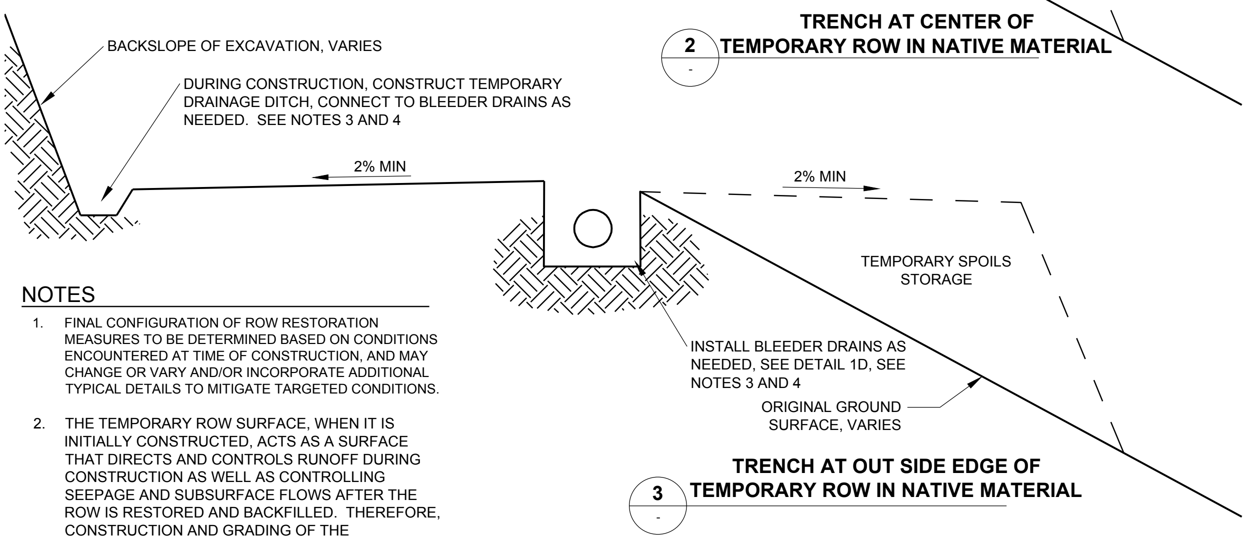
PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	1H



TRENCH AT TOE OF BACKSLOPE IN NATIVE MATERIAL



TRENCH AT CENTER OF TEMPORARY ROW IN NATIVE MATERIAL



TRENCH AT OUT SIDE EDGE OF TEMPORARY ROW IN NATIVE MATERIAL

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

2. THE TEMPORARY ROW SURFACE, WHEN IT IS INITIALLY CONSTRUCTED, ACTS AS A SURFACE THAT DIRECTS AND CONTROLS RUNOFF DURING CONSTRUCTION AS WELL AS CONTROLLING SEEPAGE AND SUBSURFACE FLOWS AFTER THE ROW IS RESTORED AND BACKFILLED. THEREFORE, CONSTRUCTION AND GRADING OF THE TEMPORARY ROW SURFACE SHOULD BE COMPLETED TO SO AS TO MAINTAIN POSITIVE DRAINAGE (I.E. APPROXIMATELY 2% SLOPE) AWAY FROM THE PIPELINE TRENCH, AND TO OUTBOARD SIDES OF THE ROW THAT DISCHARGE ONTO NATURAL SLOPES DIRECTED AWAY FROM THE ROW, SO THAT RUNOFF ON THE TEMPORARY ROW SURFACE DOES NOT ACCUMULATE OR POND.

3. FOR TEMPORARY CONSTRUCTION WORK PERIOD, WHERE THE TEMPORARY ROW SURFACE MUST SLOPE TO AN INSIDE AREA, WHERE ACCUMULATED RUNOFF CAN POND, THEN DRAINAGE MEASURES SHOULD BE IMPLEMENTED THAT COLLECT AND EVACUATE THE PONDED WATER DURING TEMPORARY CONSTRUCTION PERIODS AND FOR PERMANENT RESTORATION.

4. FOR PERMANENT RESTORATION, CONVERT TEMPORARY DRAINAGE DITCH TO FRENCH DRAINS AND/OR TARGETED SEEP COLLECTORS, AS NEEDED. SEE DETAILS 1A, 1C, 1D AND 1E.

CLIENT
WILLIAMS OVM

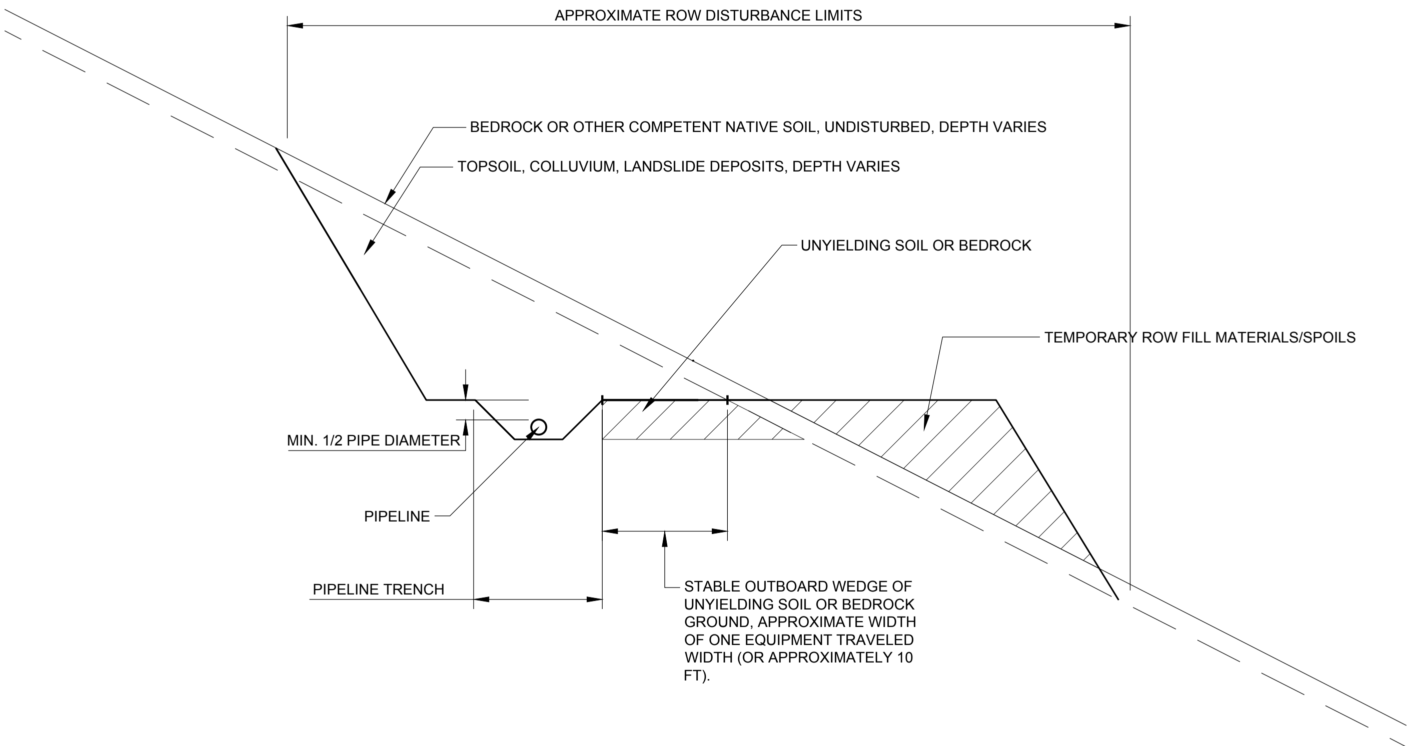
PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

YYYY-MM-DD	2014-05-30
PREPARED	ACF
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
GRADING TEMPORARY ROW SURFACE

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	1	2A



NOTE

BASED ON INFORMATION FROM WILLIAMS

FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

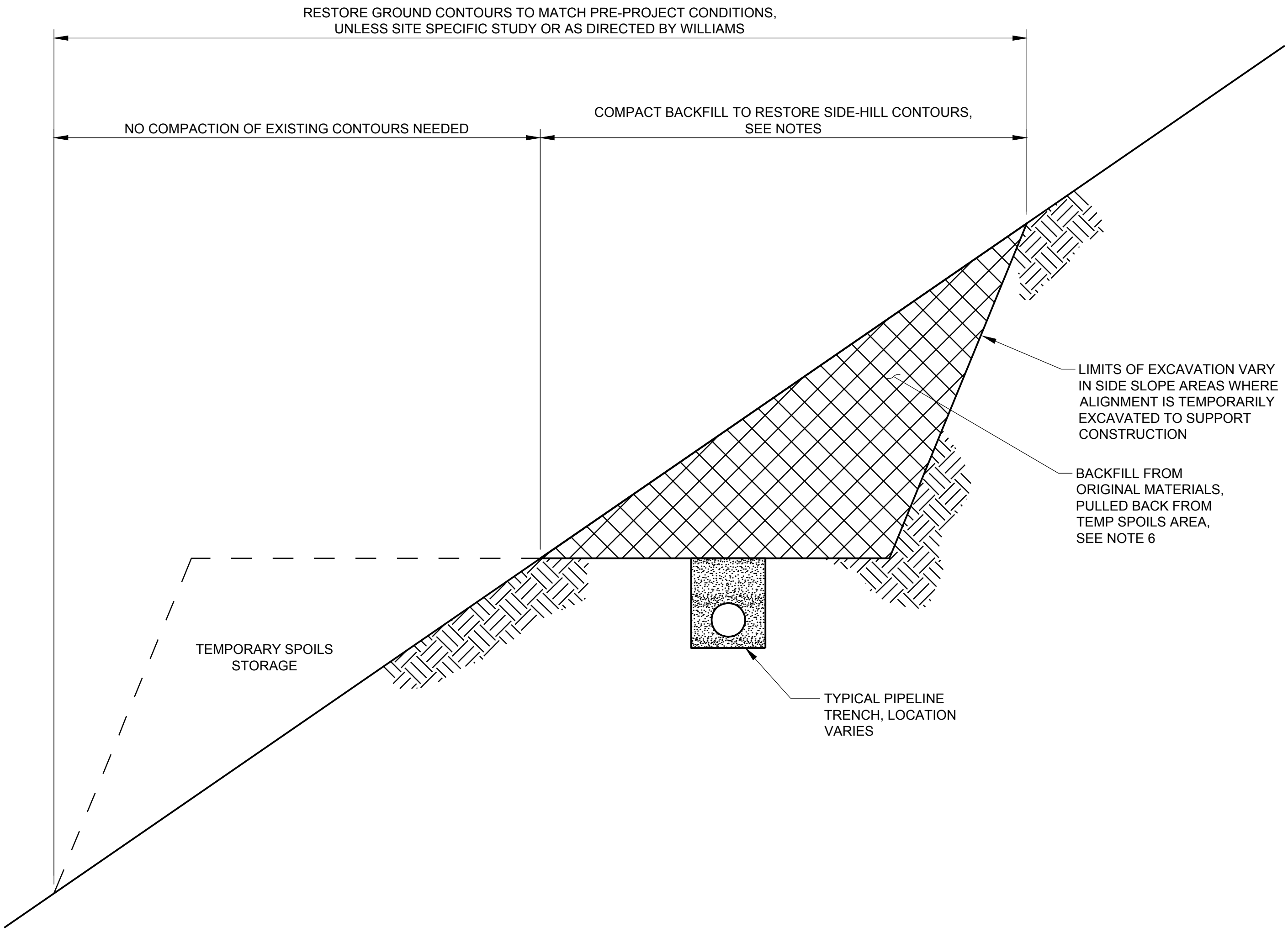
CLIENT	PROJECT
WILLIAMS OVM	TYPICAL DETAILS

CONSULTANT: Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
GRADING TRENCH WITH STABLE OUTBOARD WEDGE

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	2B



NOTES:

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. RECOMMEND COMPACTING SIDE SLOPE AREAS USING “SHEEP’S FOOT” COMPACTION EQUIPMENT IN HORIZONTAL LAYERS.
3. BACKFILL MATERIALS SHOULD BE AT OR NEAR OPTIMUM MOISTURE CONTENT (DRYING SOILS OR ADDING WATER AS NECESSARY), VISUALLY DETERMINED BY A COMPETENT ON-SITE REPRESENTATIVE. SEE TYPICAL DETAIL 2D FOR DRYING BACKFILL.
4. SOILS COMPACTION SHOULD BE COMPLETED IN LIFTS SUCH THAT BACKFILL MATERIALS ARE STABLE, SHED WATER AND DO NOT EASILY BECOME SATURATED, AND ARE AT APPROXIMATELY THE MAXIMUM DRY DENSITY, VISUALLY DETERMINED BY A COMPETENT ON-SITE REPRESENTATIVE.
5. ADDITIONAL COMPACTION REQUIREMENTS MAY APPLY AT ROAD CROSSINGS, AREAS IDENTIFIED BY WILLIAMS, OR AT OTHER LOCATIONS AS MAY BE REQUIRED BY LAWS AND REGULATIONS. SEE TYPICAL DETAIL 2I FOR COMPACTION REQUIREMENTS ACROSS ROADS.
6. BACKFILL CONFIGURATION MAY VARY TO FIT SITE CONDITIONS, AND MAY BE USED IN OTHER ROW CROSS-SECTION BACKFILL GEOMETRIES, AS DIRECTED BY WILLIAMS.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
COMPACT BACKFILL

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	2C

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

2. SATURATED ON-SITE SOILS MAY NEED TO BE DRIED BEFORE RE-USE AND PLACEMENT AS BACKFILL. DRYING MAY INCLUDE WIND-ROWING AND TURNING OVER IN FURROWS TO ALLOW FOR AIR EXCHANGE AND EVAPORATION TO DRY THE MATERIALS, OR ADDITION OF ADD-MIXTURES TO DRY THE SOILS.

3. THE USE OF ADD-MIXTURES TO SATURATED SOILS SHOULD BE REVIEWED AND APPROVED BY WILLIAMS PRIOR TO USE.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT

Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
DRY SOILS AND BACKFILL

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	2D

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. WHERE THE PLACEMENT OF SPOILS ON THE SITE MAY INITIATE OR EXACERBATE LANDSLIDES OR RESULT IN SLOPE INSTABILITY, THE MATERIALS SHOULD BE REMOVED FROM THE SITE AND SPOILED AT A SAFE AND OFF-SITE LOCATION.

