Rockfall in New Jersey:
A Proactive and Collaborative Approach

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Abstract

In heavily traveled New Jersey, a single rockfall event has the potential to cause serious injuries and costly damages. Within a landscape of budget constraints and competing project priorities, the NJDOT, working with the consultant community, has been successful in developing and implementing a proactive rockfall mitigation approach. NJDOT's Engineering Geology unit and Project Management group have partnered in the development of a multi-year Rockfall Mitigation Program that advances projects for remediation that have been prioritized in NJDOT's Rockfall Hazard Management System. Every rock slope and situation is unique, and there are numerous possible rockfall mitigation techniques. In the Concept Development phase, NJDOT subject matter experts work closely with consulting engineering geology experts to evaluate the rockfall hazards and project constraints, and then build a consensus with the stakeholders regarding the preferred mitigation alternative. This collaborative approach helps streamline the subsequent project phases by reducing or eliminating re-work and facilitating an efficient path to final design and construction to stretch available project dollars.

Introduction

As the most densely populated of the 50 States, New Jersey relies heavily upon its widespread system of toll roads, interstate and state highways to connect communities, which range from urban to rural. From the famous Jersey Shore to the Delaware Water Gap, from Cape May to High Point, from Washington Crossing to the Statue of Liberty, New Jersey's highways provide access to the state's wide variety of cultural, historical and natural attractions. In addition to its own cities, the state is 'bookended' by two major metropolitan areas, New York City and Philadelphia, and so many of New Jersey's roads see heavy daily commuter traffic on a year-round basis. Safety of the traveling public is a primary concern, of which highway rockfall is one aspect. Factors that may impact rockfall projects include urban settings with tight spatial constraints and heavy traffic volumes, as well as rural settings with environmental, cultural and historical considerations.

In addition to its geographical and cultural variety, New Jersey has a wide variety of bedrock geologic conditions. The southern portion of the state is located within the Coastal Plain physiographic province, which consists mainly of unconsolidated sand, silt and clay deposits overlying deep ‘basement’ bedrock. However, in the northern half of the state, bedrock is either exposed or near ground surface. A full range of igneous, sedimentary and metamorphic rock types are present, which contain numerous contacts, fractures, faults and other discontinuities. In the Piedmont physiographic province, rift basin sedimentary and igneous rock formations frequently outcrop, like the Palisades Sill along the Hudson River or the tall basalt slopes along Interstate 280. The folded and faulted formations of the Highlands and Valley and Ridge physiographic provinces are also often exposed, typically along roadways. The Valley and Ridge province and approximately half of both the Highlands and Piedmont provinces were affected by the most recent glaciation, while the remaining areas were not. When combined with a high degree of man-made impacts (both recent and historical), this wide range of geologic settings results in a multifaceted transportation environment, requiring an adaptable approach to engineering geology in general, and rockfall mitigation in particular.

Transportation agencies have long contended with rockfall events along roadways and rail lines wherever they cross, cut through or skirt mountainous terrain. Routes can be blocked for days depending on the severity of the incident and impact emergency services, evacuation routes, or other vital community interactions. The resulting costs of clean up and repair can far exceed the cost of mitigation measures. Therefore, a proactive approach should be taken to safeguard people and property. In the past, transportation agencies responded reactively by cleaning up the debris to clear the route as soon as possible, until the next event. A train derailment and subsequent fatalities caused by a rockfall event in Canada (Brawner and Wyllie 1976) was the likely impetus for the United States to begin a proactive approach to rockfall.

This paper presents an overview of rockfall hazards and discusses the approach to rockfall mitigation projects in New Jersey, including the evaluation and ranking of potential project sites, the funding and processes of project execution, and some details regarding the Concept Development phase, which includes collaboration between entities to streamline and optimize rockfall mitigation projects. These processes can reduce or eliminate re-work and facilitate an efficient and cost-effective path to final design and construction.

Rockfall hazards and risks

Rockfall hazards along roadways can be attributed to either natural rock outcrops or constructed cuts, which exhibit current or long-term instability due to degradation from natural forces or man-made disturbance. Several identifying factors that help to characterize the hazards associated with potential rockfall events include, but are not limited to, morphology of the slope (height, dip angle, significance of the back slope), frequency and orientations of discontinuities with the rock mass, degree of weathering of the rock mass as well as along discontinuities, and the presence of water and vegetation on the slope. The photograph in Figure 1 illustrates several rockfall hazards.

Figure 1. Original (left) and annotated (right) photograph of rockfall hazards.

A rockfall event can be composed of large masses of rock blocks or small, discreet blocks. The blocks become dislodged from the main rock mass and fall, bounce, slide or roll downslope. Some of the possible triggers for these events include heavy or sustained rainfall, snowmelt, channel runoff, groundwater seepage, ice jacking caused by freeze-thaw cycles, differential erosion, and root jacking caused by vegetation growth (e.g. McCauley et al. 1985).

Rockfall hazards and risks are linked but distinctly different. *Rockfall Characterization and Control* (Turner and Jayaprakash 2012) defines a rockfall hazard as a natural occurrence that creates a danger or threat and can be described by its geometry, failure mechanism, or other characteristics; and defines a rockfall risk as the consequences realized when the hazard fails and is measured in terms of adverse effects to people or property. Therefore, a rock slope exhibiting severe rockfall hazards could have little risk to the public or structures if there is an adequate catchment area or the slope is far away. Figure 2 illustrates the rockfall hazards versus rockfall risks along the same rock slope.

