Alaska Department of Transportation and Public Facilities

Geotechnical Asset Management Plan

Executive Summary

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Introduction

The Alaska Department of Transportation and Public Facilities (AKDOT&PF) is developing a Transportation Asset Management Plan (TAM Plan) to provide guidance over a ten-year timeframe on the development of preservation and replacement projects and programs for pavements and bridges. This is partly in response to the requirements of the federal and state legislation, and partly an internal effort to make better use of data and engineering economics to improve the productivity of Department investments: to do more with less.

Geotechnical assets – such as rock and soil slopes, embankments, retaining walls, and material sites – support and protect the Department's pavements and bridges, and provide the material from which these assets are built and maintained. They are the front line of the Department's site-based risk management strategies, as they bear the brunt of natural hazards such as extreme weather, floods, and earthquakes. In terms of reconstruction cost they are more than three times as valuable as the Department's bridge inventory, and are a continuing focus of maintenance and preservation expenditures.

While federal rules do not require the inclusion of geotechnical assets in the TAM Plan, the Department nonetheless has recognized the need to address its geotechnical assets using best-practice TAM principles. Therefore this Geotechnical Asset Management Plan (GAM Plan) is prepared using the same structure as is required for pavements and bridges, so it can be readily added to the AKDOT&PF TAM Plan when the Department is ready to do so. Alternatively, it can serve as an appendix to the TAM Plan.

The GAM Plan provides guidance for, and summarizes, the Department's management process for its geotechnical assets. This process, described in Exhibit 1, ensures that the Department is continuously measuring its performance, and programming investments that are most cost-effective to improve performance. It is based on the principle that what gets measured gets done.

Key features of the process in Exhibit 1 are the use of inventory and condition data, and quantitative forecasting models based on engineering and economic analysis, to optimize the development and selection of preservation and risk mitigation investments. As these optimized investments are delivered, their effectiveness is measured, to ensure that Department objectives are achieved and to further improve the forecasting and delivery capability. In this way, the Department engages in a process of continuous improvement.

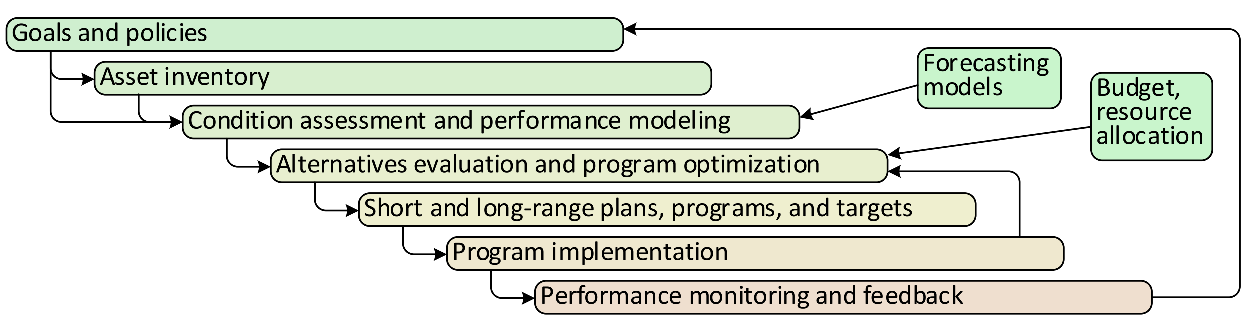

Exhibit 1. Transportation Asset Management (TAM) process

Examples of geotechnical assets

The following photographs provide some examples of assets that have recently been inspected for the geotechnical inventory.

Exhibit 2. Rock slope in fair condition, South Tongass Highway. Rockfalls are occasionally able to reach the road and cause a safety hazard.

Exhibit 3. Soil slope in Poor condition, Tok Highway. Movement is relatively rapid, necessitating frequent maintenance to keep the road passable.

Exhibit 4. Retaining wall in Poor condition, Seward Highway. The wall is bowed outward, causing deformation of the guardrail and pavement (which was recently repaired but is already cracking again).