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

1 in

0

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

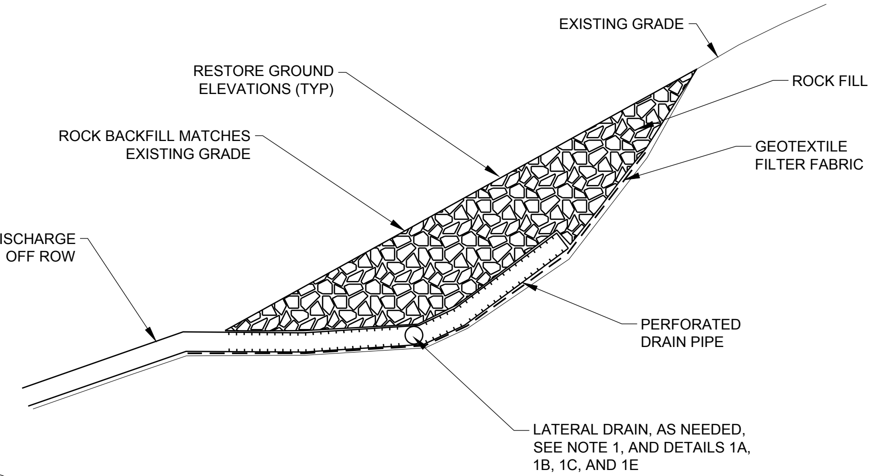
YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
REMOVE UNSUITABLE EXISTING SOILS AS BACKFILL

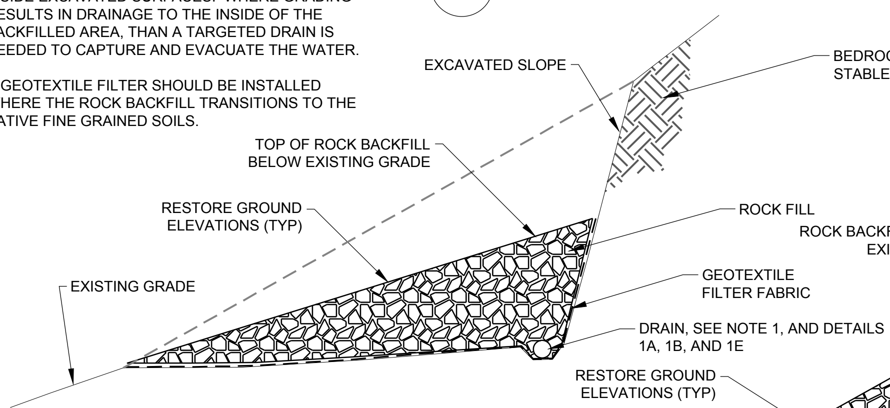
PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	2E

NOTES

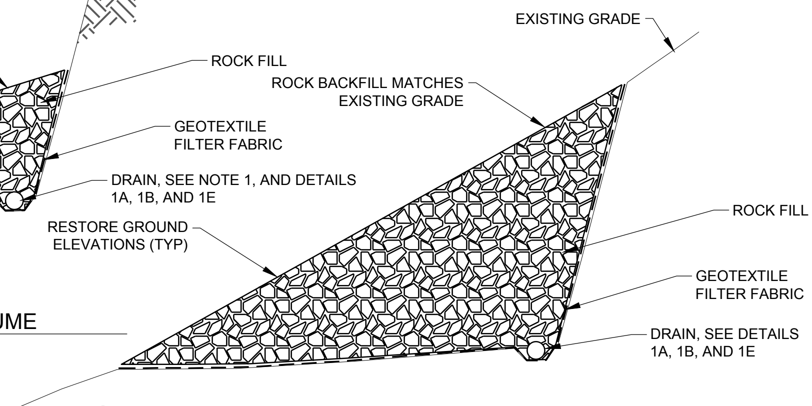
1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. WHERE LOCAL SOILS ARE NOT SUITABLE FOR BACKFILL DUE TO SATURATED CONDITIONS OR OTHER NON-COMPLIANT CONDITIONS (I.E. ORGANICS, DEBRIS, ETC.), AND BACKFILL IS NEEDED TO RESTORE GROUND CONTOURS, THEN USE OF SMALL DIAMETER ANGULAR ROCK FILL IS RECOMMENDED.
3. ROCK BACKFILL SHOULD BE UNIFORMLY GRADED (I.E. GENERALLY THE SAME SIZE), SMALL IN SIZE (APPROXIMATELY 4-8 INCH DIAMETER), AND FREE OF FINES OR OTHER NON-COMPLIANT MATERIALS.
4. INSTALL A DRAIN AT THE INSIDE CATCH OF THE EXCAVATED SLOPE WHERE ROCK FILL IS INSTALLED.
5. GRADE THE BOTTOM OF THE BACKFILLED AREA TO PROVIDE POSITIVE DRAINAGE TO THE OUTBOARD SIDE (I.E. AWAY FROM THE INSIDE CUT BANK) OF THE BACKFILLED AREA. THE INTENT IS TO NOT ACCUMULATE SEEPAGE OR DRAINAGE ON ANY INSIDE EXCAVATED SURFACES. WHERE GRADING RESULTS IN DRAINAGE TO THE INSIDE OF THE BACKFILLED AREA, THAN A TARGETED DRAIN IS NEEDED TO CAPTURE AND EVACUATE THE WATER.
6. A GEOTEXTILE FILTER SHOULD BE INSTALLED WHERE THE ROCK BACKFILL TRANSITIONS TO THE NATIVE FINE GRAINED SOILS.



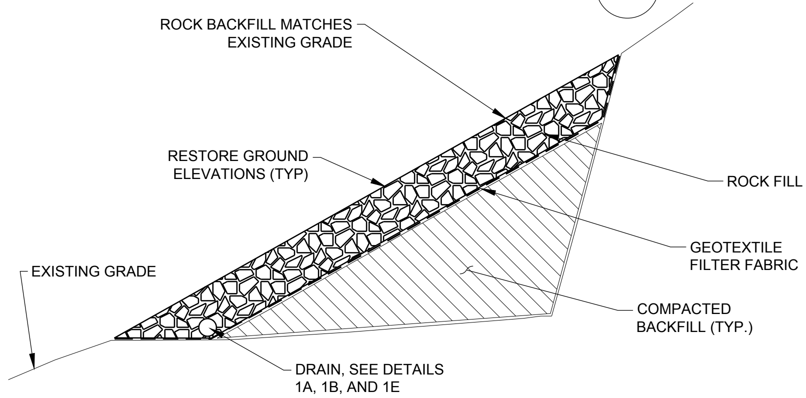
1 - RESTORE SLUMP OR SMALL SLIPS



2 - PARTIAL FILL TO REDUCE BACKFILL VOLUME



3 - SIDEHILL FILL TO RESTORE FULL ROW SECTIONS



4 - SLIVER FILL TO PROVIDE ARMOR ON BACKFILL AND/OR RESTORE CONTOURS

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

YYYY-MM-DD	2014-05-30
PREPARED	ACF
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
ROCK BACKFILL (WITH DRAIN)

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	1	2F

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. RESTORATION OF ROW SURFACES SHOULD GENERALLY RE-CONSTRUCT THE GROUND SURFACE TO MATCH THE PRE-PROJECT CONTOURS.
3. CHANGES IN THE FINAL GRADING MAY BE NEEDED TO ADDRESS SPECIFIC TARGETED GEOTECHNICAL OR HYDROTECHNICAL OR GEOLOGIC ENGINEERING ISSUES (I.E. CORRECT DRAINAGE PROBLEMS, MINIMIZE DELIVERY OF WATER TO LANDSLIDE SITES, ETC.).
4. FINAL GRADING TO BE REVIEWED AND APPROVED BY WILLIAMS PRIOR TO COMPLETION.

1 in

0

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
GRADING TO MATCH EXISTING CONTOURS

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	2G

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

2. MINIMIZE THE PLACEMENT OF BACKFILL MATERIALS WHEN RESTORING AND RE-CONSTRUCTING LANDSLIDE SITES, IN ORDER TO REDUCE THE IMPOSED LOAD ON LANDSLIDE SITES.

3. MINIMIZE THE PLACEMENT OF SPOILS FROM GRADING WORK IN OTHER AREAS ALONG THE ROW THAT MAY OVERLAP OTHER LANDSLIDES, IN ORDER TO REDUCE THE POTENTIAL FOR INITIATING NEW LANDSLIDES.

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

1 in

0

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

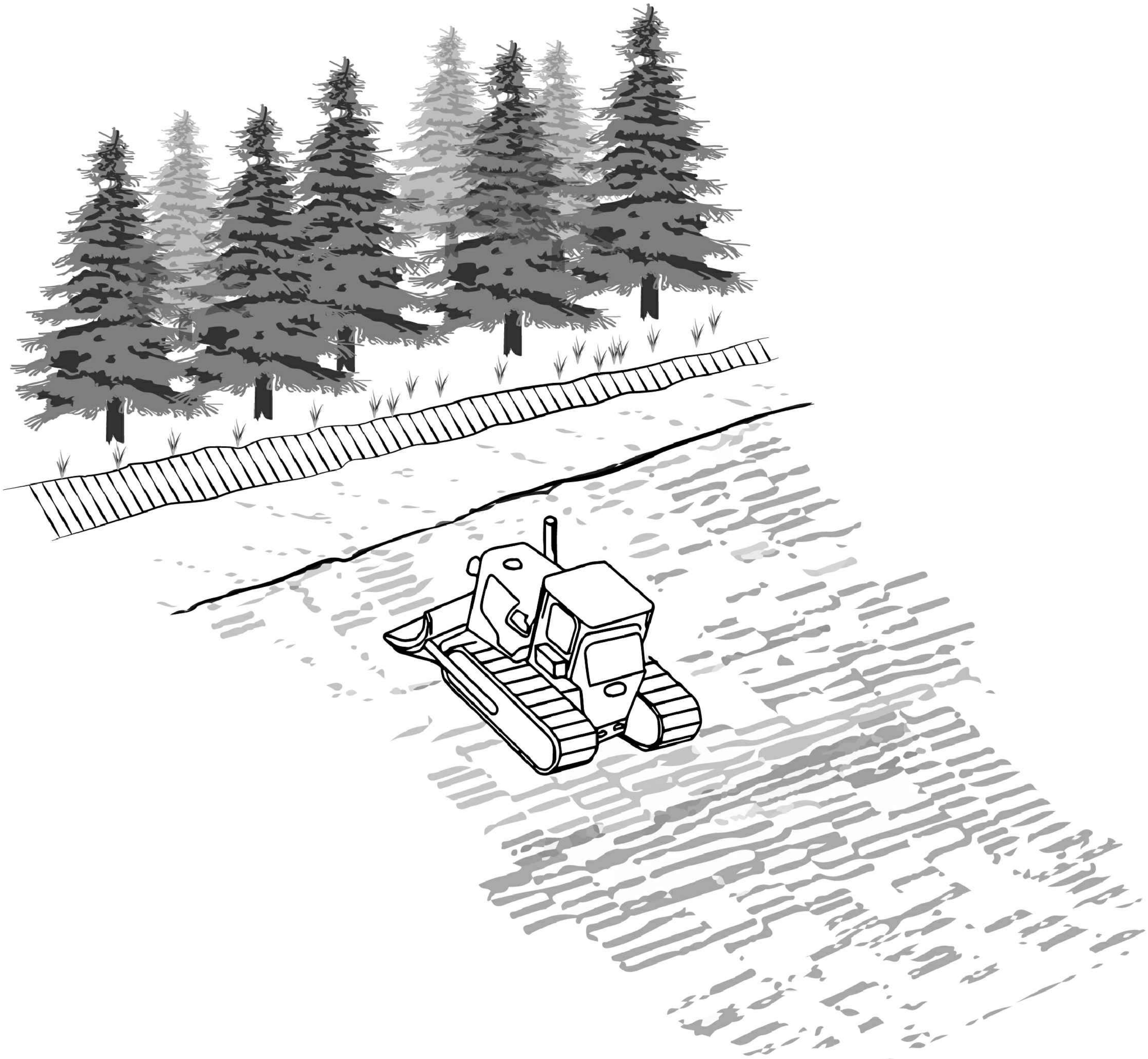
CONSULTANT

Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
GRADING TO MINIMIZE BACKFILL OVER LANDSLIDE

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	2H



NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. INFORMATION FOR DETAIL PROVIDED BY WILLIAMS.
3. TRACKING SLOPES IS DONE BY RUNNING TRACKED MACHINERY UP AND DOWN THE SLOPE, LEAVING TREAD MARKS PERPENDICULAR TO THE SLOPE.
4. IF A BULLDOZER IS USED, THE BLADE MUST BE UP.
5. CARE SHOULD BE EXERCISED ON SOILS HAVING HIGH CLAY CONTENT TO AVOID OVER COMPACTION.

NOT TO SCALE

CLIENT WILLIAMS OVM	PROJECT TYPICAL DETAILS

CONSULTANT			TITLE
Golder Associates	YYYY-MM-DD	2014-02-28	**TRACK DISTURBED SLOPES**
	PREPARED	BJV	
	DESIGN	BJV	
	REVIEW	AGM	
	APPROVED	AQK	

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	3A

0 1 in

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. RE-VEGETATE DISTURBED SLOPES WITH NATIVE GRASS SEED MIX PER REGULATORY AND PERMIT REQUIREMENTS.
3. FINAL SEED MIX TO BE REVIEWED AND APPROVED BY WILLIAMS PRIOR TO INSTALLATION.

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

0 1 in

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

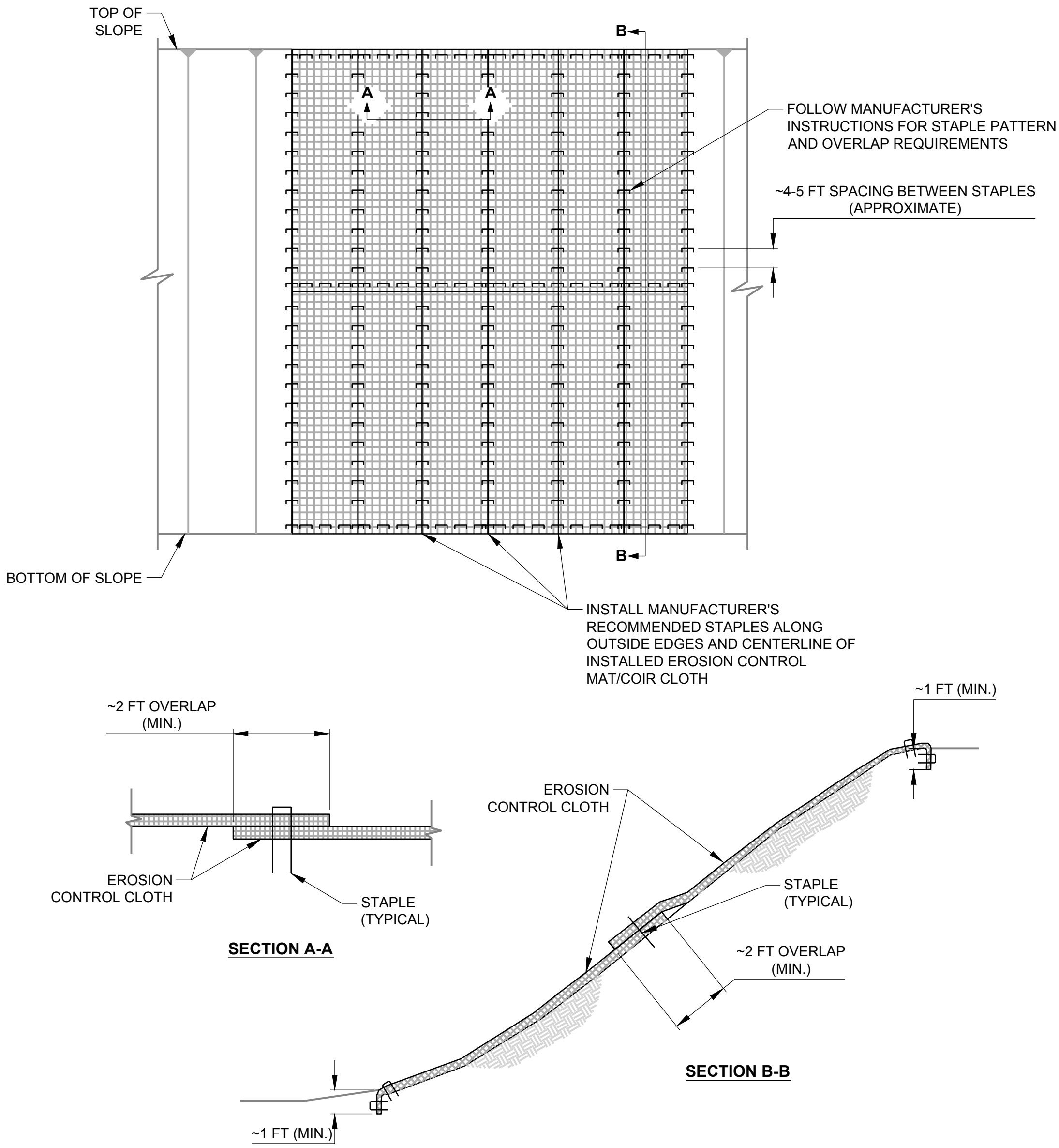
CONSULTANT

Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
RE-VEGETATE DISTURBED SLOPES

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	3B



NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. INSTALL BLANKETS IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS.
3. PREPARE SOIL BEFORE INSTALLING BLANKETS, INCLUDING GRADING REMOVAL OF LARGE ROCKS AND DEBRIS, AND THE APPLICATION OF SEED AND FERTILIZER IF NOT USING PRE-SEEDED BLANKET.
4. EROSION CONTROL BLANKETS SHALL EXTEND COMPLETELY ACROSS DISTURBED AREAS TO PROTECT ERODIBLE SURFACES.
5. BEGIN AT THE TOP OF THE SLOPE BY ANCHORING THE BLANKET IN A MIN. 12- INCH WIDE AND 312-INCH DEEP TRENCH. BACKFILL AND COMPACT THE TRENCH AFTER STAPLING.
6. ROLL THE BLANKETS DOWN THE SLOPE IN THE DIRECTION OF THE WATER FLOW.
7. AS AN ALTERNATIVE TO STAPLES, WOODEN STAKES CAN BE USED IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS.
8. ENSURE COMPLETE CONTACT BETWEEN THE BLANKETS AND THE SLOPE FACE.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