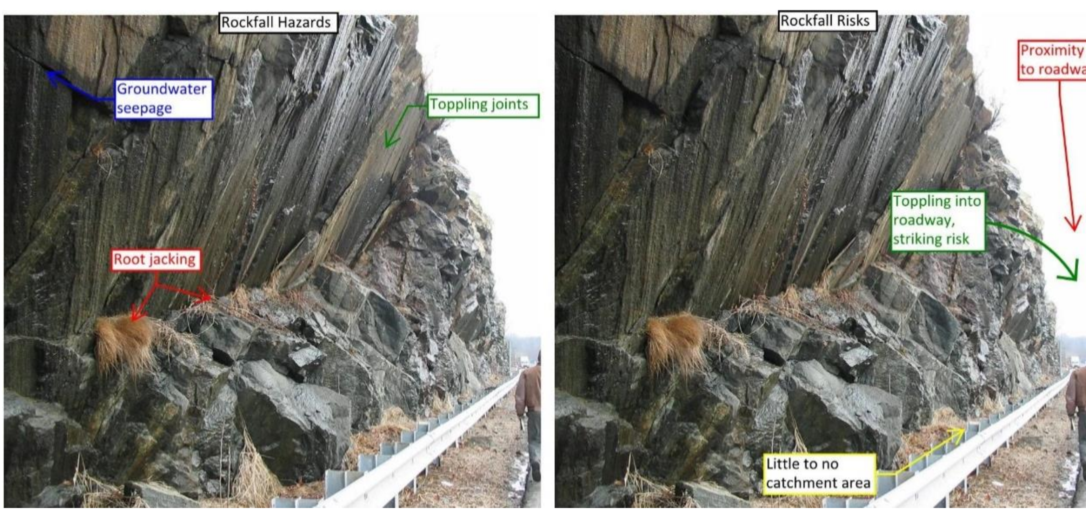

Figure 2. Photograph of a foliated diorite rock slope adjacent to a NJ highway, showing rockfall hazards on the left and rockfall risks on the right.

The risk of rockfall depends on factors like proximity to the roadway, presence and/or adequacy of a catchment area, amount of traffic on the roadway (i.e. what percentage of the time are the traveling public passing by the rock slope in question), sight distance and width of roadway (e.g. Pierson and Vickle 1993). Rockfall risks center on the likelihood of a motorist being impacted by a falling or fallen rock: will the rocks enter the road (proximity to roadway and catchment area), if so can the motorist react in time to avoid it (sight distance), and will they have room to avoid it (width of roadway).

New jersey rockfall hazard management system

The New Jersey Department of Transportation (NJDOT) has jurisdiction of all non-toll Interstate and State highways contained within New Jersey. As such, the NJDOT has the responsibility to address rockfall hazards on those highways containing rock cut slopes. There are currently 444 highway cut slopes on NJDOT-maintained roads. In 1994, NJDOT adopted and began using the Rockfall Hazard Rating System (RHRS) for evaluating and ranking highway rock cut slopes. The RHRS was originally developed by the Oregon Department of Transportation, sponsored by the Federal Highway Administration (FHWA), in order to address the need for a proactive rockfall methodology to uniformly evaluate rock slopes and numerically differentiate apparent risk at rockfall sites. The RHRS methodology forms the basis for the NJDOT's Rockfall Hazard Management System (RHMS), which is used to evaluate, prioritize and program rockfall mitigation projects for implementation on NJDOT-maintained roads. The RHMS is administered and maintained by the Engineering Geology unit within NJDOT's Division of Bridge Engineering & Infrastructure Management.

When evaluating rock cut slopes, NJDOT applies the RHRS' original two-phase approach, which consists of a Preliminary and Detailed rating phase. The Preliminary rating phase addresses the likelihood of rockfall events to occur (rockfall hazards) as well as the likelihood of material from such an event reaching the roadway surface (rockfall risks). There are three Preliminary rating values: 'A' (high), 'B' (moderate), and 'C' (low). The Detailed rating phase develops a numerical rating for each slope, utilizing site-specific categories. However, while the original RHRS methodology stipulates that Preliminary ratings be performed on all cut slopes and that Detailed ratings are to be initially performed only on 'A' rated cut slopes, the NJDOT has implemented Detailed ratings on all cut slopes within the inventory, regardless of the Preliminary rating determination. This practice allows for equivalent evaluation of all slopes, and subsequent decision-making on whether to 'bundle' any or all 'B' slopes incurring higher detailed ratings along with high-priority 'A' slopes for mitigation. The rating criteria used for the Detailed ratings are summarized in Figure 3.

CATEGORY			RATING CRITERIA AND SCORE			
			POINTS 3	POINTS 9	POINTS 27	POINTS 81
SLOPE HEIGHT			25 FEET	50 FEET	75 FEET	100 FEET
DITCH EFFECTIVENESS			Good catchment	Moderate catchment	Limited catchment	No catchment
AVERAGE VEHICLE RISK			25% of the time	50% of the time	75% of the time	100% of the time
PERCENT OF DECISION SIGHT DISTANCE			Adequate sight distance, 100% of low design value	Moderate sight distance, 80% of low design value	Limited sight distance, 60% of low design value	Very limited sight distance 40% of low design value
ROADWAY WIDTH INCLUDING PAVED SHOULDERS			44 feet	36 feet	28 feet	20 feet
GEOLOGIC CHARACTER	CASE 1	STRUCTURAL CONDITION	Discontinuous joints, favorable orientation	Discontinuous joints, random orientation	Discontinuous joints, adverse orientation	Continuous joints, adverse orientation
		ROCK FRICTION	Rough, Irregular	Undulating	Planar	Clay infilling, or slickensided
	CASE 2	STRUCTURAL CONDITION	Few differential erosion features	Occasional differential erosion features	Many differential erosion features	Major differential erosion features
		DIFFERENCE IN EROSION RATES	Small difference	Moderate difference	Large difference	Extreme difference
BLOCK SIZE / VOLUME OF ROCKFALL/EVENT			1 Foot / 3 cubic yards	2 Feet / 6 cubic yards	3 Feet / 9 cubic yards	4 Feet / 12 cubic yards
CLIMATE AND PRESENCE OF WATER ON SLOPE			Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation or short freezing periods or intermittent water on slope	High precipitation or long freezing periods or continual water on slope	High precipitation and long freezing periods or continual water on slope and long freezing periods
ROCKFALL HISTORY			Few falls	Occasional falls	Many falls	Constant falls

Figure 3. Summary sheet for the RHRS (FHWA and NHI 1993).