Exhibit 5. Material site on the Parks Highway, a source of crushed stone for Alaska DOT&PF construction and maintenance projects.

Objectives and measures

Alaska Statute AS 37.07.014(f) calls for "results-based government." This law requires each state agency to quantify its service objectives, to allocate resources to achieve the desired results, to measure progress toward performance outcome targets, to reduce or avoid future costs while working toward the desired outcomes, to plan for the short term and long term, and to achieve accountability for results. Transportation planning goals and objectives are listed in the Alaska Administrative Code, 17 AAC 05.125(a), to include economic vitality of the state, safety, mobility, and preservation of the system. Federal legislation (23 USC 150(b)) lists similar objectives. The Department is now engaged in a program of Results-Based Alighment with a similar aim of linking business processes to desired outcomes.

Geotechnical assets affect these objectives in a positive way when they function as designed, and in a negative way when natural forces cause deterioration and movement, resulting in rockfalls, landslides, pavement damage, and disruption of service. DOT&PF engineers and geologists regularly inspect state highway slopes and retaining walls to identify emerging hazards and act to reduce the risk of service disruptions. The trained inspectors record a variety of attributes affecting the likelihood of future disruption, including geometry, geological character, effectiveness of protective systems, and especially physical condition. Condition determinations can be synthesized down to the following categories:

Good: Identified defects, if any, are minor and do not require corrective action. Asset performance and life cycle cost are not adversely impacted by condition.
Fair: Significant deterioration has been identified. Corrective action is feasible and would extend the service life and/or improve the performance of the asset.
Poor: Deterioration is advanced. Significant mitigation, repairs, rehabilitation, or reconstruction are needed to restore full functionality.

These assessments are based on physical evidence as follows:

- Rock slopes: Catchment effectiveness of ditches, barriers, fences, and other features intended to prevent rocks from reaching the road. Slope characteristics that produce loose rocks.
- Soil slopes and embankments: Evidence of movement including slide deposits and disruption of the road surface. Soil, hydrology and permafrost characteristics; affected roadway length.
- Retaining walls: Correct wall alignment. Movement or damage to the road. Corrosion, spalling, or other material or component degradation.
- Material sites: Quality of material and distance to potential maintenance or construction sites, affecting the cost of construction.

All of these characteristics affect the frequency of safety, mobility, and economic problems, impacting the quality of transportation service and the economic vitality of the state. The Department uses quantitative engineering and economic models to provide the best possible estimates of the magnitude of risk, the rate of further deterioration, and the cost and effectiveness of repairs. These models are used to estimate life cycle costs, considering the economic value to the state of avoidable risks. Projects that produce the best long-term value to the state are prioritized for funding and delivery.

AKDOT&PF is developing a statewide inventory system that can track condition over time, using maps and graphics to show the trouble spots and trends in performance.

Inventory and conditions

Alaska's highway system faces enormous challenges due to the scale of natural hazards throughout the state and relatively intense weather. Retreating permafrost is impacting roadway embankments and soil cuts that were previously on frozen ground, but that now are experiencing increased freeze-thaw cycles and deeper seasonal thaw. The result is deep settlement and premature deformation of the pavement requiring expensive annual repairs; soils sliding or flowing onto the road from above; and loss of support as embankments and slopes degrade and subside. Rock slopes and retaining walls are also experiencing accelerating deterioration rates and impacting roadways, due to increased rainfall, water infiltration, and freeze-thaw cycles. Thawing at higher elevations is increasing the occurrence of debris flows in established drainage systems, which can damage bridges and culverts that were not originally designed to handle such events. Statewide, highway facilities are experiencing weather conditions well outside their original design parameters, a cause of increasing maintenance costs and mobility disruption.