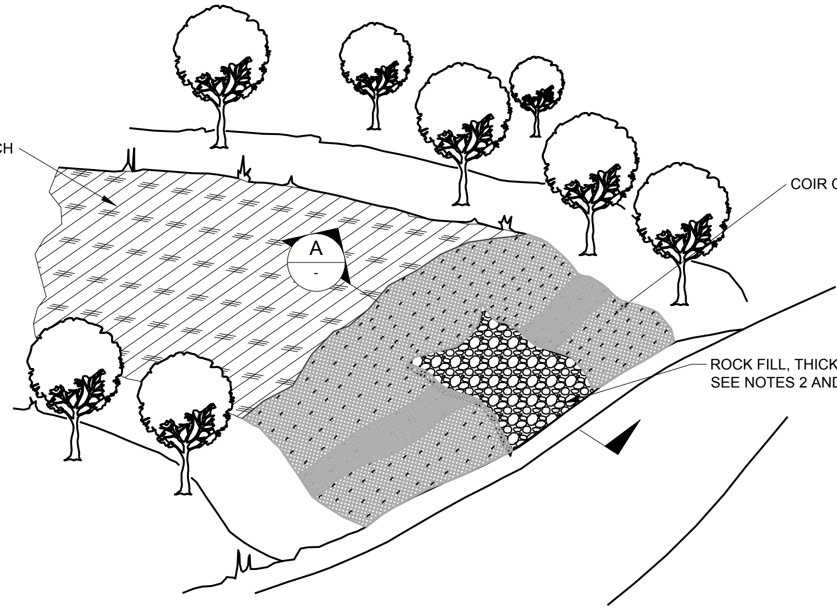
CONSULTANT
Golder Associates

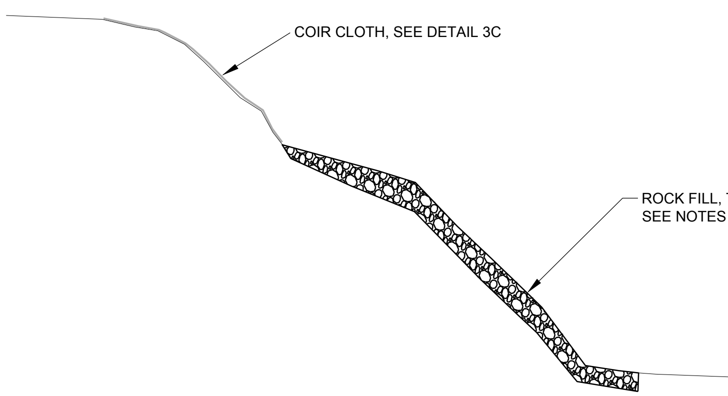
YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
COIR CLOTH ON DISTRUBED SLOPES

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	3C

NOTES





A
-
ROCK ARMORING ON DISTURBED SLOPE

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

2. USE OF RIPRAP ARMORING ON SLOPES MAY BE REQUIRED FROM GRADES ARE STEEP OR SURFACE RUN-OFF IS PRESENT AND MAY RESULT IN SURFACE EROSION. DO NOT USE GEOTEXTILE FABRIC UNDER RIPRAP.

3. REFER TO 6F FOR RIPRAP MATERIAL GRADATIONS.

CLIENT
WILLIAMS OVM

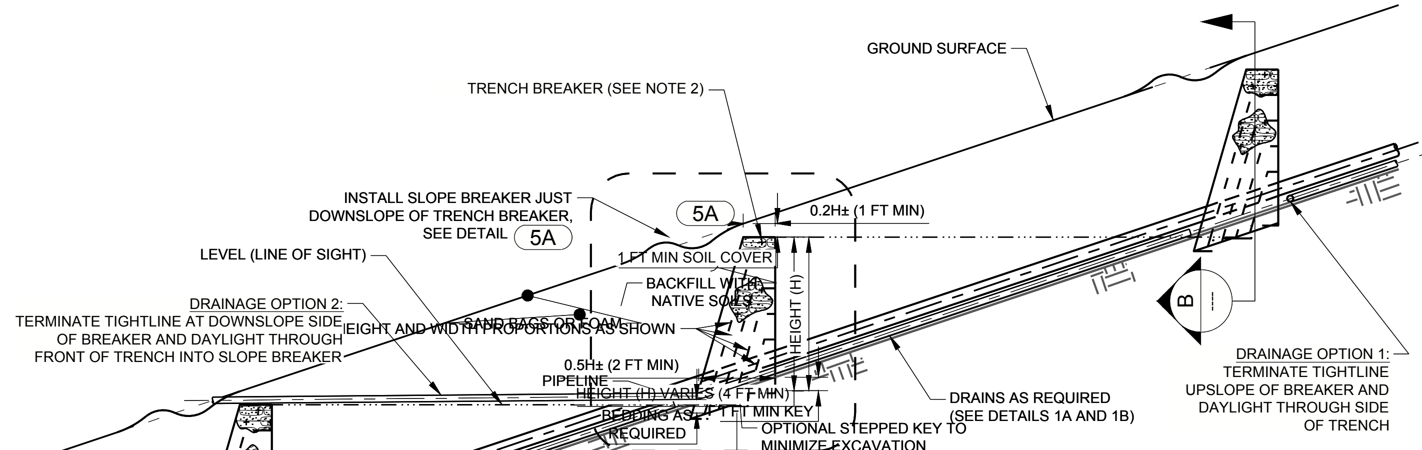
PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

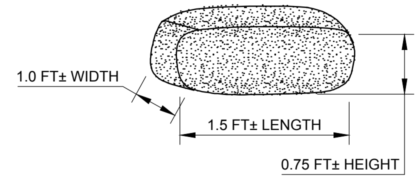
TITLE
ROCK ARMORING ON DISTRUBED SLOPES

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	3D



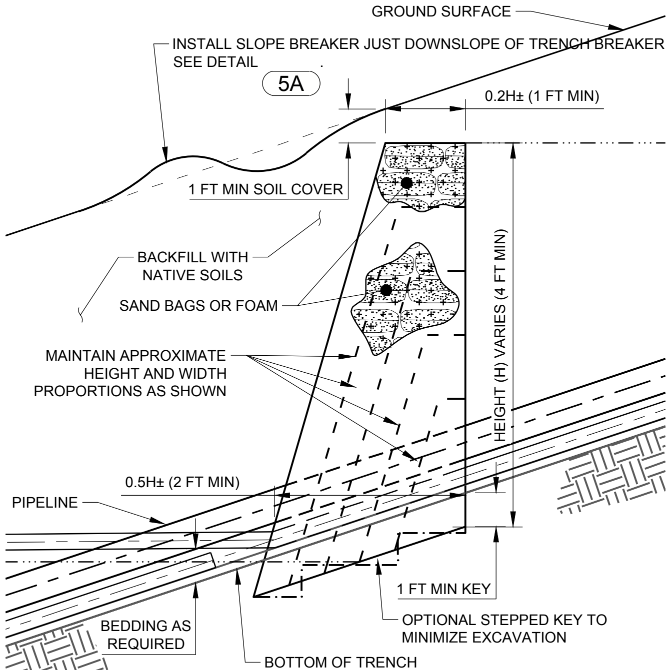
APPROXIMATE SPACING AND ARRANGEMENT

N.T.S.

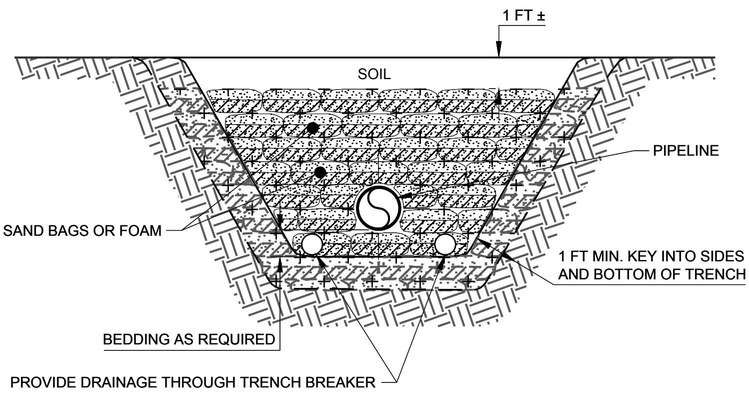


SAND BAG DETAIL

N.T.S.



N.T.S A TRENCH BREAKER DETAIL



N.T.S B SECTION

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. THE PURPOSE AND INTENT OF TRENCH BREAKERS IS TO SLOW THE FLOW OF WATER IN THE TRENCH AND TO DIVERT WATER INTO DRAINS AS NECESSARY.
3. TOPSOIL SHALL NOT BE USED TO CONSTRUCT TRENCH PLUGS/BREAKERS.
4. SPACING OF BREAKERS SHALL BE AS SHOWN OR LOCATED AS DIRECTED BY COMPANY REPRESENTATIVE TO MEET FIELD CONDITIONS.
5. AT LOCATIONS WHERE BREAKERS ARE SPECIFIED ON DETAILS, PLANS OR AS DIRECTED BY COMPANY REPRESENTATIVE, SOFT PLUGS (UNEXCAVATED SECTIONS ALONG TRENCH-LINE) MAY BE LEFT IN PLACE TO PERFORM FUNCTION OF PERMANENT BREAKERS PRIOR TO PIPE PLACEMENT.
6. THE TRENCH SHALL BE DEWATERED THROUGH A SEDIMENT TRAP, FILTER BAG, OR DEWATERING STRUCTURE.
7. PERMANENT TRENCH BREAKERS SHALL BE INSTALLED BEFORE THE TRENCH IS BACKFILLED.

CLIENT
WILLIAMS OVM

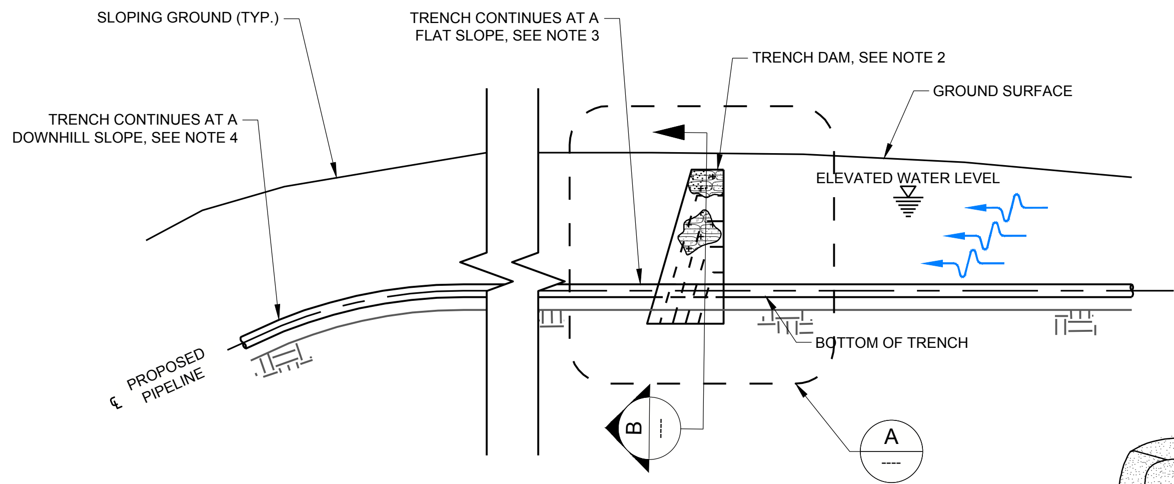
PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

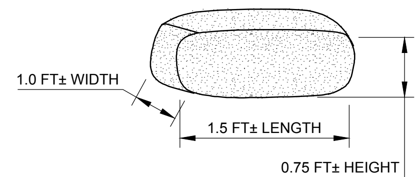
YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
TRENCH BREAKERS (FOAM AND SANDBAGS)

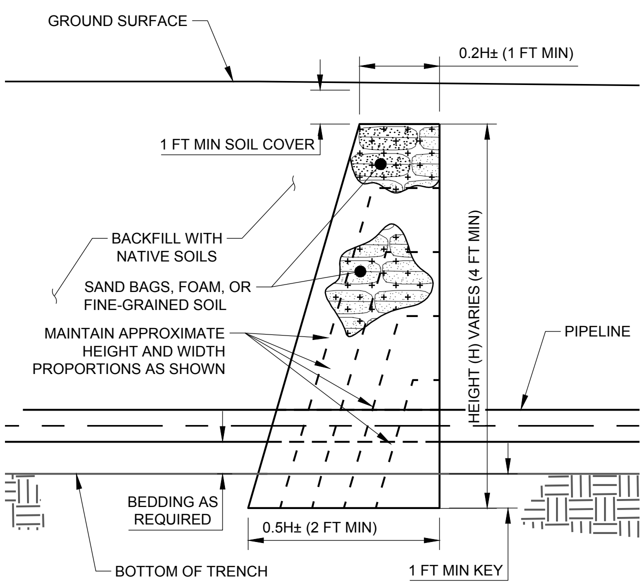
PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	4A



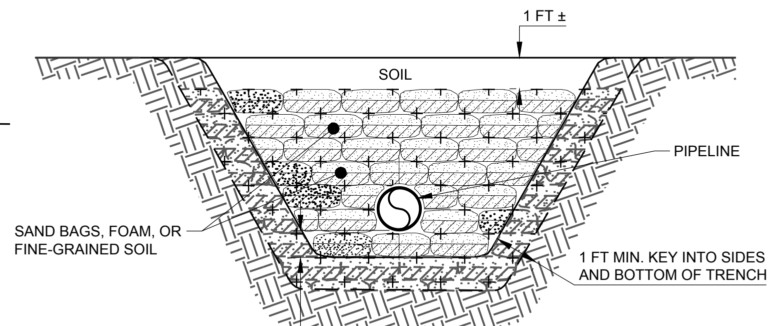
TRENCH DAM CONFIGURATION
N.T.S.



SAND BAG DETAIL
N.T.S.



N.T.S A TRENCH DAM DETAIL



N.T.S B SECTION

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. THE PURPOSE AND INTENT OF TRENCH DAMS IS TO STOP THE FLOW OF WATER IN THE TRENCH WHERE ELEVATED WATER SURFACES MAY EXIST (SUCH AS STREAM CROSSINGS OR PONDED AREAS).
3. INSTALL TRENCH DAM IN LOW / FLAT TERRAIN AREAS THAT MAY HAVE ELEVATED WATER LEVELS. THE PURPOSE OF THE TRENCH DAM IS TO STOP FLOW OF WATER FROM RUNNING DOWN THE FLAT TRENCH.
4. INSTALL TRENCH DAM AT THE TOP OF SLOPES AT AREAS THAT MAY HAVE ELEVATED WATER LEVELS. THE PURPOSE OF THE TRENCH DAM IS TO STOP FLOW OF WATER FROM RUNNING DOWN THE TRENCH ON THE HILL SLOPE.
5. AT LOCATIONS WHERE DAMS ARE SPECIFIED ON DETAILS, PLANS OR AS DIRECTED BY COMPANY REPRESENTATIVE, SOFT PLUGS (UNEXCAVATED SECTIONS ALONG TRENCH-LINE) MAY BE LEFT IN PLACE TO PERFORM FUNCTION OF PERMANENT DAMS PRIOR TO PIPE PLACEMENT.
6. THE TRENCH SHALL BE DEWATERED THROUGH A SEDIMENT TRAP, FILTER BAG, OR DEWATERING STRUCTURE.
7. PERMANENT TRENCH DAMS SHALL BE INSTALLED BEFORE THE TRENCH IS BACKFILLED.
8. TRENCH PLUGS SHALL BE INSTALLED AT THE BANKS OF ALL PERENNIAL STREAM CROSSINGS IMMEDIATELY AFTER TRENCH EXCAVATION. THE PLUGS MAY BE TEMPORARILY REMOVED DURING PIPE PLACEMENT, BUT THEN REPLACED.
9. THE TRENCH SHALL BE DEWATERED THROUGH A SEDIMENT TRAP, FILTER BAG, OR DEWATERING STRUCTURE REFER TO TRENCH DEWATERING DETAIL (TWD).
10. PERMANENT TRENCH DAMS SHALL BE INSTALLED BEFORE THE TRENCH IS BACKFILLED.