The RHMS is utilized to prioritize and program rockfall mitigation projects for implementation within NJDOT's Capital Project Delivery Process, described below. The highest ranked cut slopes are targeted as the main initiative, while adjacent or geographically nearby lower-ranked slopes are screened and evaluated for inclusion as a group, where appropriate for benefits of cost-efficiency or other factors, such as traffic impacts or public input.

Transportation capital program

The FHWA defines Asset Management as a "systematic cost-effective process of maintaining, upgrading and operating physical assets." In January 2008, the NJDOT adopted Asset Management as the official, institutional approach to managing its infrastructure assets and making capital investment decisions.

With the current economy, and the need to spend public dollars wisely, Asset Management policy and practice are a high priority at the NJDOT. This approach supports and complements the NJDOT's federal and state-mandated investment planning documents. Focusing on the department's Core Mission—safety, infrastructure preservation, mass transit, mobility and congestion relief, and operations and maintenance—this Capital Program outlines projects and programs that rebuild New Jersey's bridges and roads, provide mass transit services, and reduce congestion.

Capital Investment Strategy

The NJDOT allocates funds to projects and programs through two main capital program documents: The Transportation Capital Program and the Statewide Transportation Improvement Program. The Transportation Capital Program is a document required by New Jersey State law. This program allocates state and federal transportation funding for the period of one state fiscal year (July 1 through June 30) for the NJDOT, New Jersey Transit (NJT), counties and municipalities. The Statewide Transportation Improvement Program (STIP) is required by federal law. Like the Transportation Capital Program, the STIP includes both state and federal funding and includes projects and programs of the NJDOT, NJT, and the counties and municipalities. The current STIP for New Jersey is for fiscal years 2018 through 2027.

A companion document, the Statewide Capital Investment Strategy (SCIS) provides transportation investment recommendations for transportation program categories based upon goals, objectives, and performance measures. The SCIS is a requirement of the Transportation Trust Fund Authority Act of 2000. The SCIS also represents an Asset Management approach to addressing New Jersey's transportation needs, which is a systematic, comprehensive process for maintaining, upgrading and operating physical assets cost-effectively.

Among many others, Safety Management is one of the asset categories. An annual investment amount seeks to maintain the current performance indicators for reducing fatality and injury severity rates, in addition to promoting strategies and partnerships to continue to achieve that reduction. Rockfall Mitigation is listed as one of the safety management programs.

Capital Project Delivery

The FHWA requires use of a formal project delivery process to obtain approval and access to federal funding. The NJDOT's Project Delivery Process aligns with FHWA's regulations. It controls and simplifies the process by which federal approval and funding is obtained. The Project Delivery Process consists of the Problem Screening Phase, Concept Development Phase, Preliminary Engineering Phase, Final Design Phase and Construction Phase, see Figure 4.

NJDOT's Project Delivery Process begins with an evaluation of potential transportation problems in the Problem Screening phase. During evaluation, NJDOT researches the problem statement to have a clear understanding of the problem and its impact. It determines how important that problem is relative to other transportation problems. The RHMS is integral to the Problem Screening phase for rockfall mitigation projects.

Project planning occurs during the Concept Development (CD) Phase and considers the problems associated with the project and evaluates alternative solutions. An alternative is selected based on environmental impacts, constructability, cost effectiveness, how effectively the alternative addresses the project need, and if the project can be constructed in a timely manner. The selected alternative becomes the Preliminary Preferred Alternative (PPA). Once NJDOT approves the PPA, it is further developed using industry standards and practices.