The brunt of these hazards is being felt on a widely under-appreciated category of assets: slopes, embankments, retaining walls, and material sites. These are collectively known as geotechnical assets. Alaska DOT&PF owns an estimated 56 million square feet of rock slopes with a value of $3.3 billion, 1.4 million linear feet (measured along the road centerline) of soil slopes worth $16.0 billion, and 4.0 million square feet of earth retaining walls worth $0.4 billion. Together at $19.7 billion, these are more than three times the value of the state's bridge inventory based on current reconstruction costs.

The magnitude and conditions of these assets are summarized in Exhibit 6. Soil slopes in Poor condition represent a significant liability for the state of Alaska, as these assets are likely to produce the biggest expenditures in reconstruction costs over the coming years. It is also apparent that there is considerable potential for relatively inexpensive preservation activities on rock and soil slopes currently in Fair condition, to keep them out of the Poor category.

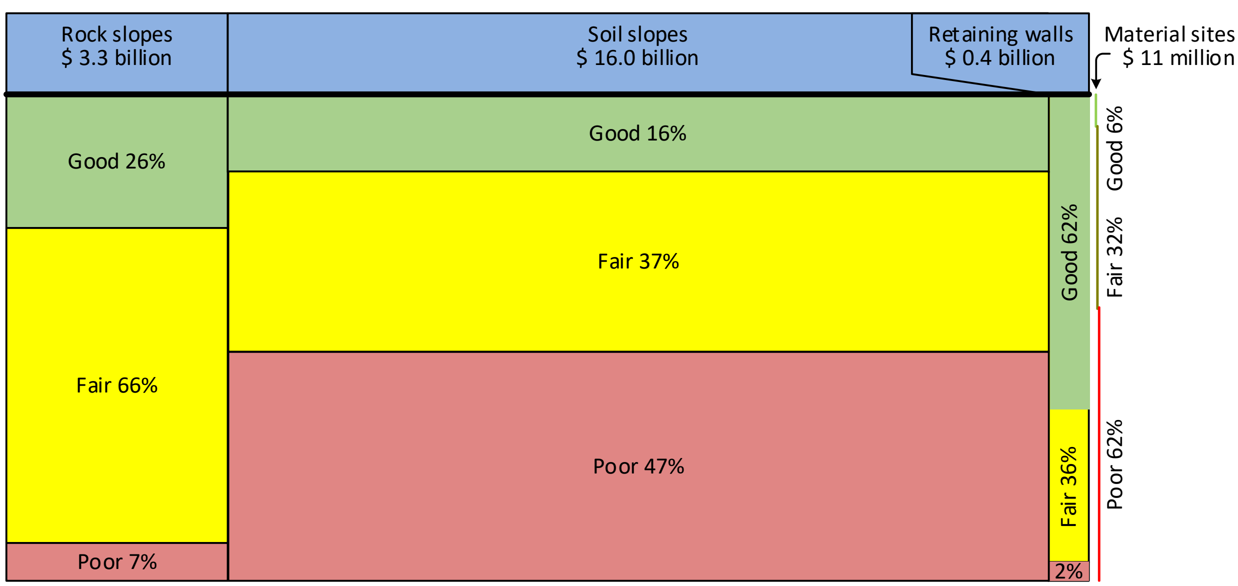

Exhibit 6. Geotechnical inventory and conditions

Life cycle cost

Over the course of its life, each slope and retaining wall will experience deterioration because of age, weather, water and earth movement, freeze/thaw, and other factors. Occasionally it is necessary to intervene to counter-act this deterioration. The kinds of actions the Department might take include:

- Routine maintenance, such as catchment ditch cleaning and crack sealing, occur potentially every year on a reactive basis. As condition declines, these activities are needed more frequently.
- Corrective action, which includes preservation and risk mitigation, is programmed work whose scope is determined by condition in the most recent inspection, and site characteristics. This category of work occurs infrequently, typically once every 20-65 years at a given site.
- Reconstruction may entail complete removal or reconstruction of the asset, or realignment of the road. This takes place at the end of the asset's service life.