CLIENT
WILLIAMS OVM

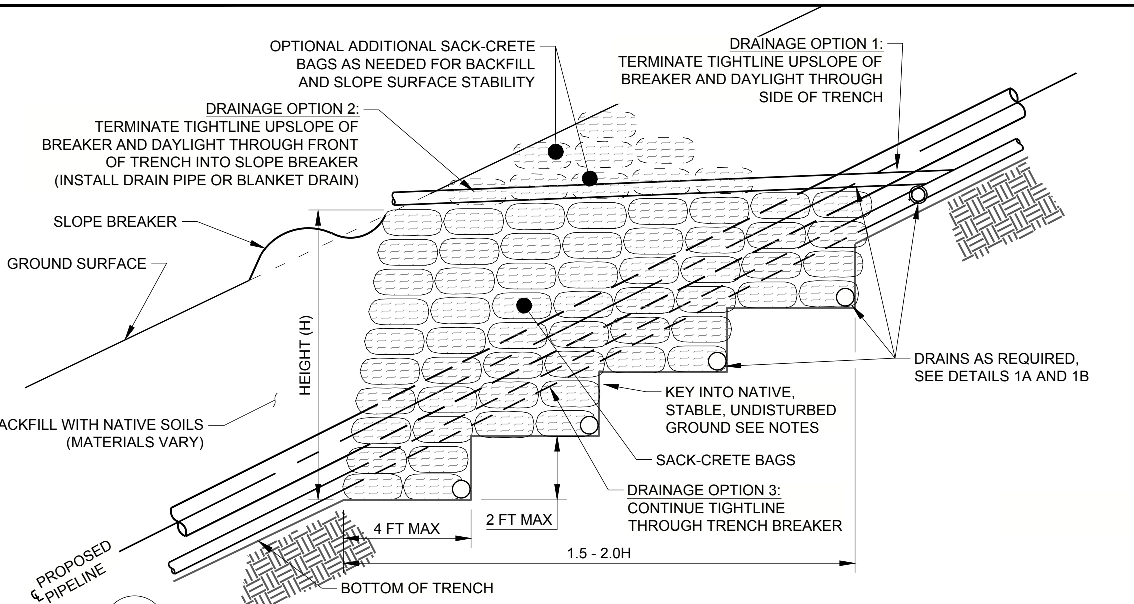
PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

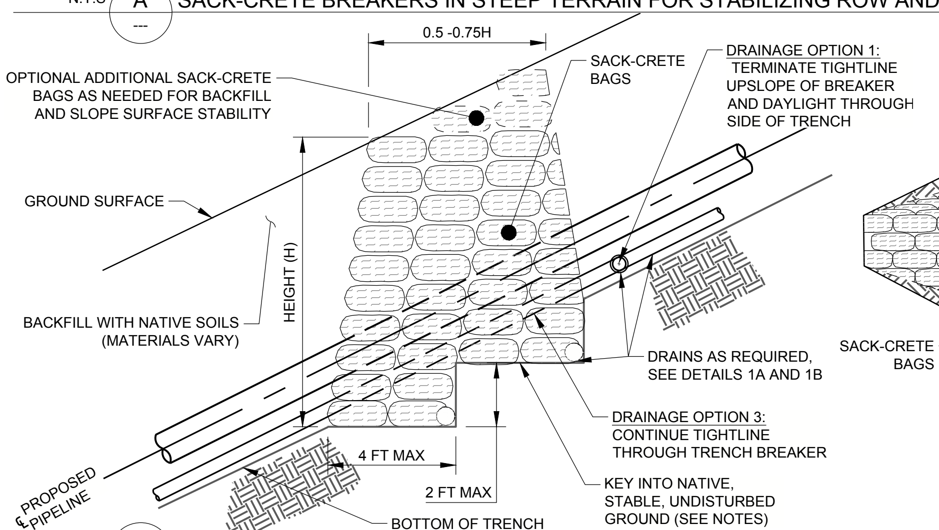
YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
TRENCH DAMS (FOAM, BAGS, OR FINE GRAINED SOILS)

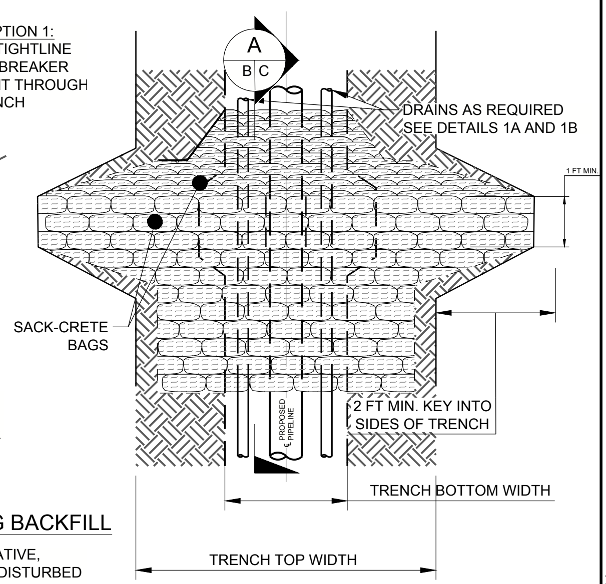
PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	4B



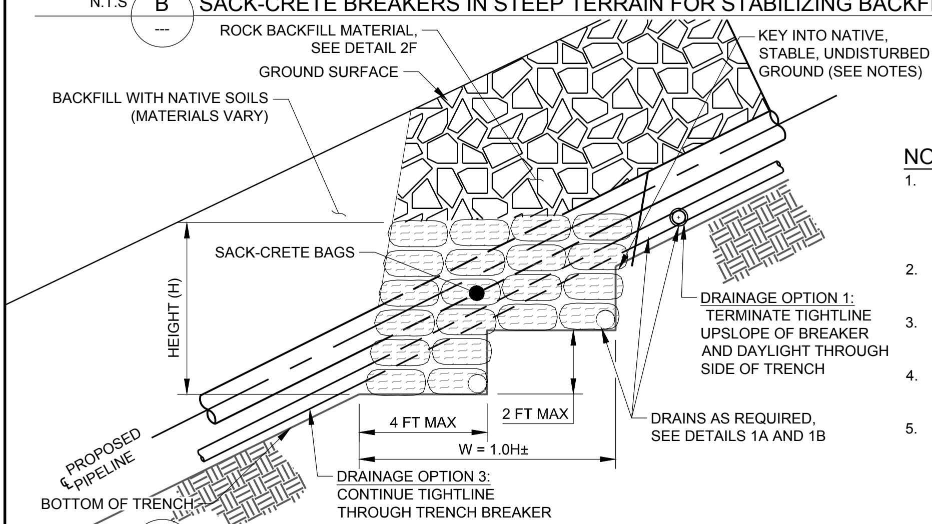
N.T.S A --- SACK-CRETE BREAKERS IN STEEP TERRAIN FOR STABILIZING ROW AND TRENCH BACKFILL



N.T.S B --- SACK-CRETE BREAKERS IN STEEP TERRAIN FOR STABILIZING BACKFILL



PLAN VIEW
N.T.S.



N.T.S C --- SACK-CRETE KEYWAY FOR ROCK BACKFILL IN STEEP TERRAIN

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. VOLUMES, GRADES, ELEVATIONS AND QUANTITIES, WILL VARY DEPENDING ON SITE CONDITIONS ENCOUNTERED.
3. ADD OR EXTEND KEYS OR PLACE ADDITIONAL SACK-CRETE BAGS AS NECESSARY TO MAINTAIN STABILITY.
4. DRAINAGE OPTION TO BE SELECTED AT THE TIME OF CONSTRUCTION BASED ON CONDITIONS ENCOUNTERED.
5. EXCAVATE KEY WITH OUTBOARD SLOPE, AND INCLUDE DRAINAGE MEASURES THAT EVACUATE ACCUMULATED SEEPAGE.

CLIENT
WILLIAMS OVM

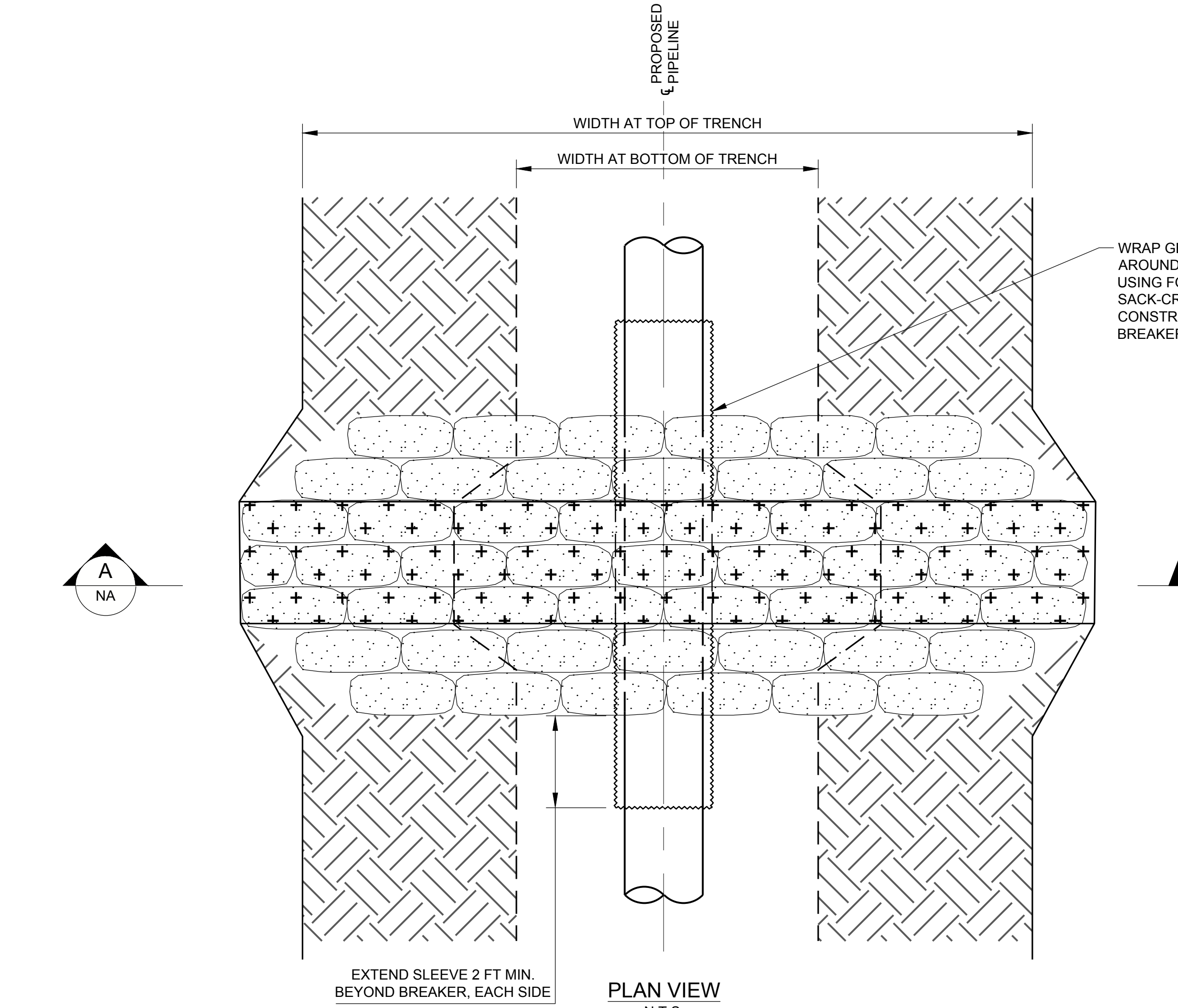
PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

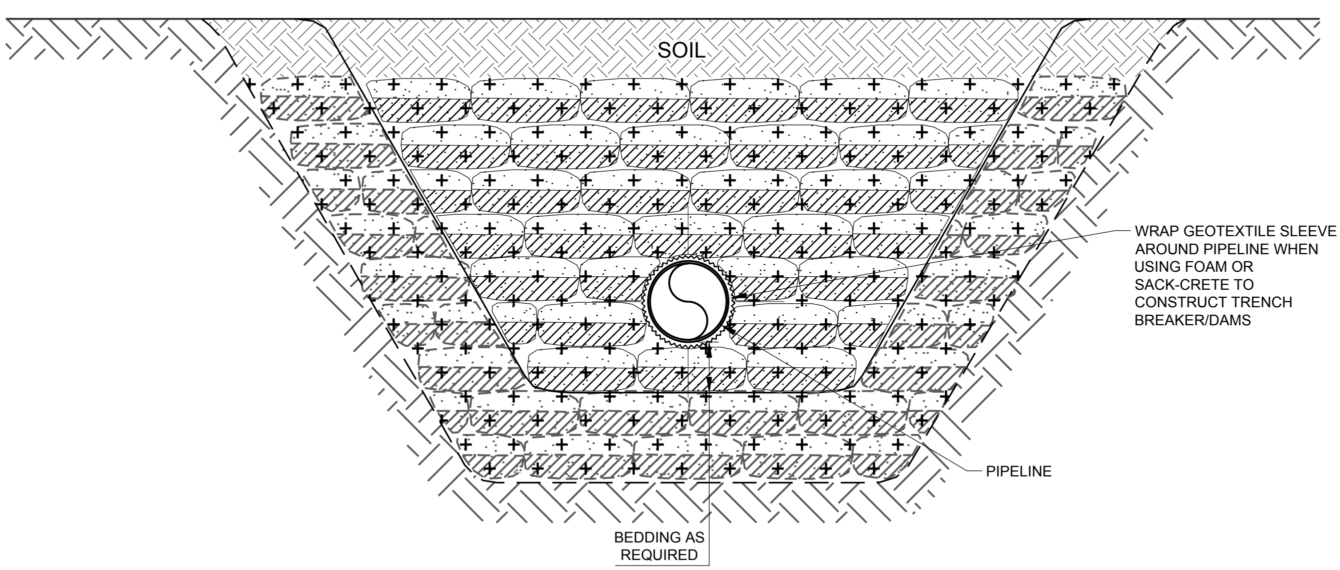
YYYY-MM-DD	2014-05-30
PREPARED	ACF
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
SACK-CRETE BREAKERS (STRUCTURAL BREAKER)

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	1	4C

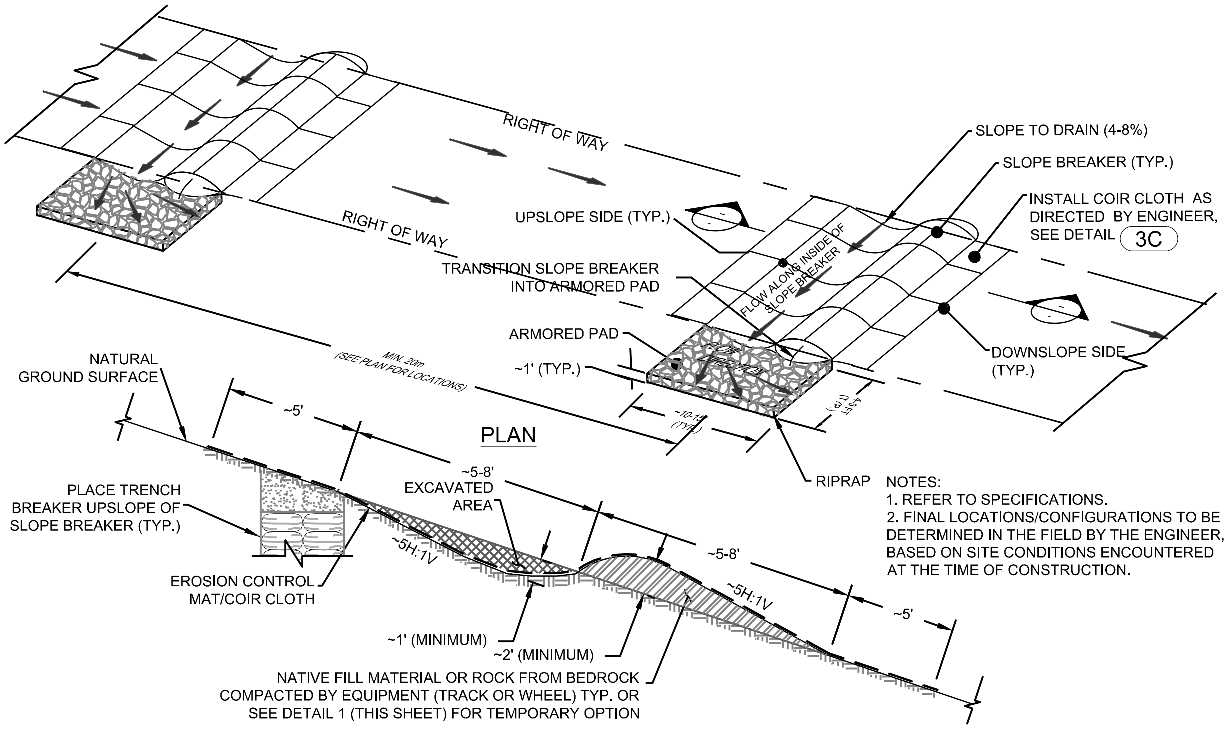


PLAN VIEW
N.T.S.