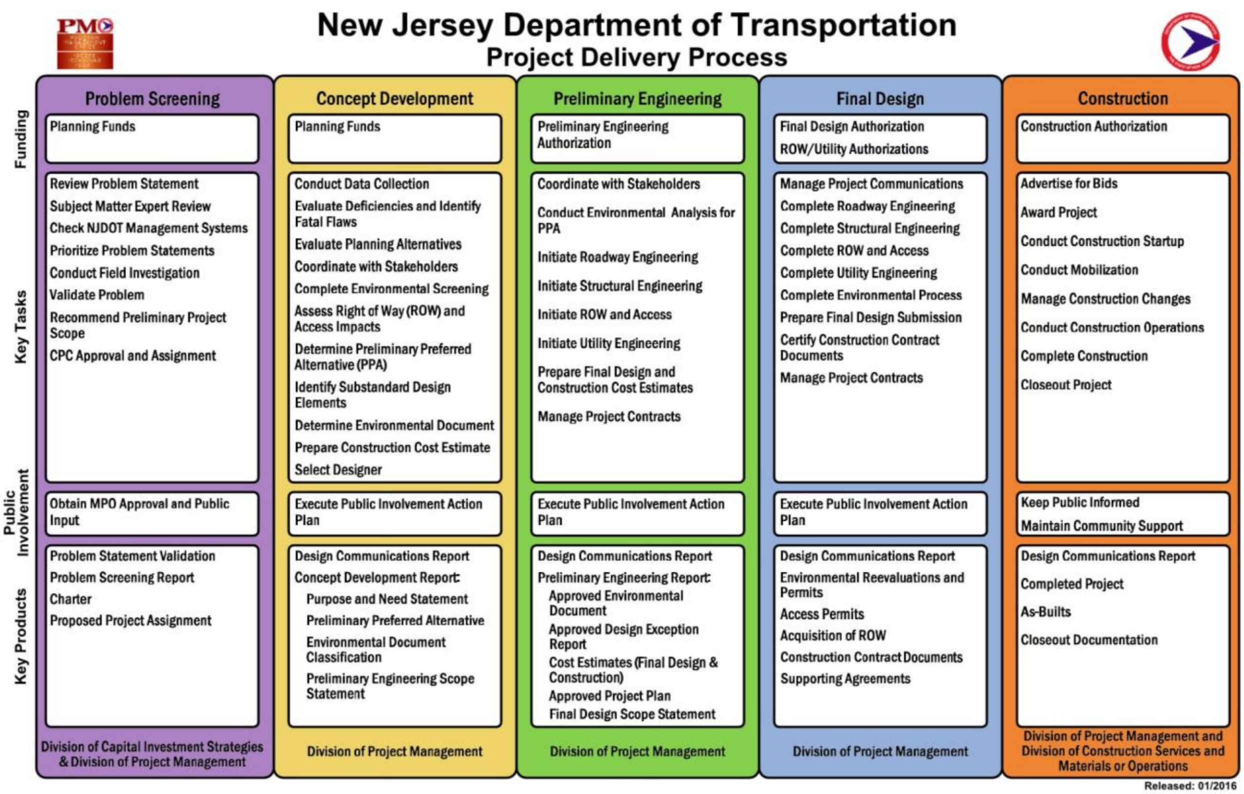

Figure 4. NJDOT's Project Delivery Process.

In the full-scope Standard Delivery Approach, the Preliminary Engineering (PE) phase includes an environmental analysis of the PPA, initiates project design work in support of the environmental document, and initiates the Right-of-Way (ROW) acquisition process for temporary or permanent construction easements. Then during the Final Design (FD) phase, a set of detailed construction plans and specifications are developed for construction of the project. In this phase, NJDOT will secure the necessary permits to begin construction. Finally, during Construction the project team ensures that the contractor is building the project according to the contract documents while minimizing impacts to the existing infrastructure and the traveling public.

The NJDOT has developed a Limited Scope Project Delivery Approach to effectively administer the planning and design of transportation-related problems with minimal impact to the project surroundings and no need for ROW acquisition. Limited Scope project types are typically pavement resurfacing, bridge deck or superstructure replacement, Intelligent Transportation Systems (ITS) installation, simple intersection improvement, guiderail replacement and rockfall mitigation projects. The main difference between the Limited Scope Approach and the Standard Delivery Approach is that the Limited Scope process does not have a formal PE phase. Eliminating the formal PE phase for this approach is possible because the project scope should not change once the PPA is selected at the end of the CD phase. The Department can realize significant administrative and engineering cost savings and time savings by eliminating this phase.

Concept development for rockfall projects

By considering the Department's fiscal goals and objectives together with the established project delivery process, the NJDOT's Engineering Geology Subject Matter Experts (SMEs) in collaboration with its Division of Project Management have developed a multi-year program of rockfall mitigation projects which have been prioritized from the RHMS for design and construction. As such, the Rockfall Mitigation Program (RMP) fits within NJDOT's SCIS. The RMP utilizes the prioritized rankings and generates mitigation projects targeting either a single high priority cut slope, or a 'bundled' group of slopes, which typically incorporate a main high priority slope with one or more moderately prioritized slopes for the purposes of cost-efficiency, geographic nearness, similarity of mitigation measures, or minimization of the recurrence of traffic impacts in a local community. The RMP serves as a programing guideline for rockfall projects within the different phases of the Project Delivery Process. In this manner, long-term funding needs can be evaluated, adjusted and requested for all costs incurred in multiple projects. The initial step in this pathway is a screening of the RHMS to propose mitigation project groupings based upon priorities within the RHMS, while also addressing other factors like cost-efficiency. Once a project grouping is screened, it is advanced into Concept Development.

The CD phase is the foundation for the remaining project phases. It builds on the rating determined through the RHRS and presents an overarching view of the project. One of the essential purposes of this phase is to establish the 'Purpose and Need' for the project. It is vital to explain why the project is necessary to stakeholders and the public because the need for rockfall projects is not as intuitive as pavement or bridge repair projects, for example. Rockfall events are generally not covered in local news unless egregious. Minor rockfall events are typically removed from roadways by maintenance personnel in a timely manner and considered to be 'debris.' Therefore, the precise range and frequency of rockfall can be unclear to NJDOT geology personnel as well as misunderstood by the public.

The rockfall hazards and risks are evaluated by qualified engineering geologists through geologic mapping and characterization, in general accordance with the recommendations within the *Rock Slopes Reference Manual* (Wyllie and Mah 1998). The results of the evaluation are presented in the CD report through annotated photographs and detailed descriptions. Some of the other details included in the CD phase are roadway and rock slope geometries, topographic maps, existing Right-Of-Way (ROW) boundaries, identification of stakeholders, as well as potential environmental or other constraints.

Approach to Identifying Rockfall Mitigation Alternatives

In addition to establishing the Purpose and Need for the project and presenting the overall project parameters, the CD phase is an alternatives analysis. The first alternative is "No Build". Typically, this alternative does not address the Purpose and Need but should be included for comparison purposes and may apply to certain low-risk slopes if the project contains more than one rock slope.

In general, viable alternatives are evaluated following the rockfall hazard mitigation approach hierarchy of (1) removal: get rid of it; (2) stabilization: don't let it fall; and (3) protection: let it fall safely. The removal approach physically eliminates the rockfall source zones, which makes it the most effective method in terms of long-term remediation of the hazards, future maintenance costs, aesthetics and other impacts. Strategies include mass rock removal through blasting, excavation or reshaping using methods such as trim blasting, hoe-ramming, boulder busting, scaling with prybars, and other mechanical means of removal, see Figure 5.