Material sites also require occasional work, including exploration, expansion of access, opening of new sites, reclamation of exhausted areas, and stockpiling of materials transported from elsewhere.

Corrective action is especially important. If relatively inexpensive preservation and risk mitigation work are done in a timely manner, the need for much more expensive reconstruction can be delayed or avoided, thus saving significant amounts of money in the long term. Routine maintenance costs may also be reduced.

Life cycle cost analysis is the method commonly used in the transportation industry to compare investment alternatives in terms of scope and timing, to find the one which is least expensive in the long run. GAM research performed by Alaska DOT&PF has developed preliminary models of deterioration rates and the cost and effectiveness of various types of actions performed on geotechnical assets. Exhibit 9 shows the typical pattern of condition over time for soil slopes, as an example where preservation prolongs the lifespan of the asset. The research found a 38% return on investment for corrective action on rock slopes, 15% on soil slopes, and 148% on retaining walls. Material site development returns 882% in haul cost savings.

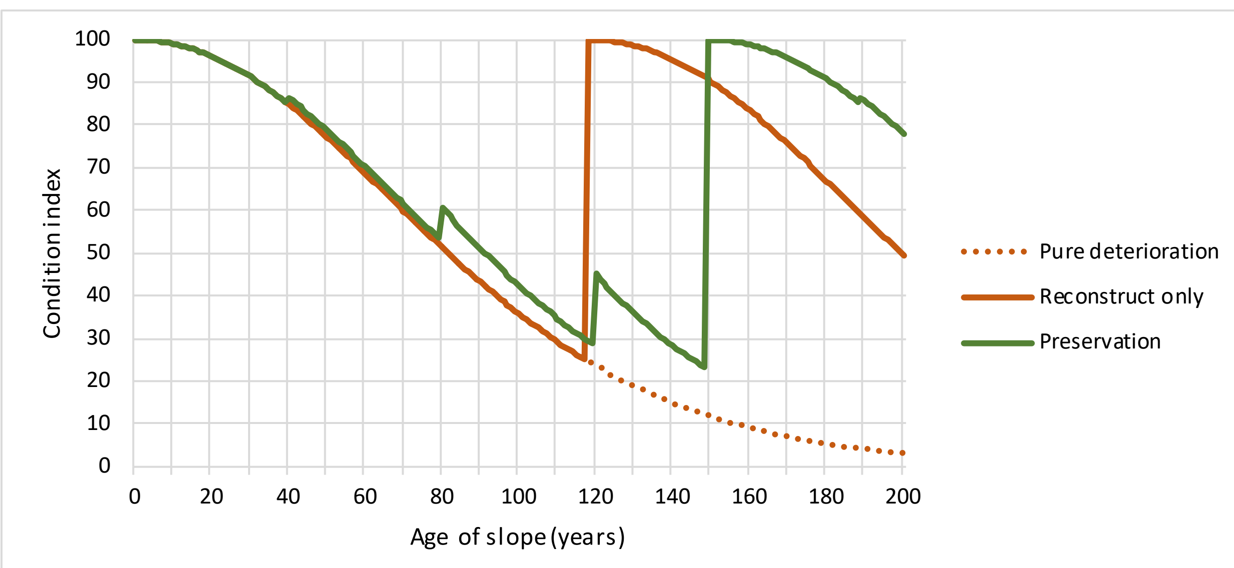

Exhibit 9. Deterioration, preservation, and reconstruction of soil slopes

Risk management

Geotechnical assets impact transportation system performance primarily by means of the risk of service disruption. Therefore it is very common for geotechnical hazards to be addressed as part of an agency's risk management planning process. By their nature, adverse geotechnical events such as rockfall, debris flows, washouts, and landslides are uncommon and unpredictable at a given site (Exhibit 10), but total impacts are reasonably predictable on a statewide long-term basis. The business process is made more manageable and efficient by focusing on programmed corrective actions that the agency can take, in response to periodic inspections, to identify sites with the highest risk and work on reducing that risk.