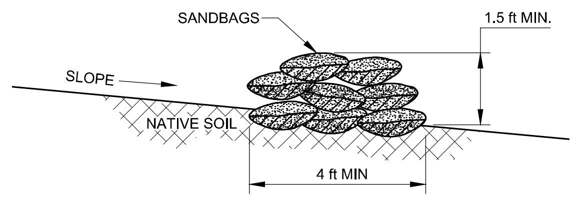
N.T.S A --- ELEVATION

CLIENT	WILLIAMS OVM
PROJECT	TYPICAL DETAILS
CONSULTANT	Golder Associates
YYYY-MM-DD	2014-05-30
PREPARED	ACF
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK
TITLE	SLEEVE INTERFACE BETWEEN PIPELINE AND BREAKER
PROJECT No.	
ISSUED FOR	CONSTRUCTION
Rev.	1
SHEET	4D

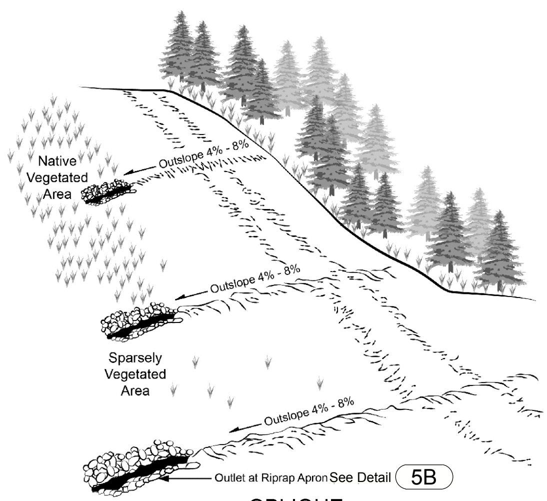


PROFILE

NOTES:
1. REFER TO SPECIFICATIONS.
2. FINAL LOCATIONS/CONFIGURATIONS TO BE DETERMINED IN THE FIELD BY THE ENGINEER, BASED ON SITE CONDITIONS ENCOUNTERED AT THE TIME OF CONSTRUCTION.



DETAIL 1



OBLIQUE

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. TEMPORARY SLOPE BREAKERS WILL BE INSTALLED DURING CONSTRUCTION AS NECESSARY TO PREVENT EXCESSIVE EROSION; PERMANENT SLOPE BREAKERS WILL BE INSTALLED FOLLOWING BACKFILLING AND REGRADING. INSTALL SLOPE BREAKER ON MODERATE AND STEEP SLOPES TO DIVERT SURFACE WATER OFF RIGHT-OF-WAY. ALSO INSTALL SLOPE BREAKER IMMEDIATELY DOWNSLOPE OF TRENCH BREAKERS TO COLLECT SEEPAGE FORCED TO SURFACE.
3. INSTALL DIVERSION BERM AND CROSS DITCH OR MODERATE AND STEEP SLOPES TO DIVERT SURFACE WATER OF RIGHT-OF-WAY. ALSO INSTALL BERMS IMMEDIATELY DOWNSLOPE OF TRENCH BREAKERS TO COLLECT SEEPAGE FORCED TO THE SURFACE.
4. SKEW BERM ACROSS THE RIGHT-OF-WAY AT A DOWNHILL GRADIENT OF 4% TO 8%.
5. CONSTRUCT DIVERSION BERM OF COMPACTED NATIVE SUBSOILS WHERE EXTENSIVE DISTURBANCE OF THE SOD LAYER HAS OCCURRED. AVOID USE OF ORGANIC MATERIAL WHERE NATIVE MATERIAL IS HIGHLY ERODIBLE, PROTECT UPSLOPE OF BERM AND BASE OF CROSS DITCH BY BURYING A GEOTEXTILE LINER 6 TO 8 INCHES BELOW THE SURFACE OR ARMOUR UPSLOPE FACE OF BERM WITH EARTH FILLED SAND BAGS.
6. NOTE THAT TYPICAL DIVERSION BERM HEIGHT AND WIDTHS ARE APPROXIMATELY 12 INCHES. BERMS SHALL BE INSPECTED AFTER HEAVY RAINS AND THE FIRST SPRING FOLLOWING CONSTRUCTION; CONTRACTOR SHALL REPLACE OR RESTORE BERMS, IF WARRANTED.
7. LEAVE A BREAK IN TRENCH CROWN IMMEDIATELY UPSLOPE OF DIAGONAL BERM AND CROSS DITCH TO ALLOW PASSAGE OF WATER ACROSS THE RIGHT-OF-WAY.
8. USE DIAGONAL BERMS WHERE DIRECTION OF SLOPE AND SURFACE WATER MOVEMENT IS OBLIQUE TO PIPELINE RIGHT-OF-WAY.
9. USE HERRINGBONE BERM AND CROSS DITCH WHERE DIRECTION OF SLOPE AND SURFACE WATER MOVEMENT IS PARALLEL TO RIGHT-OF-WAY SO RUNOFF DOES NOT CROSS DITCHLINE.
10. DETERMINE LOCATION AND DIRECTION OF BERM BASED ON LOCAL TOPOGRAPHY AND DRAINAGE PATTERNS. ALSO INSTALL BERMS IMMEDIATELY DOWNSLOPE OF TRENCH BREAKERS. SKEW BERMS WITH DOWNHILL GRADIENT OF 4% TO 8%.
11. REFER TO TABLE FOR TYPICAL DIVERSION BERM SPACING.
12. TEMPORARY SLOPE BREAKERS AND/OR SEDIMENT LOGS SHALL BE INSTALLED AT THE BASE OF SLOPES GREATER THAN 5 PERCENT THAT ARE LESS THAN 50 FEET FROM A WATERBODY, WETLAND, OR ROAD CROSSING.
13. WILLAMS OVM TO DETERMINE LOCATION, DIRECTION AND SPACING OF SLOPE BREAKERS AND NECESSITY FOR ENERGY DISSIPATERS BASED ON LOCAL TOPOGRAPHY, DRAINAGE PATTERNS AND EXISTING SLOPE BREAKERS PRESENT ADJACENT TO THE RIGHT-OF-WAY. SLOPE BREAKER BERM (NOT TROUGH) SHALL EXTEND ALONG BASE OF ENERGY DISSIPATERS FOR APPROXIMATE THREE TO FIVE FEET TO PREVENT WATER FROM FLOWING BACK ON PROJECT DISTURBANCE BELOW THE SLOPE BREAKER.

TYPICAL SPACING

SLOPE GRADIENT	SPACING (FEET)
0-15	300, OR AS DIRECTED BY WILLIAMS
>15-30	200
>30	100

CLIENT
WILLIAMS OVM

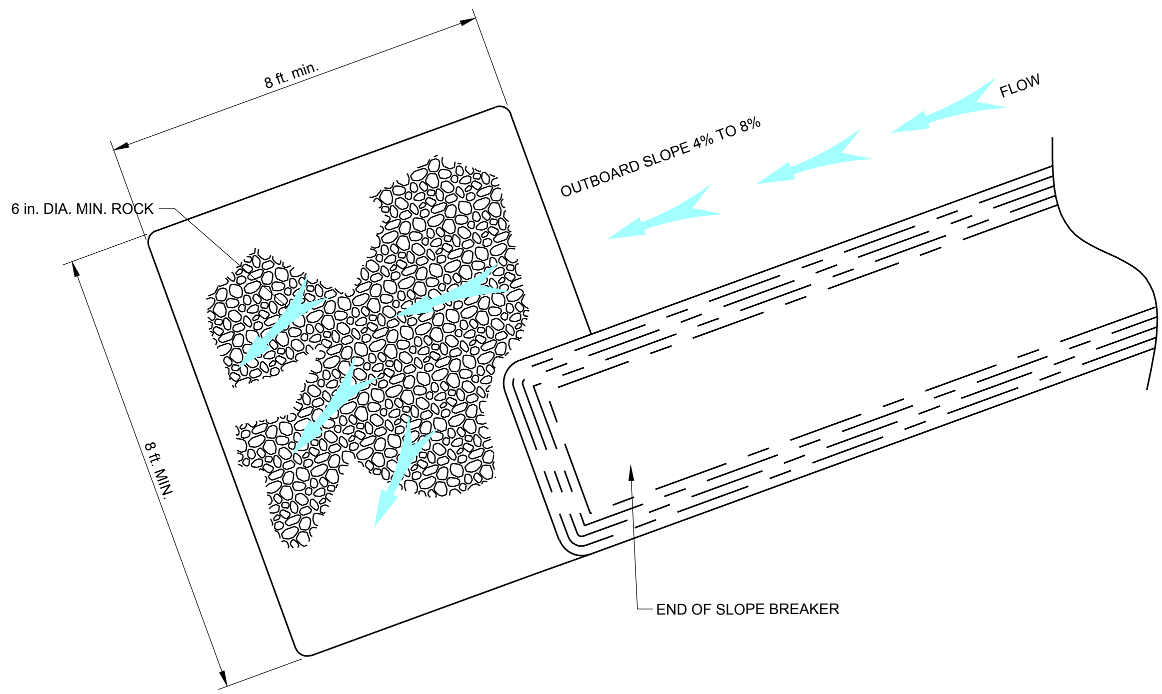
PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
SLOPE BREAKERS (TEMP AND PERMANENT)

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	5A



NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

CLIENT
WILLIAMS OVM

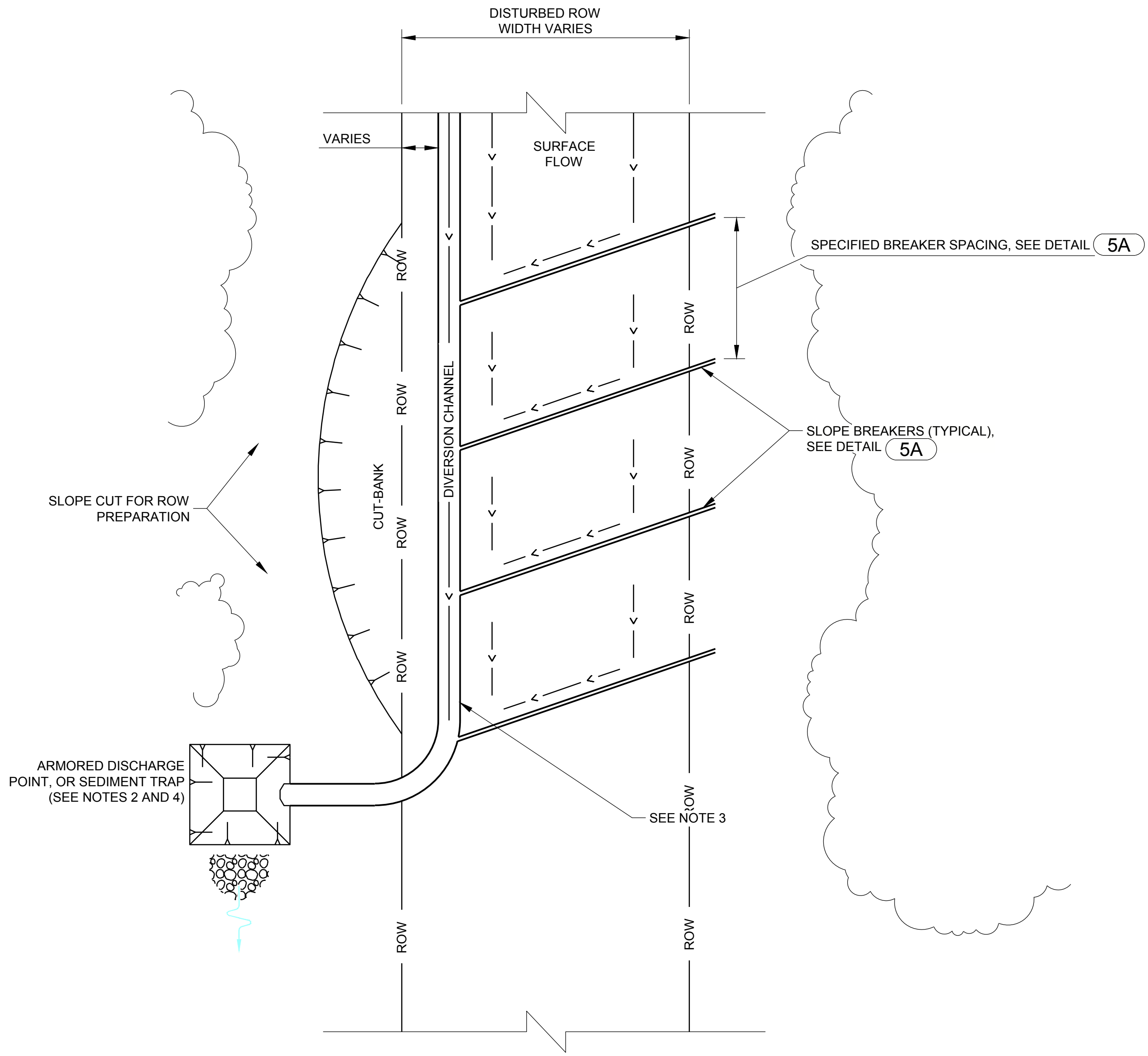
PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
SLOPE BREAKER ARMORED OUTLET

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	5B



NOTES:

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. DIVERSION CHANNEL MAY REQUIRE SITE SPECIFIC DESIGN WITH REGARD FOR SLOPE, DRAINAGE AREA, EROSION PROTECTION , DISCHARGE ARMORED PAD, CHECK DAMS, ETC.
3. DIVERSION CHANNEL MUST BE SUITABLY LINED TO PREVENT EROSION FOR INSTANCE: GEOTEXTILE EROSION CONTROL BLANKET, PLASTIC SHEETING (FOR TEMPORARY MEASURE), OR GEOTEXTILE WITH RIPRAP ARMOR (FOR PERMANENT MEASURES).
4. SEDIMENT TRAP REQUIRED WHERE SUFFICIENT BUFFER IS NOT AVAILABLE SITE SPECIFIC DESIGN OF SEDIMENT TRAP MAY BE REQUIRED, AS DIRECTED BY WILLIAMS

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT

Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
SLOPE BREAKERS WITH DIVERSION CHANNELS

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	5C

NOTES:

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

2. SPECIAL CARE AND CONSIDERATION IS REQUIRED TO CONSTRUCT DRAINAGE MEASURES FOR EXISTING, PERMANENT, AND TEMPORARY ACCESS ROADS ON A SITE-SPECIFIC BASIS. ACCESS ROADS MAY COLLECT RUNOFF FROM UPSLOPE AREAS AND DELIVER WATER TO THE ROW, PIPE TRENCH, OR TO OTHER GEOTECHNICAL, GEOLOGIC, OR HYDROTECHNICAL AREAS OF CONCERN. RECOMMENDED DRAINAGE MEASURES FOR ACCESS ROADS INCLUDE THE FOLLOWING:

   A. DRAINAGE MEASURE MAY REQUIRE SITE SPECIFIC DESIGN WITH REGARD FOR SLOPE, DRAINAGE AREA, EROSION PROTECTION , DISCHARGE ARMORED PAD, CHECK DAMS, ETC.