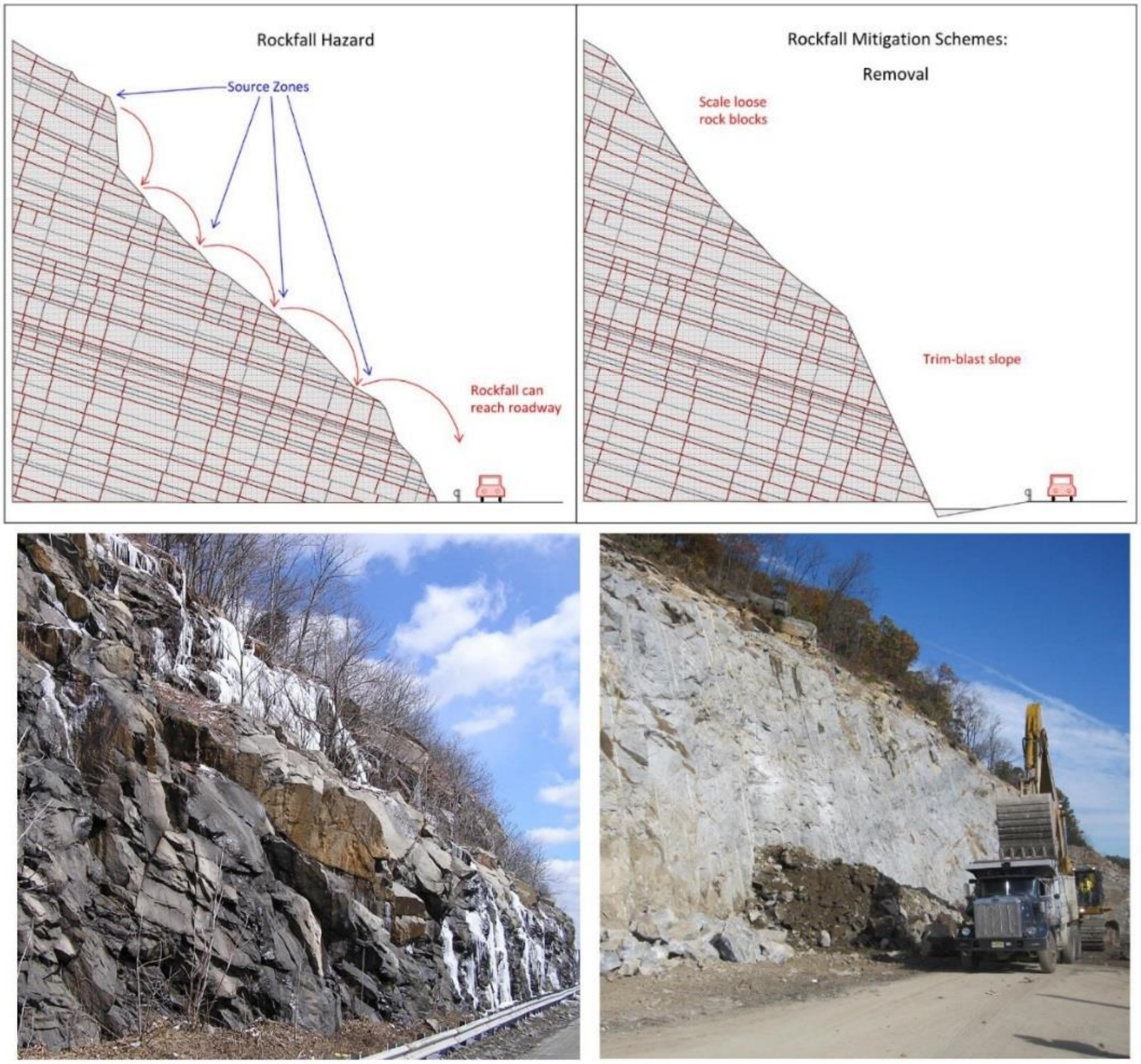

Figure 5. Sketches illustrating rockfall hazards (left) and potential removal strategies (right), with photos corresponding to the sketches below.

Stabilization consists of securing and/or reinforcing the rockfall zone to prevent rocks from moving. Available methods include targeted rock dowels or anchors, cable lashing, anchored mesh, polyurethane resin ‘grouting’, shotcrete and buttressing. The sketches and photos in Figure 6 illustrate two types of stabilization techniques: rock dowels and anchored mesh systems. The use of shotcrete and buttressing for the stabilization of shear zones along rock slopes is also a common method. Installation of these designs generally requires specialty contractors with experience executing the methodologies and working on steep slopes where access can be challenging. Permanent mechanical systems require periodic monitoring and maintenance, which should be considered in overall project costs.