In Alaska's GAM process, risk assessment consists of two parts:

- Likelihood of service disruption, a probability in percent, which depends on condition as assessed by a trained inspector.
- Consequence of service disruption, a summary in dollars of the safety, mobility, and recovery cost impacts that are likely to occur if there is a service disruption.

Risk is the product of likelihood times consequence. Procedures to estimate the dollar value of safety and mobility impacts are used in a wide variety of fields, from asset management to the development of contractual early completion incentives. As a result, the American Association of State Highway and Transportation Officials has published a manual, known as the Red Book, to guide the calculation. Significant variables affecting this calculation are traffic volume, detour length, and an inspector's estimate of potential accidents and delays or closure at each site.

Since risk is expressed in dollars, it is easily incorporated into the life cycle cost model, making it possible to prioritize projects according to benefit/cost ratio in a manner consistent with pavement and bridge management. Risk management can therefore become an integral part of the programming process for all preservation and reconstruction investments.

Exhibit 10. April 2015 washout of the Dalton Highway due to unusual North Slope spring break-up conditions

Financial plan and investment strategies

Currently the Department does not have capital accounts or maintenance activity codes specifically focused on geotechnical assets. Occasionally work activities can be reliably identified from existing activity codes combined with work descriptions and locations. Often, however, work on slopes and retaining walls is integral with pavement or drainage projects and not separately identified. As a result, the Department does not have formal budgets for this type of work, even though such work is often performed by maintenance crews and contractors. It will be important to address this situation as GAM implementation proceeds, especially in regard to corrective actions that the Department hopes to plan using GAM methods.

Even in the absence of well-defined fiscal scenarios, it is possible to use deterioration and cost models to estimate the medium range cost of maintaining assets in their current condition, and to assess the condition outcomes if funding is higher or lower than this estimate. This information can be used to establish a geotechnical preservation and reconstruction budget, and to set corresponding condition targets for the 10-year timeframe. This analysis has been performed as part of recent Alaska GAM research:

- Rock slopes (Exhibit 11). Annual funding of $9.52 million is sufficient to maintain the current statewide average condition index of 70.3 after ten years. At this level the ten-year performance targets for TAM Plan purposes would be 29% Good and 8% Poor. The total 10-year funding requirement, including 2.5% per year inflation, is $107 million.
- Soil slopes (Exhibit 12). Annual funding of $154.28 million would be necessary to maintain the current statewide average condition index of 48.4 after ten years. At this level the ten-year performance targets for TAM Plan purposes would be 19% Good and 47% Poor. The total 10-year funding requirement, including inflation, is $1.728 billion.