   B. INSTALL WATER BARS (I.E. SLOPE BREAKERS) EVERY 100-200 FEET ALONG THE ACCESS ROAD, PROVIDED THAT WATER IS NOT DISCHARGED ONTO OR ABOVE GEOTECHNICALLY SENSITIVE AREAS (LANDSLIDES, AREAS OF FILL, POTENTIALLY UNSTABLE SLOPES, ETC.) OR THE ROW.

   C. INSTALL INBOARD SLOPES WITH BAR DITCH (LINED OR ARMORED AS NECESSARY) UPSLOPE OF GEOTECHNICALLY SENSITIVE AREAS AND/OR THE ROW TO CONVEY WATER TO A STABLE DISCHARGE POINT.

   D. INSTALL FRENCH DRAINS AS NEEDED TO COLLECT WATER IN AREAS WHERE WATER BARS AND BAR DITCHES CAN NOT BE USED OR WOULD RESULT IN DIRECTING WATER INTO THE ROW OR PIPE TRENCH. FRENCH DRAINS SHOULD CONVEY COLLECTED WATER IN A TIGHTLINE (SOLID WALL PIPE) TO A STABLE DISCHARGE POINT.

   E. INSTALL EROSION PROTECTION FOR CONCENTRATED FLOWS AND DISCHARGE POINTS/OUTLETS AS NECESSARY (I.E. CHANNEL LINING, RIPRAP APRON, ETC.).

   F. DO NOT ALLOW WATER DELIVERED FROM ACCESS ROADS TO CROSS OR ENTER THE PIPE TRENCH.

   G. SPECIAL STUDY MAY BE REQUIRED FOR COMPLEX SITES OR AREAS OF CONCERN.

3. CHANGES IN THE FINAL GRADING MAY BE NEEDED TO ADDRESS SPECIFIC TARGETED GEOTECHNICAL OR HYDROTECHNICAL OR GEOLOGIC ENGINEERING ISSUES (I.E. CORRECT DRAINAGE PROBLEMS, MINIMIZE DELIVERY OF WATER TO LANDSLIDE SITES, ETC.)

4. FINAL GRADING TO BE REVIEWED AND APPROVED BY WILLIAMS PRIOR TO COMPLETION.

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

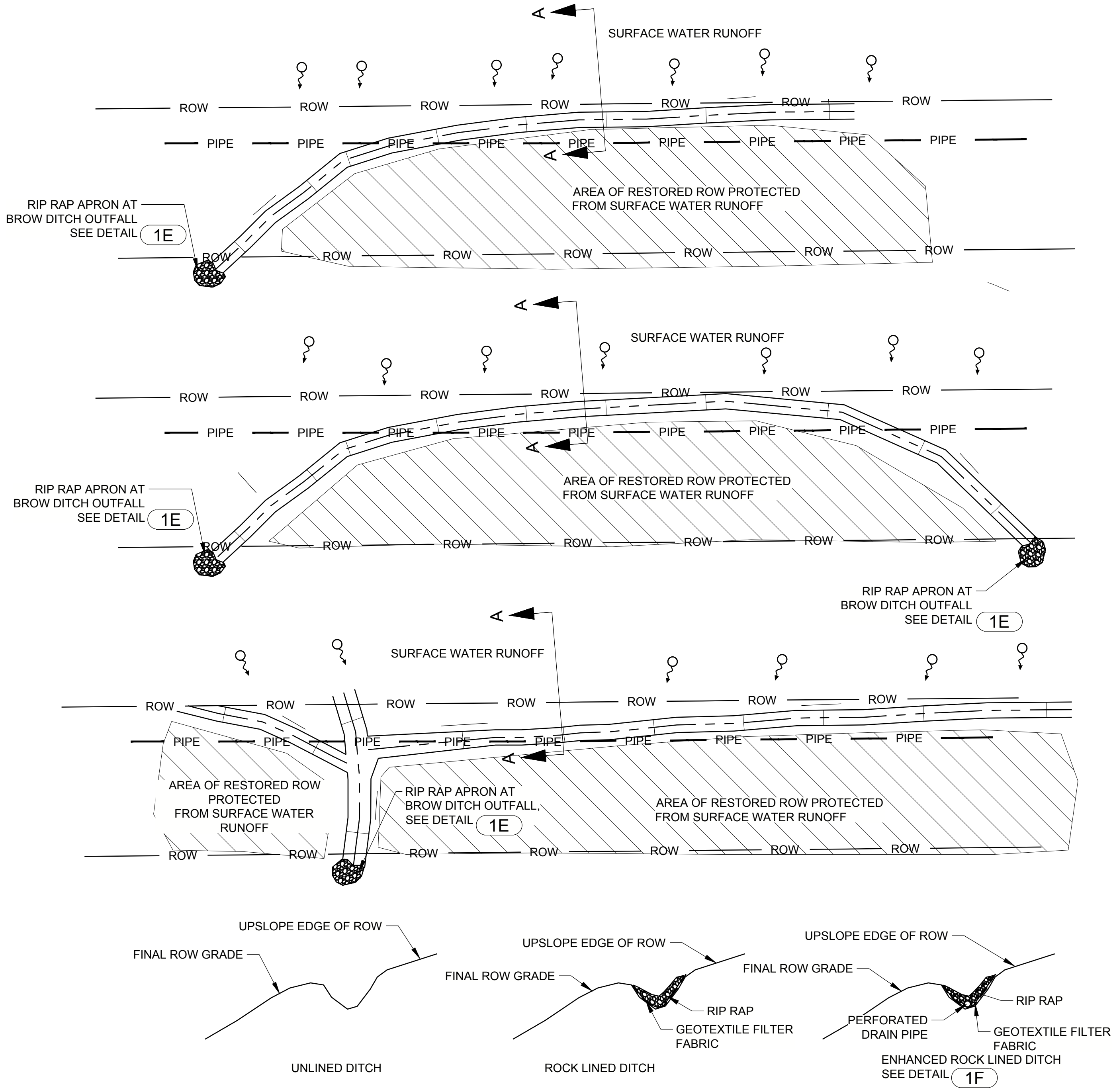
TITLE
ACCESS ROADS

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	5D

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

1 in

0



A - **BROW DITCH CONSTRUCTION OPTIONS**

CLIENT WILLIAMS OVM	PROJECT TYPICAL DETAILS

CONSULTANT

Golder Associates

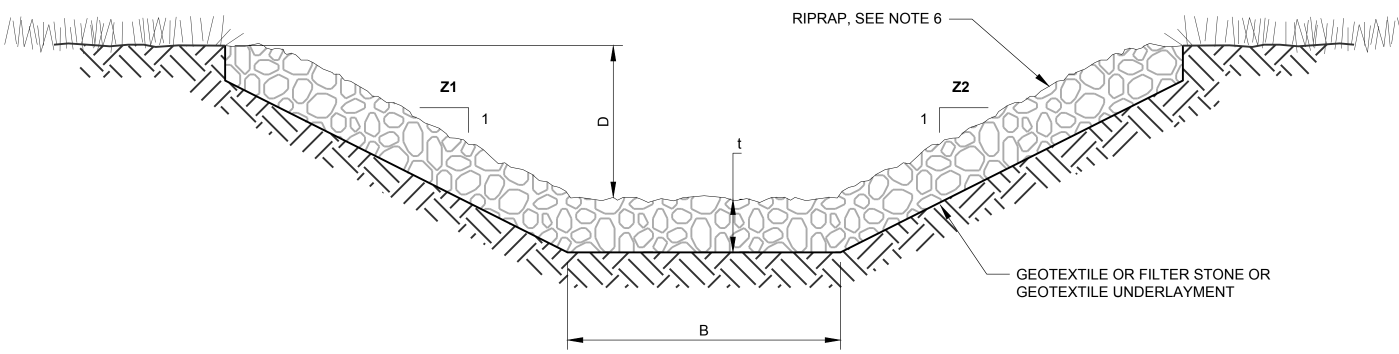
YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
BROW DITCH

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	6B

RIPRAP CHANNEL	Stations	B	D	Z1	Z2	Riprap Gradation			t
						D_{max}	D_{50}	D_{min}	
Channel Indentification	__+__- __+__	MIN. 2 FT	MIN. 3 FT	2H	2H	SEE NOTE 6			1.5 - 2 TIMES THE MAXIMUM ROCK SIZE

SEE NOTE 5



NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. USE GEOTEXTILE OR FILTERSTONE UNDERLAYMENT FOR CHANNEL GRADIENTS OF > 0.10 FT/FT.
3. CHANNEL DIMENSIONS ARE FOR COMPLETED CHANNEL (AFTER ROCK PLACEMENT). CHANNEL MUST BE OVER EXCAVATED A SUFFICIENT AMOUNT TO ALLOW FOR THE VOLUME OF ROCK PLACED WITH THE CHANNEL WHILE PROVIDING THE SPECIFIED FINISHED DIMENSIONS.
4. THE MINIMUM ROCK THICKNESS (t) IS 1.5-2.0 TIMES THE MAXIMUM ROCK SIZE.
5. CHANNEL DIMENSIONS MAY VARY DEPENDING ON SITE CONDITIONS AND AS DIRECTED BY WILLIAMS.
6. REFER TO DETAIL 6F FOR RIPRAP GRADATIONS.

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

0 1 in

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

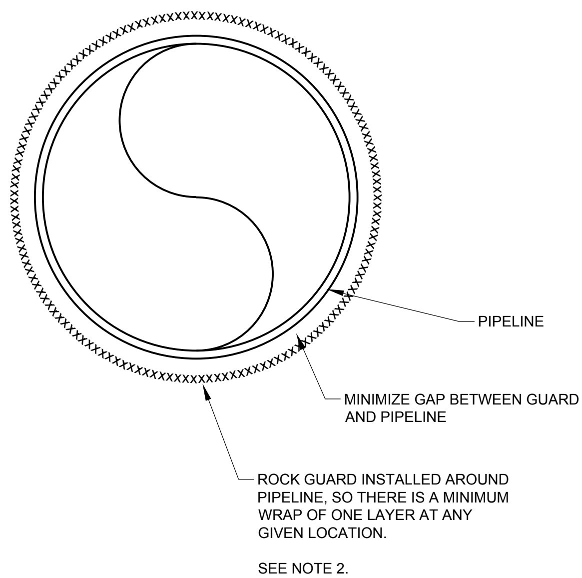
CONSULTANT

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

Golder Associates

TITLE
ARMORED CHANNEL

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	6D



NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

2. SECURE ROCK GUARD PER MANUFACTURER SPECIFICATIONS , OR AS DIRECTED BY WILLIAMS.

CLIENT
WILLIAMS OVM

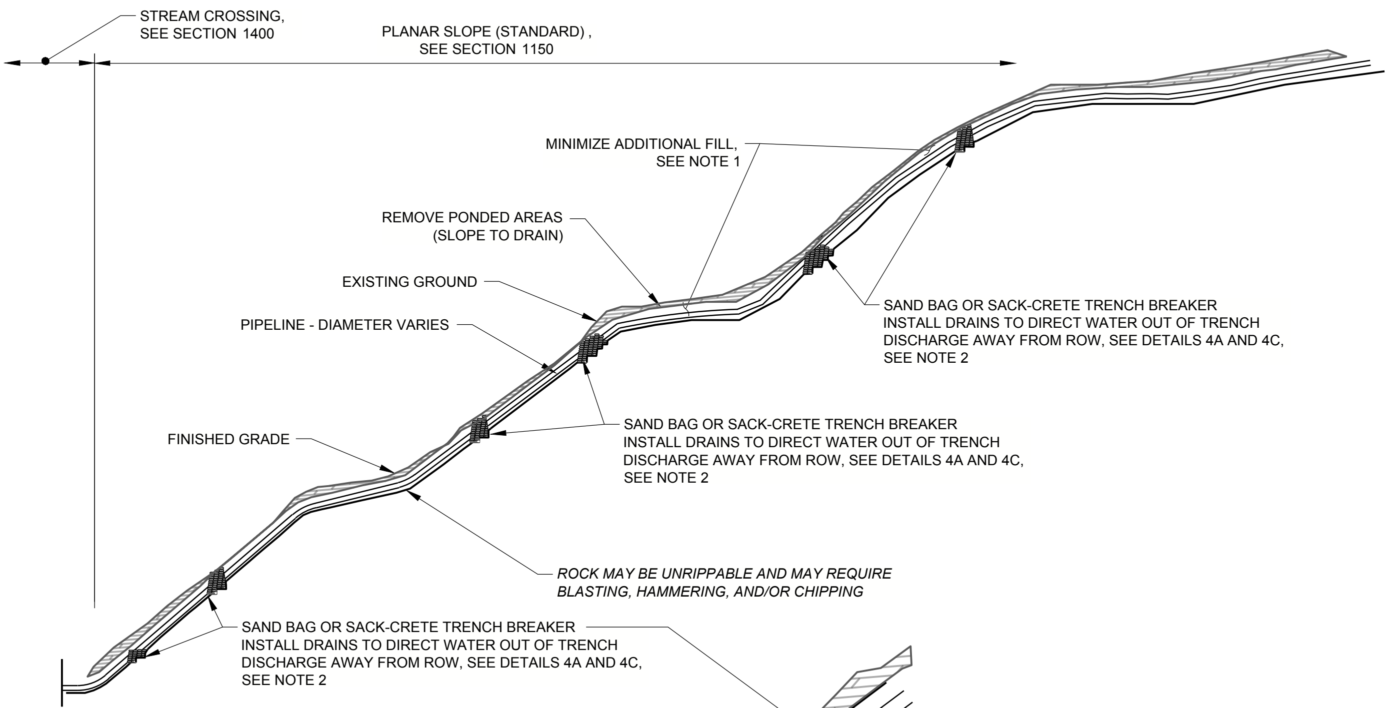
PROJECT
TYPICAL DETAILS

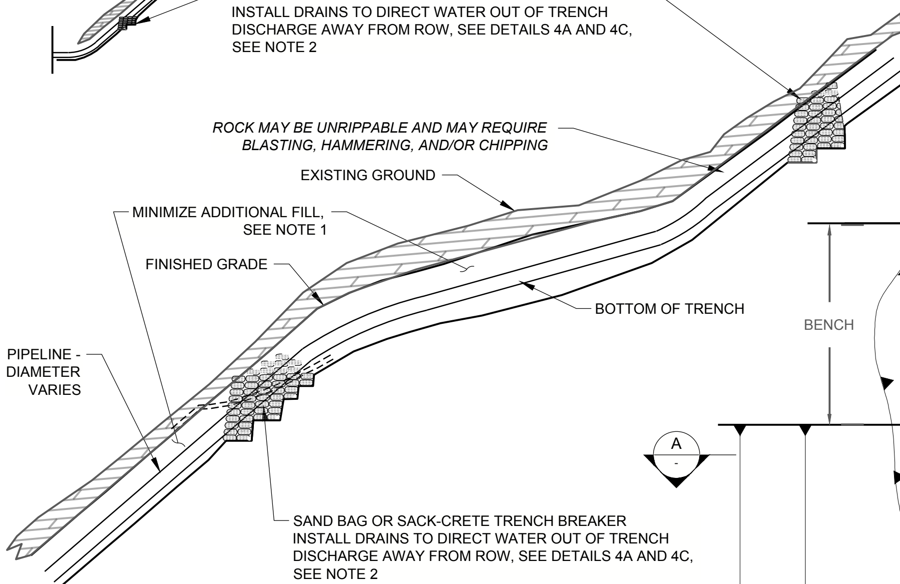
CONSULTANT
Golder Associates

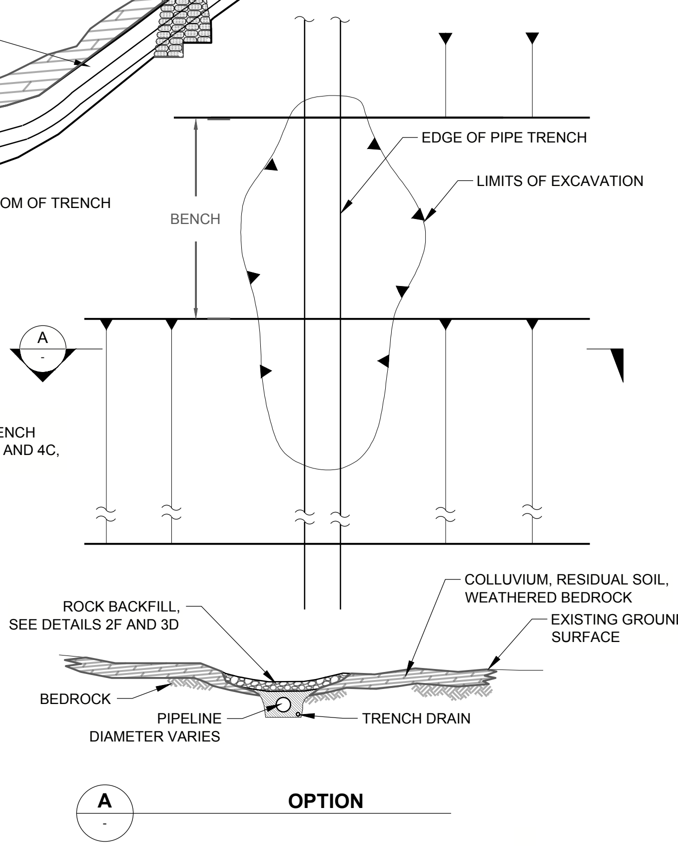
YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
ROCK GUARD ON PIPELINE

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	8A







NOTES

1. TRENCH EXCAVATIONS INTO BEDROCK IN AREAS MAY RESULT IN INSUFFICIENT AMOUNTS OF BACKFILL AND PADDING/BEDDING DUE TO LARGER, ANGULAR SPOIL MATERIAL. ROCK GUARD MATERIALS MAY BE REQUIRED TO PROTECT THE PIPELINE.