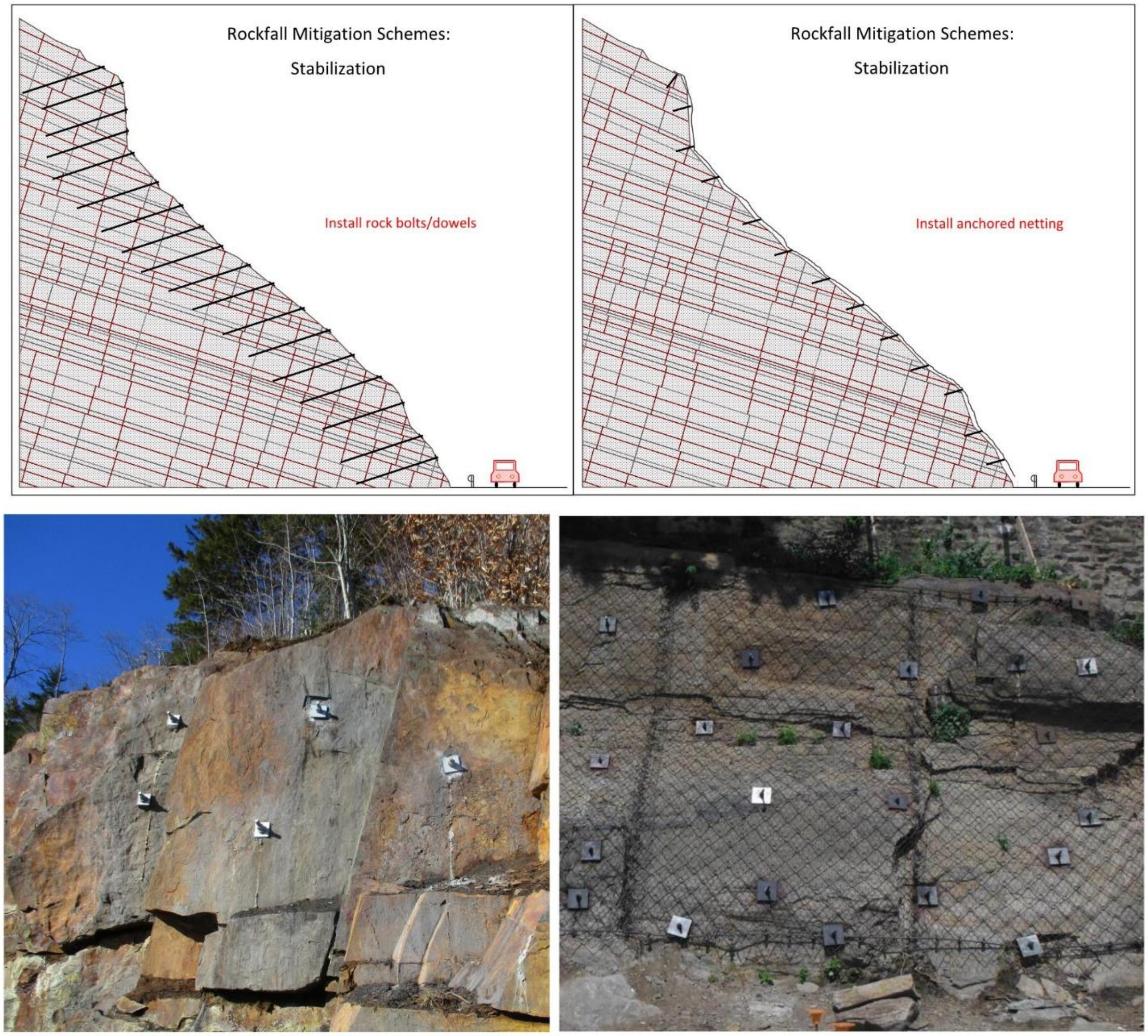

Figure 6. Sketches illustrating stabilization techniques rock dowels (left) and anchored mesh (right), with photos corresponding to the sketches below.

Protection involves intercepting and retaining rockfall before it reaches the roadway once the event has occurred. Techniques include the construction of catchment ditches, rockfall barriers and fences, rockfall sheds, earthen or engineered rockfall embankments, hybrid fence and draped mesh systems that allow controlled rockfall descent. These remedial methods typically involve the most maintenance of the three approaches, as well as more significant visual impacts. Two of the most common protection measures are rockfall barriers and catchment ditches, as shown in Figure 7.