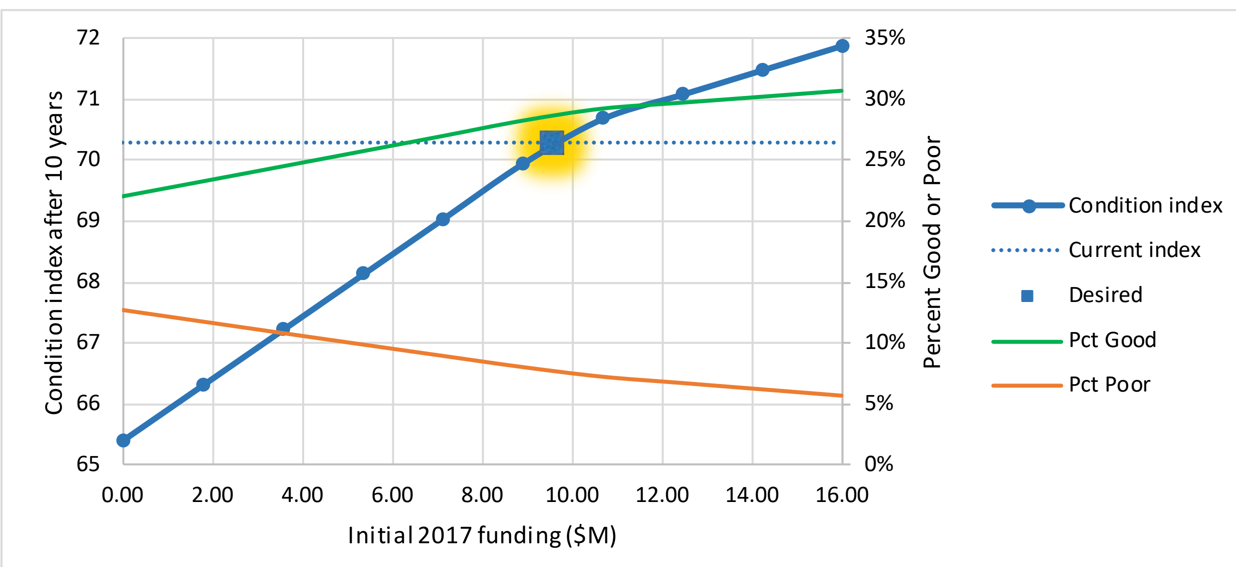

Exhibit 11. Condition vs funding for rock slopes

- Retaining walls (Exhibit 13). Annual funding of $3.73 million is sufficient to maintain the current statewide average condition index of 79.8 after ten years. At this level the ten-year performance targets for TAM Plan purposes would be 62% Good and 2% Poor. The total 10-year funding requirement, including inflation, is $42 million.
- Material sites (Exhibit 14). Annual funding of $244,000 on new site development is sufficient to maintain current statewide average material availability, with 5% of maintenance stations in Good condition (optimal availability) and 57% Poor. The total 10-year funding requirement, including inflation, is $3 million.