2. TRENCH EXCAVATIONS INTO BEDROCK IN SLOPED TERRAIN (PLANAR SLOPES & INCLINED RIDGES) WILL REQUIRE TRENCH BREAKERS WITH SUFFICIENT MASS AND GEOTECHNICAL PROPERTIES TO RETAIN BACKFILL SOILS AND/OR ROCK MATERIALS. USE OF FOAM BREAKERS IS NOT RECOMMENDED. SANDBAG OR SACK-CRETE BREAKERS ARE RECOMMENDED.

3. ALTERNATING LAYERS OR WEAKER BEDROCK AND STRONGER BEDROCK MATERIALS OFTEN CREATES A "BENCHED" OR "STAIR-STEPPED" APPEARANCE TO EXISTING HILL SLOPES, ILLUSTRATED IN THE FIGURE SHOWN ON THIS SHEET. MINIMIZE BACKFILL IN THESE SITUATIONS, AND WARP THE SLOPES AT THE ROW BOUNDARIES TO MEET TO EXISTING TERRAIN, BUT MAINTAIN A MORE UNIFORM, POSITVELY DRAINING SLOPE ACROSS THE ROW. BUILDING BENCHES ALTERNATING WITH FILL ACROSS THE ROW TO MATCH THE EXISTING TOPOGRAPHY IS NOT RECOMMENDED.

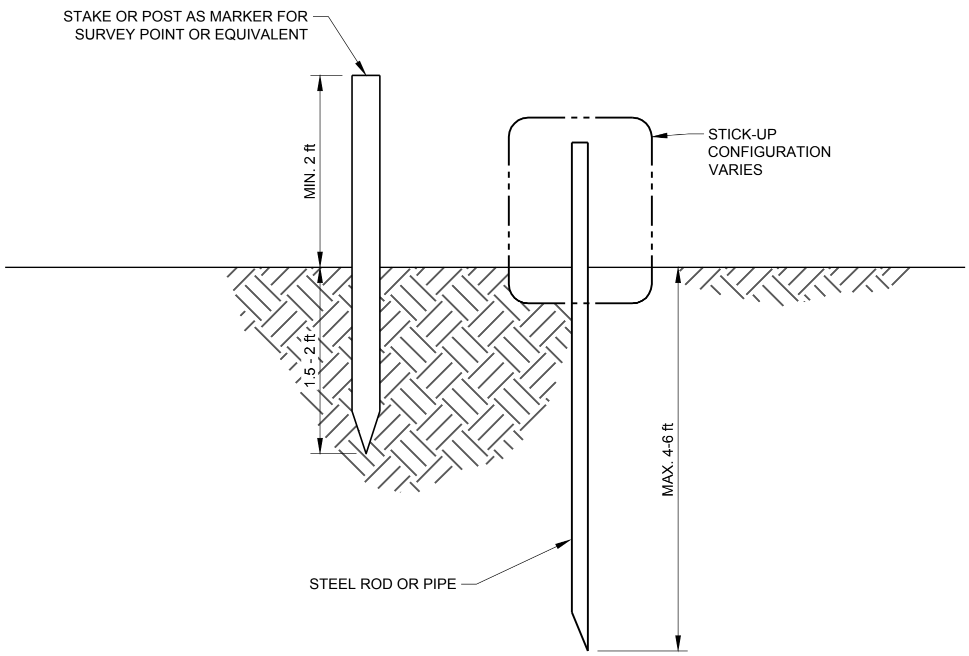
CLIENT	PROJECT
WILLIAMS OVM	TYPICAL DETAILS

CONSULTANT: Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
BENCH RE-CONSTRUCTION THROUGH NATURAL STEPS

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	10A



NOTES

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CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

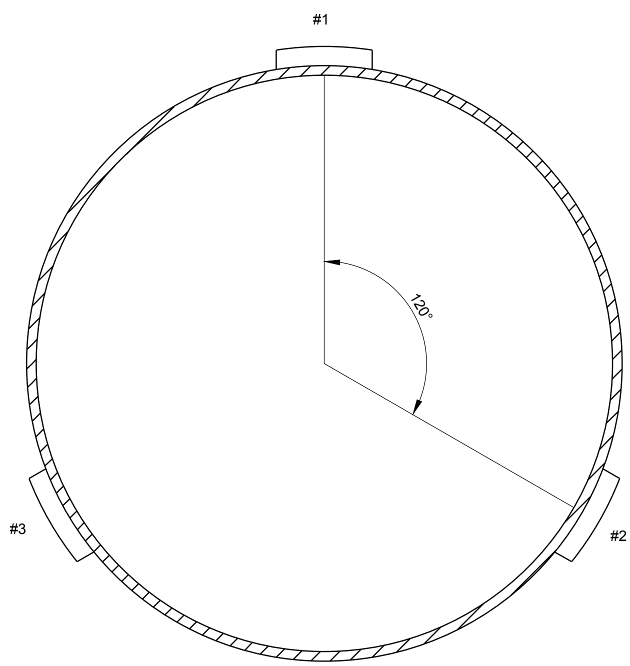
CONSULTANT

Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
GEODETIC MONITORING

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	11A



NOTES

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CLIENT
WILLIAMS OVM

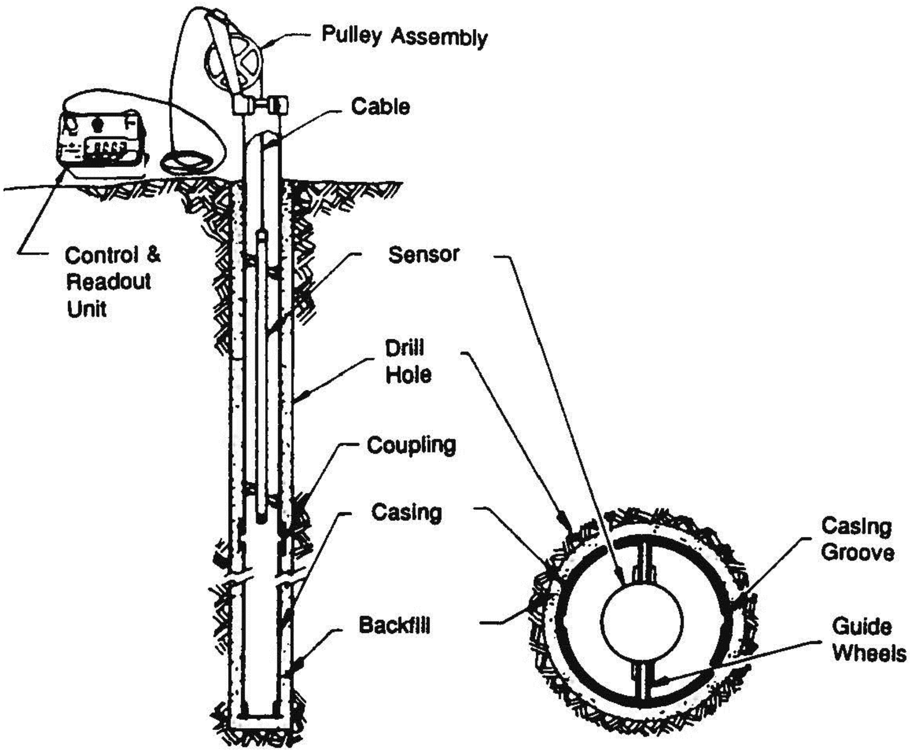
PROJECT
TYPICAL DETAILS

CONSULTANT
Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
STRAIN GAUGE MONITORING

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	11B



NOTES

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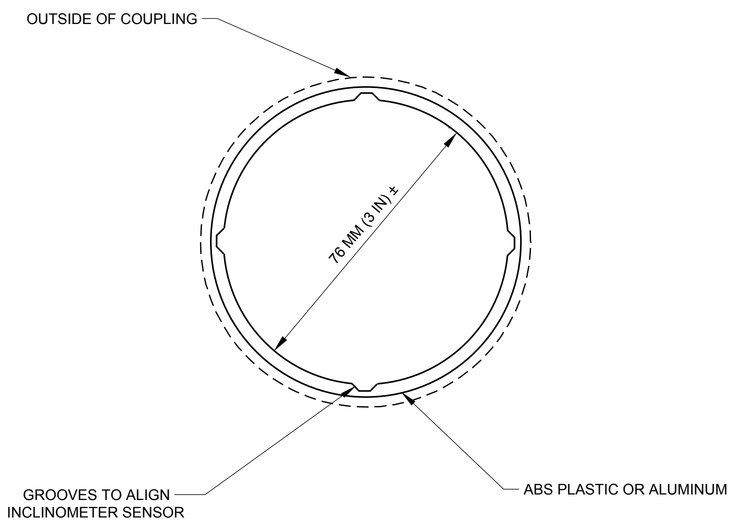
CLIENT WILLIAMS OVM		PROJECT TYPICAL DETAILS	
CONSULTANT Golder Associates	YYYY-MM-DD	2014-02-28	TITLE SLOPE INCLINOMETER MONITORING
	PREPARED	BJV	
	DESIGN	BJV	
	REVIEW	AGM	PROJECT No. / ISSUED FOR CONSTRUCTION / Rev. 0 / SHEET 11C
	APPROVED	AQK	



NOTES

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CLIENT	WILLIAMS OVM
PROJECT	TYPICAL DETAILS
CONSULTANT	Golder Associates
YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK
TITLE	**SLOPE INCLINOMETER CASING**
PROJECT No.	
ISSUED FOR	CONSTRUCTION
Rev.	0
SHEET	11D

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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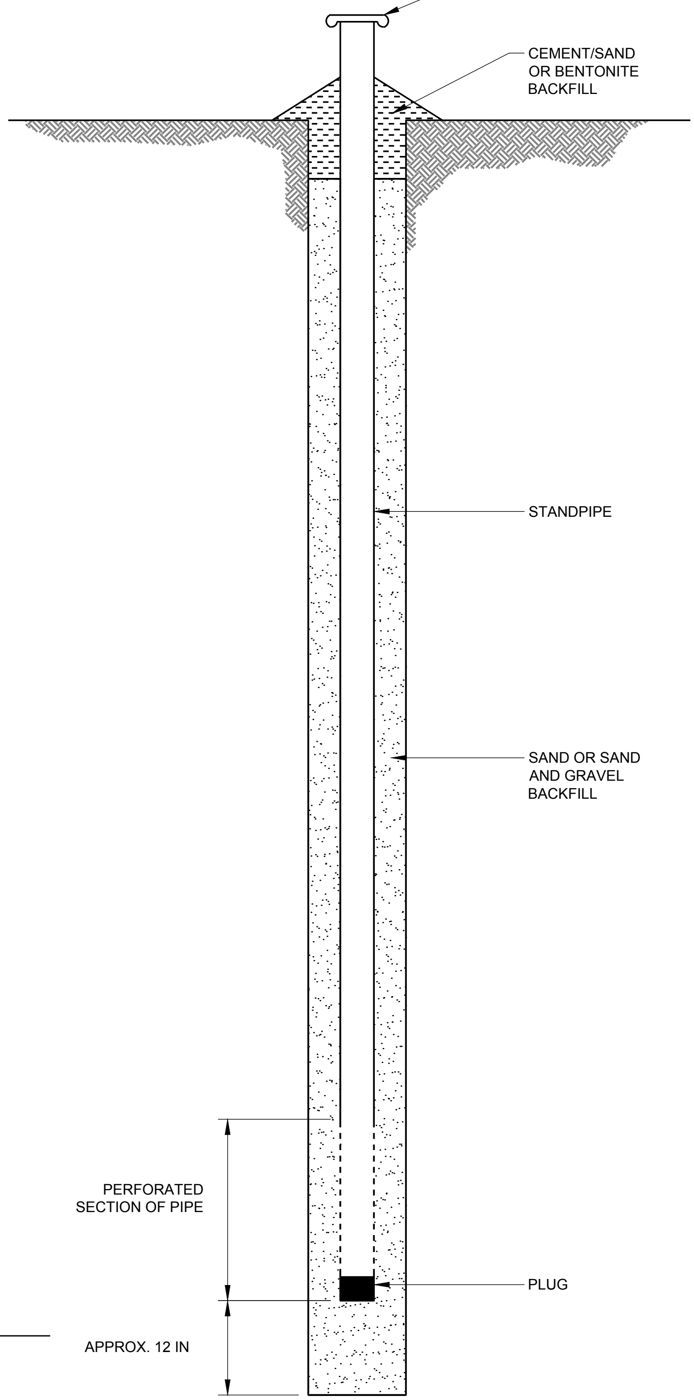

NOTES

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CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

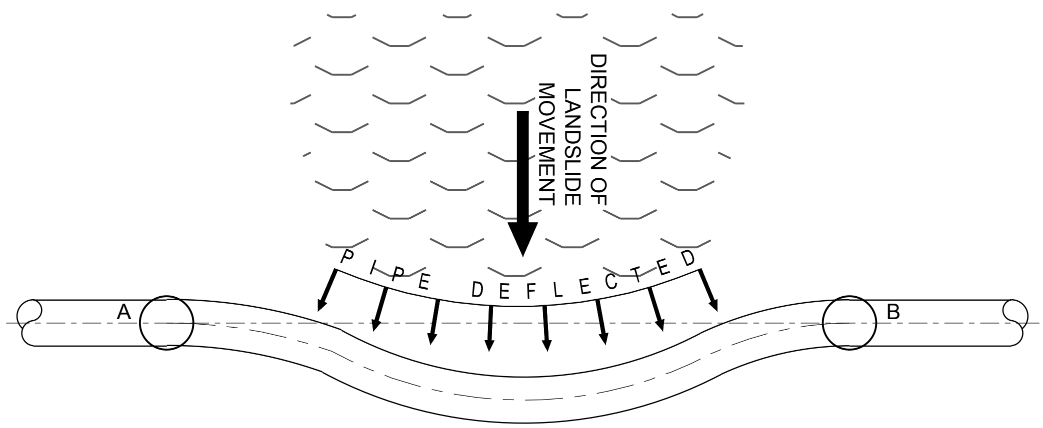
CONSULTANT
Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