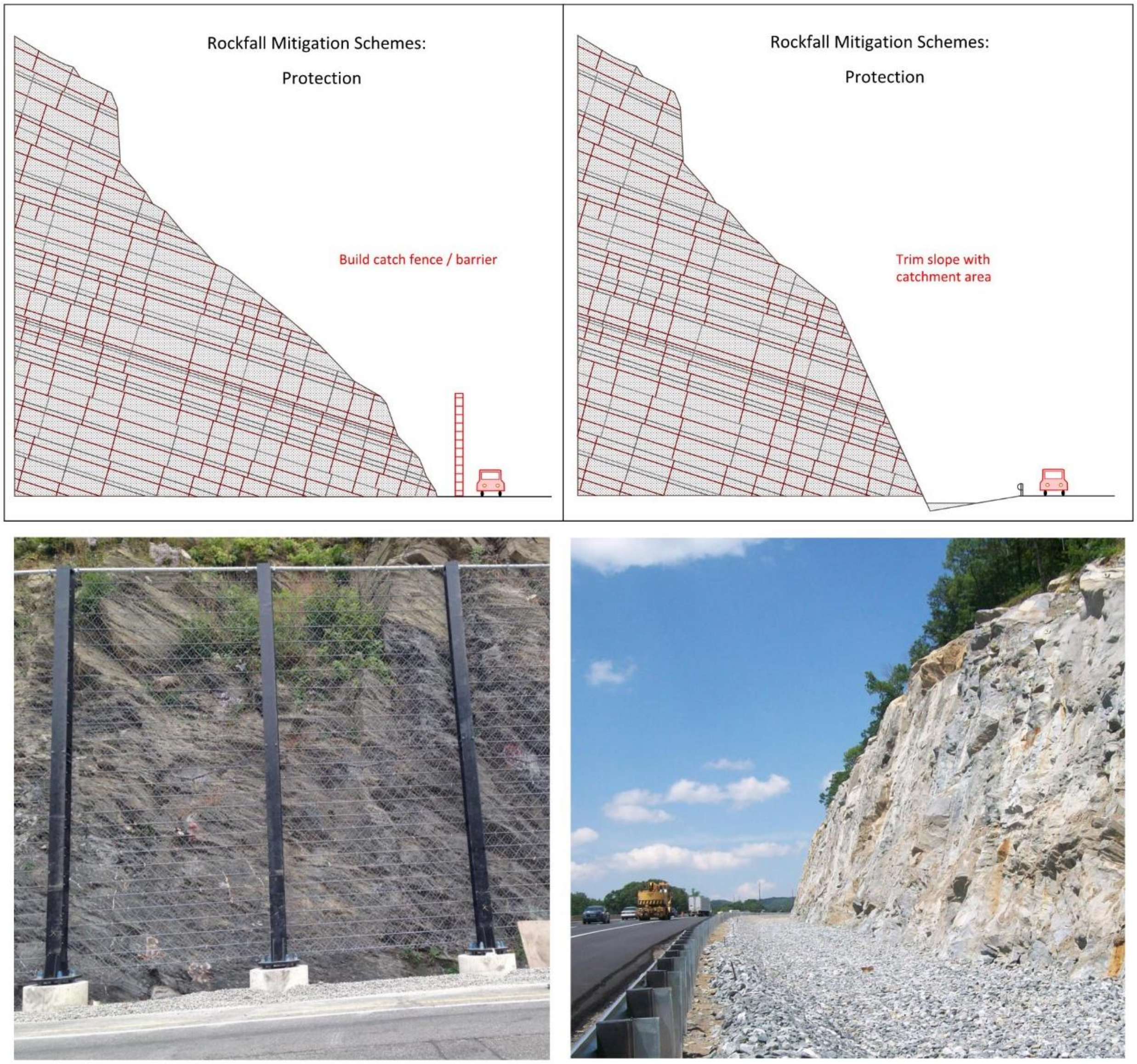

Figure 7. Sketches illustrating the protection techniques rockfall barrier fencing (left) and a rockfall catchment ditch (right), with photos corresponding to the sketches below.

In most cases, a combination of all three mitigation approaches are used to design the most effective and feasible mitigation system. In practice, three to five viable alternatives are typically considered for each slope evaluated. Each alternative, except for the “No Build” alternative, are presented in a figure that includes an existing conditions photograph, the topography of the slope that shows the proposed alternative in plan view, and a sketch illustrating the proposed alternative in cross-section view (Figure 8). Presenting the most pertinent information in one relatively simple figure helps the project team focus on the most important aspects of each alternative.

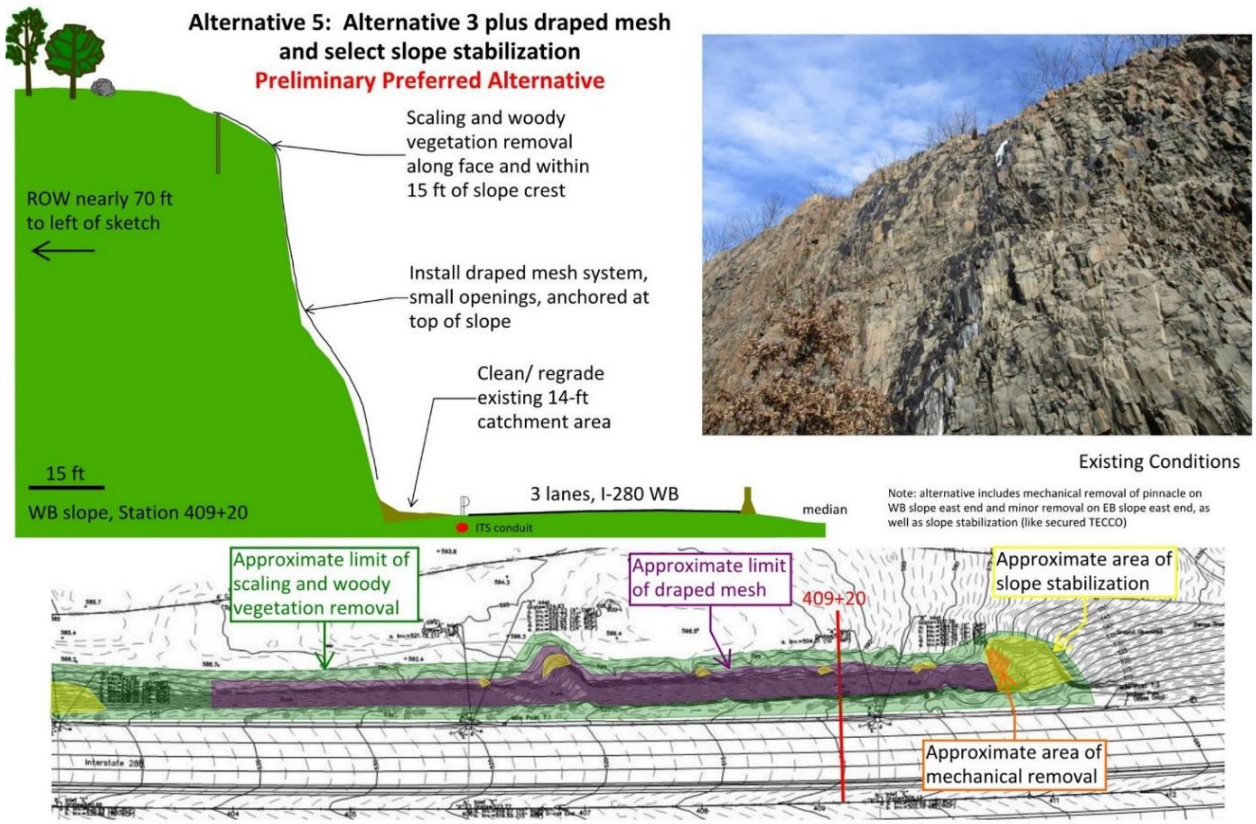

Figure 8. An example of a figure within a CD-phase report illustrating a proposed rockfall mitigation alternative.

Evaluating Alternatives with Simple Matrices

Evaluating the various alternatives is a process that needs to include more than simply considering the remediation of rockfall hazards and risks or the technical performance. For example, constructability and safety during construction are paramount considerations; providing sufficient working space and shielding to the traveling public needs to be incorporated into the design. In addition, aesthetics play an important role in all cases but is elevated near or within designated and protected natural, historic or culturally significant areas. Strategies for improving aesthetics include colorized elements (like mesh, shotcrete or fencing), hydro-seeding or boulder-scaping. Beyond attaining the required performance and risk avoidance, the best mitigation designs are characterized by simple, practical components with an emphasis on constructing within the existing easements, durability, longevity, and no or low maintenance requirements.