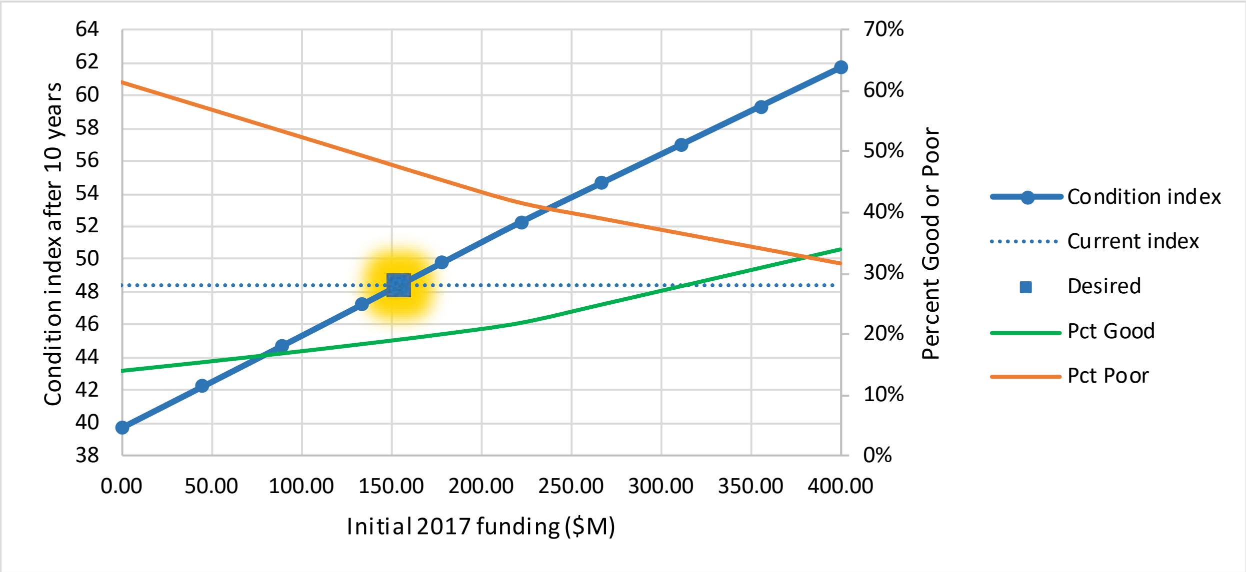

Exhibit 12. Condition vs funding for soil slopes

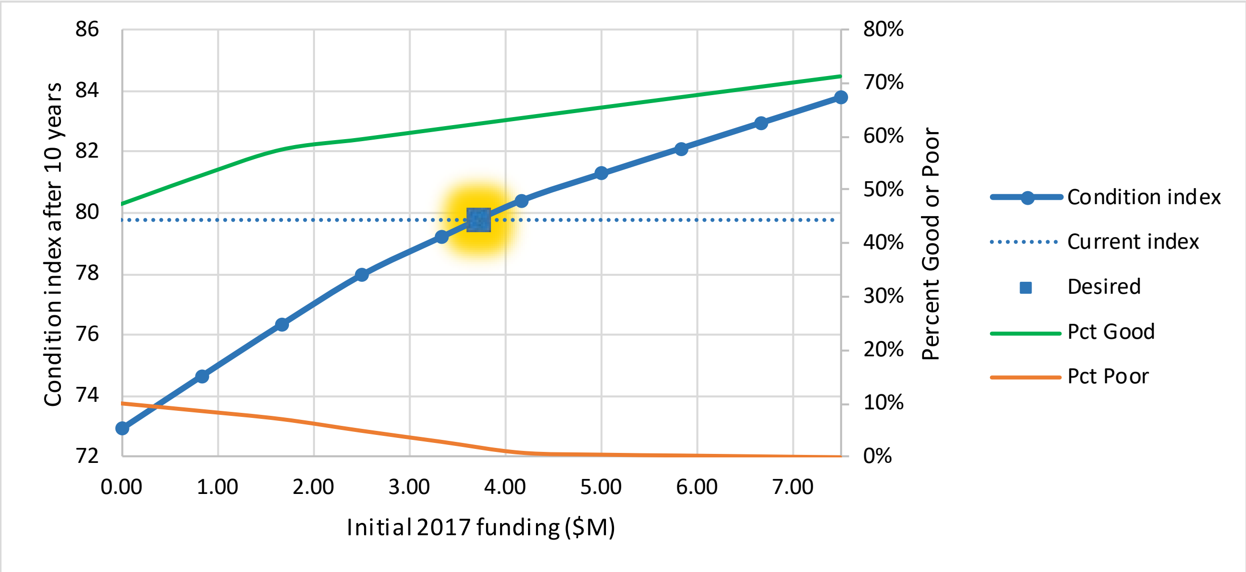

Exhibit 13. Condition vs funding for retaining walls

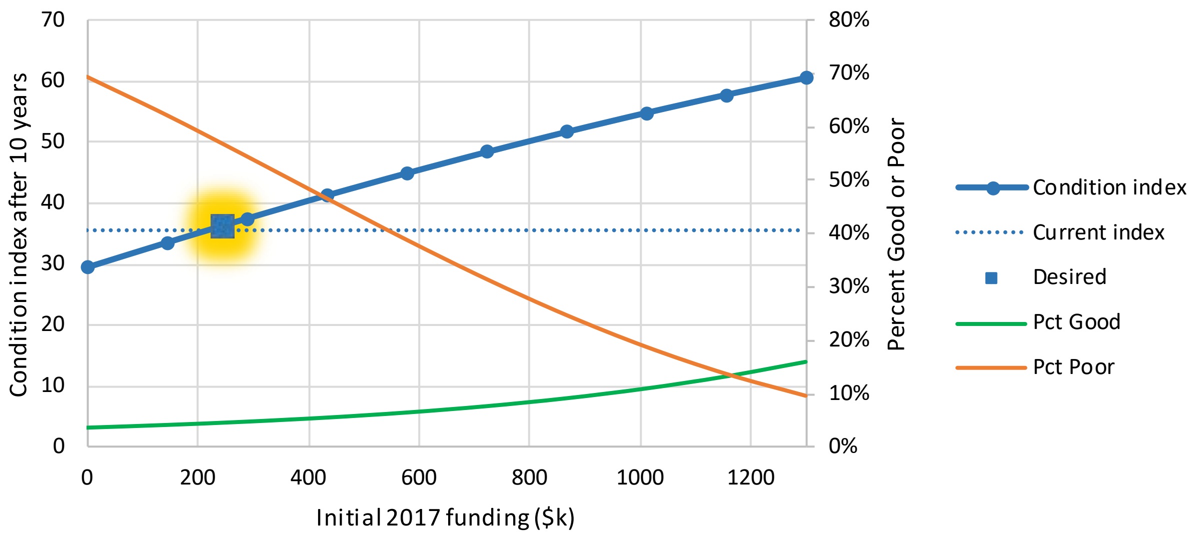

Exhibit 14. Condition vs funding for material sites

Since the cost to maintain current condition for soil slopes in particular is far beyond the Department's fiscal capability, it can be expected that conditions of unstable soil slopes will decline over time. Some of the consequences will be realized in the form of increased reconstruction costs for pavements located on unstable soil slopes, and some will be realized in the form of slower travel speeds and increased vehicle damage on uneven surfaces. Operational strategies such as speed restrictions and temporary or permanent closures can be a way to cope with declining conditions. These may become especially relevant in areas of the state experiencing permafrost instability, where soil slope deterioration rates are fastest. Exhibit 12 shows with no soil slope mitigation, conditions after ten years will be 14% Good and 61% Poor. The effects of other investment levels can be interpolated from the graph.

Process improvements

Since this is the Department's – indeed, the nation's – first Geotechnical Asset Management Plan, its development entailed a considerable amount of research and the development of new tools and concepts. In particular, the effort has produced a new procedure for inspecting and documenting the conditions of slopes, embankments, retaining walls, and material sites; and a new set of methods for quantifying life cycle cost and risk. The research has generated a significant amount of national interest from agencies wishing to repeat the process for themselves.

For Alaska, the work is not concluded, because now it is necessary to institutionalize the business processes of GAM as standard operating procedures, so they can be repeated much more easily in the future and can be steadily improved as the Department learns from the experience. Recommended implementation steps concerned with geotechnical assets include:

- Completion of the asset inventory.
- Policy recommendations. Prototype language was provided in several policy areas that have been valuable in asset management, especially related to data standards and decision criteria
- Routine budgeting of geotechnical asset inspection, commensurate with the inspection intervals specified in the inspection policy.
- Enhancements to the inventory database to support the inspection process, including inspection crew and equipment scheduling, quality assurance review, storage of historical data, issuance of work requests, and management reports.
- Development of an asset-level analysis of risk and life cycle cost to be used in project planning and programming. This might take the form of a spreadsheet model using the methods documented in the GAM Plan Technical Report.
- Maintenance of a STIP line item for geotechnical asset preservation activities, with the intention of using federal funding where appropriate.
- Public reporting of geotechnical asset condition as part of the Results-Based Alignment process.
- Biennial update of the GAM Plan, and inclusion in the federal TAM Plan. Begin reporting condition trends over time with comparison to targets.
- Improvements in work reporting in DOT&PF systems for maintenance and contract management, including reliable gathering of location, type of work, quantity, and cost.
- Improve accident reporting procedures to indicate when asset limitations or failures are contributing factors.
- After a second inspection cycle is completed, begin to develop statistical models of asset deterioration. It is important to refine and improve the models of deterioration, cost, and effectiveness over time.
- Pursue research to develop better preservation strategies for soil slopes. The research noted a very large need and relatively low return-on-investment for existing methods, indicating the potential for developing new methods in this area.
- Promote national or pooled-fund research where possible to improve deterioration, cost, effectiveness, and risk models.

Future GAM Plans should monitor this list of process improvements and report on the status and future plans.