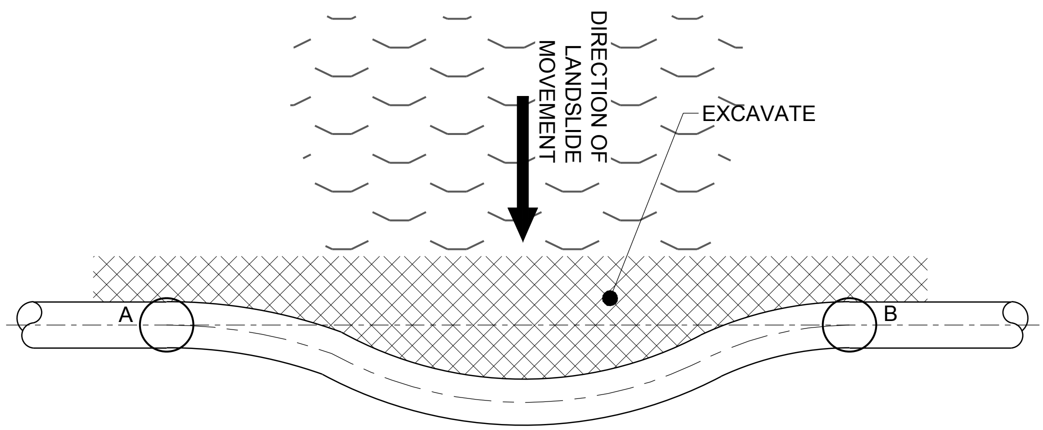
TITLE
STANDPIPE PIEZOMETER MONITORING

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	11E

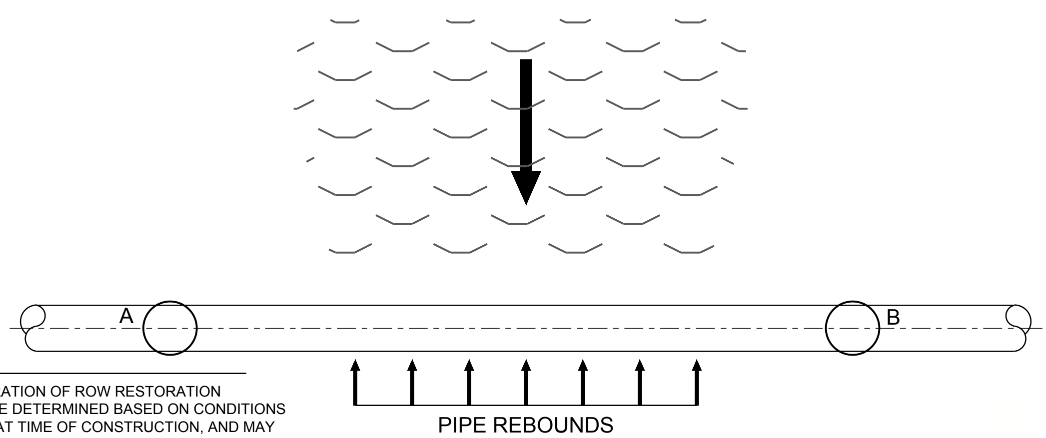
BEFORE STRAIN RELIEF EXCAVATION



DURING STRAIN RELIEF EXCAVATION



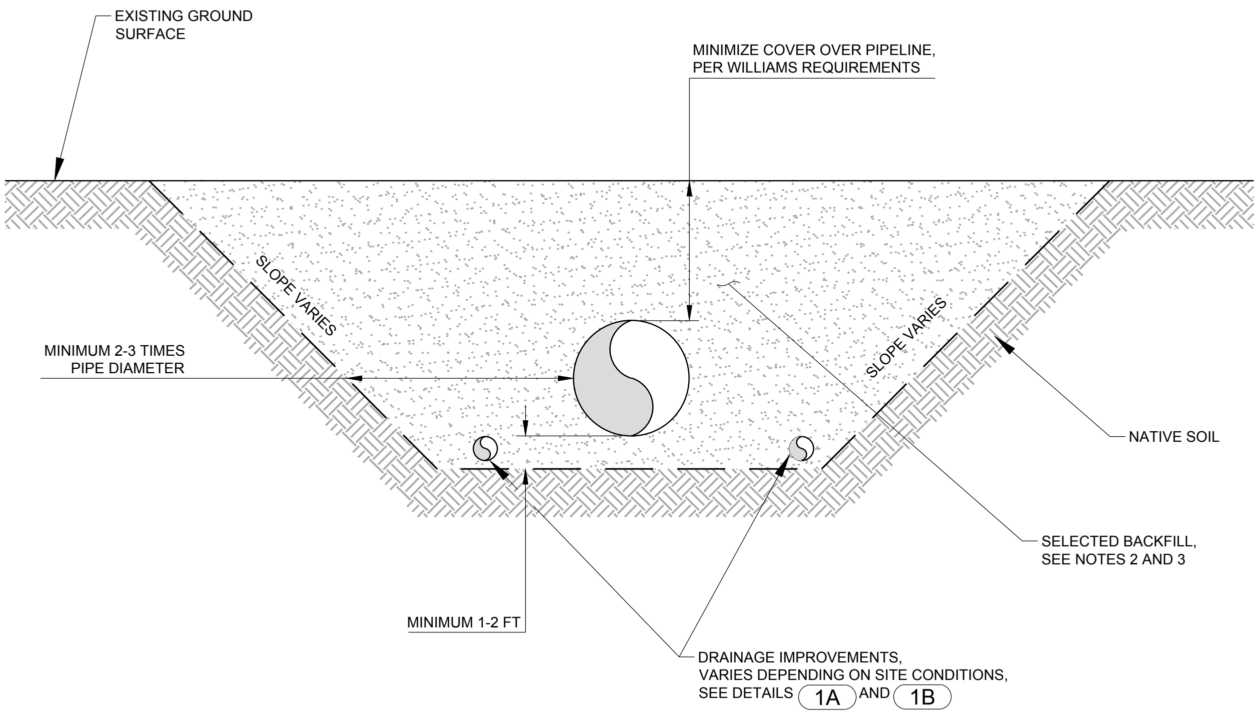
AFTER STRAIN RELIEF EXCAVATION



NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

CLIENT	WILLIAMS OVM
PROJECT	TYPICAL DETAILS
CONSULTANT	Golder Associates
YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK
TITLE	**STRESS RELIEF EXCAVATIONS**
PROJECT No.	
ISSUED FOR	CONSTRUCTION
Rev.	0
SHEET	12A



NOTES:

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

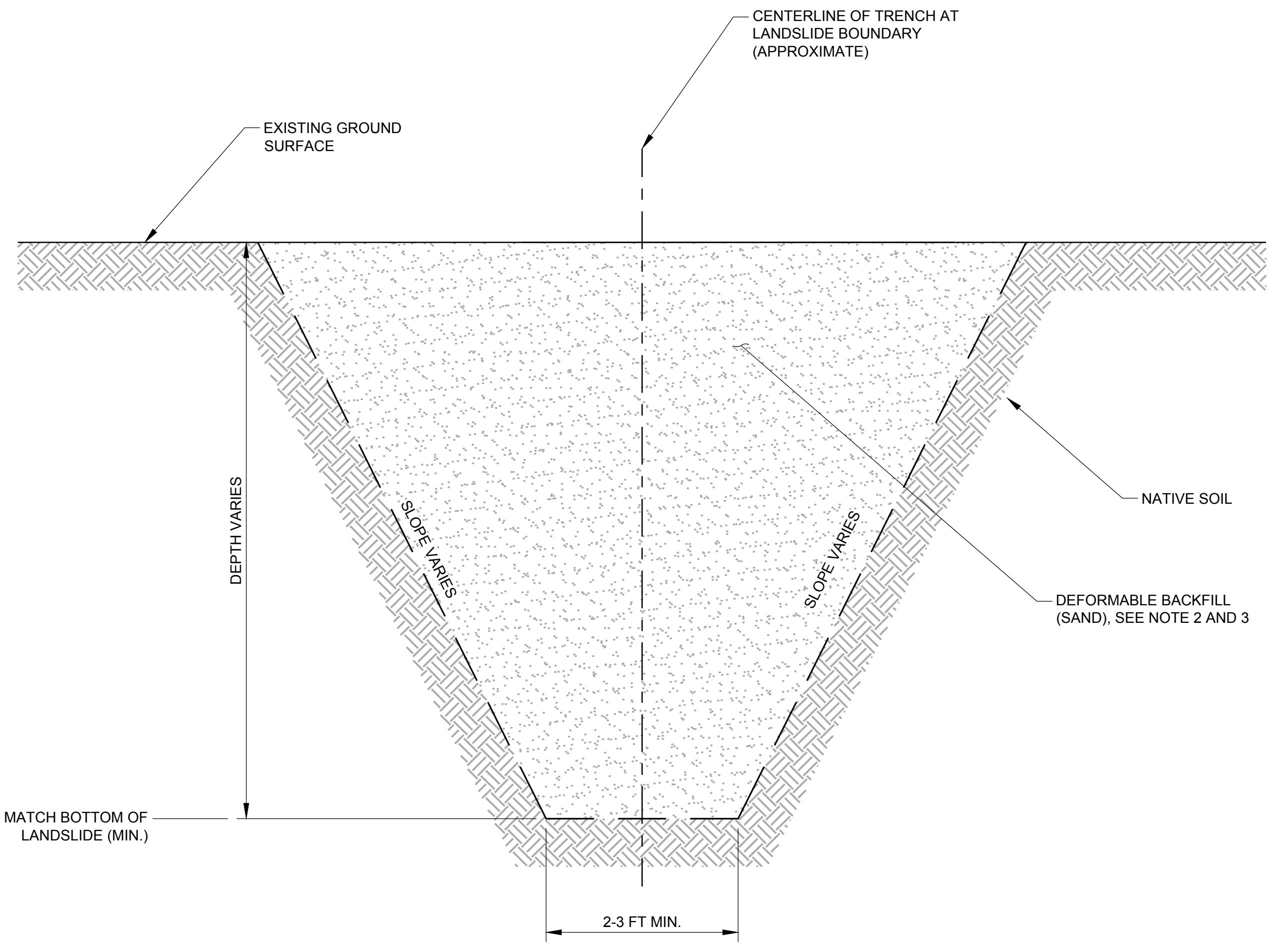
2. SELECT BACKFILL SHALL CONSIST OF SANDY. INVERT GRANULAR MATERIAL, EITHER NATURALLY OCCURRING OR PROCESSED. IT SHALL BE FREE FROM ORGANICS, SILT CLAY, SWELLING SOILS, GARBAGE, WOOD, OR OTHER EXTRANEOUS OR OBJECTIONABLE MATERIAL.

3. SAND SHALL BE WELL GRADED FROM COARSE TO FINE. THE GRAIN SIZE DISTRIBUTION SHALL CONFORM TO THE FOLLOWING.

GRAIN SIZE TABLE

PERCENT PASSING	MINIMUM
$\frac{3}{8}$ INCH	100
U.S. NO. 4	96
8	78
16	60
30	34
50	14
100	2
200	0

CLIENT	WILLIAMS OVM
PROJECT	TYPICAL DETAILS
CONSULTANT	Golder Associates
YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK
TITLE	**SELECT (DEFORMABLE) BACKFILL AROUND PIPELINE IN LANDSLIDE**
PROJECT No.	
ISSUED FOR	CONSTRUCTION
Rev.	0
SHEET	12B



NOTES:

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.
2. SELECT BACKFILL SHALL CONSIST OF SANDY. INVERT GRANULAR MATERIAL, EITHER NATURALLY OCCURRING OR PROCESSED. IT SHALL BE FREE FROM ORGANICS, SILT CLAY, SWELLING SOILS, GARBAGE, WOOD, OR OTHER EXTRANEOUS OR OBJECTIONABLE MATERIAL.
3. SAND SHALL BE WELL GRADED FROM COARSE TO FINE. THE GRAIN SIZE DISTRIBUTION SHALL CONFORM TO THE FOLLOWING.

GRAIN SIZE TABLE	
PERCENT PASSING	MINIMUM
$\frac{3}{8}$ INCH	100
U.S. NO. 4	96
8	78
16	60
30	34
50	14
100	2
200	0

CLIENT
WILLIAMS OVM

PROJECT
TYPICAL DETAILS

CONSULTANT

Golder Associates

YYYY-MM-DD	2014-02-28
PREPARED	BJV
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
SHEAR TRENCH

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	12C

0 1 in

NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

2. ADJUST ROUTING AND/OR ROW EASEMENTS, AND/OR PROPOSED REMEDIATION MEASURES AS NECESSARY TO AVOID POTENTIAL HAZARDS WHERE POSSIBLE.

CLIENT	WILLIAMS OVM
PROJECT	TYPICAL DETAILS
CONSULTANT	Golder Associates
YYYY-MM-DD	2014-05-30
PREPARED	ACF
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK
TITLE	**AVOIDANCE**
PROJECT No.	
ISSUED FOR	CONSTRUCTION
Rev.	1
SHEET	15A

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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NOTES

1. FINAL CONFIGURATION OF ROW RESTORATION MEASURES TO BE DETERMINED BASED ON CONDITIONS ENCOUNTERED AT TIME OF CONSTRUCTION, AND MAY CHANGE OR VARY AND/OR INCORPORATE ADDITIONAL TYPICAL DETAILS TO MITIGATE TARGETED CONDITIONS.

2. SITE INVESTIGATIONS NEEDED TO CONFIRM LATERAL AND VERTICAL EXTENT OF IDENTIFIED LANDSLIDE OR OTHER UNSTABLE SLOPE CONDITIONS.

3. INVESTIGATION MAY INCLUDE PROBES, TEST PITS, EXCAVATIONS ALONG PIPELINE TRENCH, GEOPHYSICAL METHODS (I.E. NON-INTRUSIVE GPR, SEISMIC OR ELECTRICAL METHODS), OR MAY REQUIRE DEEPER SUBSURFACE DRILLING METHODS. FINAL INVESTIGATION METHONGS(S) TO BE DETERMINED BASED ON SITE CONDITIONS AND REQUIREMENTS OF SITE WORK.

4. EXCAVATIONS TO REMOVE IDENTIFIED LANDSLIDE OR OTHER UNSTABLE SLOPE CONDITIONS SHOULD BE COMPLETED FOR THE FULL EXTENT OF CHARACTERIZED HAZARD AREA, AT A MINIMUM MATCHING OR EXCEEDING THE UNDERLYING AND/OR LATERAL BOUNDING FAILURE SURFACE AND/OR SLIP PLANE. THE GOAL AND INTENT OF THIS MITIGATION APPROACH IS TO ESSENTIALLY REMOVE THE SLOPE HAZARD FROM THE SITE BY DIGGING OUT THE LIMITS OF THE IDENTIFIED HAZARD.

5. REMOVAL OF TARGETED LANDSLIDE AND/OR UNSTABLE SLOPE MATERIALS MAY REQUIRE SPECIAL CONSIDERATIONS FOR OTHER DIRECTLY OR INDIRECTLY RELATED OR CONNECTED SITE MITIGATION MEASURES AND/OR SITE ACTIVITIES TO ADDRESS SAFETY, SLOPE STABILITY, ACCESS, CONSTRUCTION FEASIBILITY, ETC, THEREFORE, PLANNING FOR IMPLEMENTATION OF THIS OPTION SHOULD INCLUDE A COMPREHENSIVE REVIEW OF EXISTING PROPOSED WORK AT THE SITE.

6. EXCAVATED MATERIALS SHOULD BE SPOILED IN LOCATION(S) THAT DO NOT ACCELERATE OR EXACERBATE THE TARGETED LANDSLIDE OR UNSTABLE SLOPE AREA, OR IMPACT OTHER NEIGHBORING LANDSLIDES OR UNSTABLE SLOPE AREAS.

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

1 in

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CLIENT WILLIAMS OVM	PROJECT TYPICAL DETAILS

CONSULTANT

Golder Associates

YYYY-MM-DD	2014-05-30
PREPARED	ACF
DESIGN	BJV
REVIEW	AGM
APPROVED	AQK

TITLE
EXCAVATION REMOVAL OF HAZARD

PROJECT No.	ISSUED FOR	Rev.	SHEET
	CONSTRUCTION	0	15B

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