A matrix of potential alternatives compares key elements or categories of concern for a rockfall mitigation project. The following is a list of typical categories within the matrix that are used by NJDOT project teams:

- Risk reduction;
- ROW impacts;
- Long-term maintenance;
- Service life;

- Construction impact;
- Difficulty of construction;
- Aesthetic impacts;
- Utility impacts;
- Length of construction; and
- Range of costs.

The categories can then be color coded or numerically rated with respect to desirability (green is desirable, yellow is neutral, and red is undesirable). An example of an alternative comparison matrix is shown in Figure 9.

Alternative	Description	Risk Reduction	Beyond ROW	Long Term Maintenance	Service Life	Construction Impact	Difficulty of Construction	Aesthetic Impacts	Utility Impacts	Length of Construction (days) Low	Length of Construction (days) High	Range of Costs (x $1,000) Low	Range of Costs (x $1,000) High
EB and WB													
1	No build	None	No	High	N/A	N/A	N/A	N/A	N/A	0	0	0	0
2	Rockfall Fencing	High	No	Moderate	Moderate to High	Low to Moderate	Low to Moderate	High	Yes	130	160	1,026	1,924
3	Scaling, woody vegetation removal, clean and regrade ditch	Low	No	High	Low	Low	Moderate	Low	No	140	170	557	1,045
4	Alternative 3 plus shotcrete expansion and repair, reinforced slope stabilization netting	High	No	Moderate	Moderate	Moderate	Moderate to High	Low to Moderate	No	210	250	1,173	2,199
5	Alternative 3 plus draped mesh and reinforced slope stabilization netting	High	No	Low to Moderate	Moderate to High	Moderate	Moderate to High	Moderate to High	No	220	260	1,462	2,742
6	Trim Blasting	High	No/Maybe	Low	High	High	High	Moderate	Yes	400	460	2,580	4,838

Color key:	Desirable	Neutral	Undesirable

Figure 9. A typical comparison matrix of rockfall mitigation alternatives.

Team collaboration – Identifying the preliminary preferred alternative

One of the processes that has been developed and is highly effective for NJDOT rockfall mitigation projects is the selection of the preliminary preferred alternative, or PPA. Part of that process is an alternatives workshop held with the designer and NJDOT personnel. During the workshop, the project team works together to complete the comparison matrices described above and come to a consensus as to the best rockfall mitigation strategy for the project. This consensus is the basis for the remaining steps in the PPA selection process, which include consideration of the National Environmental Policy Act of 1969 (NEPA) requirements and public outreach processes.

As the recipient of federal transportation funds, NJDOT must comply with FHWA's implementing NEPA regulations (codified at 23 CFR 771 *Environmental Impact and Related Procedures*). NEPA provides a planning and decision-making framework for selecting the most feasible and prudent project alternative that avoids or reduces negative social, economic, and environmental impacts. Many of NJDOT's rockfall mitigation projects comply with permitting for publicly owned lands, historic and cultural resources, and threatened and endangered species, among others.

The NJDOT also implements a Public Involvement Action Plan (PIAP) for every project. The PIAP is established during the CD phase and continues throughout the NJDOT Project Delivery Process. The plan will typically include meetings with local officials (Public Officials Briefings) as well as one or several Public Information Centers held in the project area. Other meetings may be held with identified special interest groups, such as neighborhood associations and community activist groups, watershed associations, local or regional bus service providers, emergency services providers, business groups, etc. As safety projects, rockfall mitigation projects are vital for traveling motorists, but they are often misunderstood. Therefore, the PIAP for these projects often need to include an overview of rockfall hazards in general for educational purposes.

After coming to a design-related consensus, evaluating the environmental components of the project and soliciting public feedback, the NJDOT can then advance the project with the selected PPA to the PE phase (or the Final Design phase if the project qualifies for the Limited Scope Approach).

Conclusion

Historically, the NJDOT only developed rock engineering work through incorporation within other projects; for example, if a new roadway alignment was proposed and designed, and it would include a cut in rock areas, rock engineering aspects would naturally be incorporated into the project scope. However, in the case of rockfall mitigation on existing roadways, such work would normally only be achieved through 'piggybacking' onto other projects (whether structurally-related or otherwise) within the same geographic area. Unfortunately, since these sorts of partnerings were driven by other engineering goals (such as bridge replacements), this process was 'hit or miss' in terms of targeting the high-priority cut slopes for rockfall mitigation.

Now, to better implement the Asset Management approach, NJDOT's Engineering Geology SME's have succeeded in establishing internal partnerings with NJDOT's Project Management unit to develop a pathway to program, design and implement rockfall mitigation projects as 'stand-alone' projects of their own. Through this partnering, and the subsequent acceptance by NJDOT Senior Management, NJDOT's Engineering Geology SMEs have been able to utilize their RHMS to take the lead in screening high-priority cut slopes for programming into the NJDOT's Project Delivery Process. The result of this effort has been the establishment of a Rockfall Mitigation Program (RMP), which proactively initiates and furthers rockfall mitigation projects that are solely targeting the highest priority cut slopes within the RHMS inventory, thereby fulfilling the prioritization intent of the RHRS methodology.

Collaboration of the project team in the CD phase is essential to the success of the RMP. The systematic evaluation of mitigation techniques using simple comparative tools helps to minimize project schedules and soft costs by reducing waste and revisions. Projects that qualify for the Limited Scope Approach can be significantly streamlined by eliminating the PE phase. Working from an agreed-upon PPA should eliminate the need for further alternatives analyses and associated engineering costs in the PE and/or FD phases. The consensus-building workshops and 'on-the-board' review processes provide a solid foundation for future project stages.

To date, the NJDOT has successfully 'graduated' seven rockfall mitigation projects from the CD phase into the design phase of project development under this methodology, with another four projects expected to advance by the end of 2018. This programmatic approach has provided both NJDOT Senior Management and FHWA with a high level of confidence in the advancement of these unique projects. With this record of success, NJDOT is poised to continue moving ahead as a leader in rockfall hazard management.

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