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Tier I Alternatives Analysis-Potential Research Variables for Study

Revegetation Action	Reference			Research Type		TerraLogic Remarks
	Research	State DOT	CDOT	Research Testing Variable	CDOT Process Testing Variable	
Seed mixes specific to soil type, soil chemistry and site specific to native ecozone			x	x	x	Could do comparison of templated seed mix to site specific seed mix
Revegetation training needed for PE and Water Pollution Control Manager for installation and inspection monitoring			X		X	Identify a revegetation problem early in the process
Specifications may not being followed by contractors regarding soil preparation and soil amendments			X		X	Contractor monitoring and oversight
Need better revegetation and erosion control inspections during hand off from contractor to CDOT Maintenance			X		X	
On-Call revegetation contractors needed to repair work in a region.			X		X	Using pre-qualified revegetation contractors would increase the effectiveness of repair work in a region. Right now maintenance crews with tight budgets are performing these tasks.
Ensure clarity, accuracy and consistency in pre and post construction percent cover calculations			X		X	TerraLogic has noticed inconsistency in measuring 70% vegetative cover; some regions use weed cover, some use native plant cover or some do not use the metric at all; CDOT may consider revising the guideline
Provide contract incentive bonus to Contractor to reach 70% revegetation or other milestones	X					Idea from Western States Reclamation
Provide guidance to PE and/or WPCM on how to inspect the revegetation process; there is limited knowledge on equipment and associated specifications			X		X	
Historically evaluate past construction projects by measuring plant species, diversity, density, slope, topsoil management, planting types, mulching, embankment drainage, ditch type			X	X		Forensic Plant Study to evaluate success based upon historical implementation that assumes specifications have been followed by Contractors
Pre-seeding/revegetation meetings between CDOT PE/WPCM and Contractors to increase communication and discuss expectations for growth success			X		X	Could be done during PE weekly meeting
Additional revegetation oversight needed at initiation of seeding and mulching			X		X	Assume Project Engineer will oversee contractor revegetation
Organic granular amendments in sandy soils			X	X		Compost just floats on top of sandy soils in eastern part of region. Seeing success with organic granular amendments.
Use sulfur coated urea instead of bio-sol for soil amendment			X	X		
Top soil being imported seems to be of low quality and needs to be monitored for additional amendments			X	X	X	Study could assess imported top soil conditions state wide (if top soil will be imported on the job)
Enforcing standards when they are critical to success			X		X	An example was the length of straw mulch used on projects. Contractors are sometimes trying to use straw mulch that is too short in length to get a proper crimp which results in poor coverage of the planted seed.
Test Microrizo and humates as soil amendments			X	X		
Increase maintenance budgets to address potential reseeding or other revegetation corrective actions			X		X	
Forensic revegetation analysis study; on selected sites (different ecozones) evaluate what plants exist after several years; reference to seed mix and nearby plant species			X	X		Compare success on slopes and evaluate veg density and slopes
Test bio-sol as a soil amendment			X	X		Boulder County testing bio sol currently; used spring application but fall application would have been best
Ensure clarity, accuracy and consistency in pre and post construction percent cover calculations			X	X	X	The ground cover calculation approach may be flawed; noxious or non natives used to initial calculation but natives may not come in at the same density and cover for final stabilization; CDOT guidance not clear on calculations using non-native and noxious weed in initial and final determinations; could double check and verify construction sites calculations for vegetative cover
Evaluate watering trucks for irrigation in especially urban areas; place in specifications or in contract			X	X	X	Test in urban environments to assess revegetation success in urban areas

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Role should expand for Water Pollution Control Manager to address Spec 212 in addition to 208			X		X	Could be done during monthly inspections
Evaluate hand pocketing seeding success			X	X		Limited success in some applications
Evaluate Bio-Char soil amendments			X	X		potential test variable on construction site or test plots
Work with Cities on revegetation when they dictate revegetation approaches within their city limits			X		X	Non native and unsustainable plants selected for some revegetation projects
Seed application density needs to be revisited or better rationale provided			X		X	Should be plenty of information on this from other industries
More flexibility needed for best months to seed from specifications; each region and eco-zone may have it own optimum time and range for seeding			X	X	X	
Need to have contractor more responsible for revegetation and stabilization			X		X	Put 10-20% of total project cost in escrow to provide revegetation incentive
Develop a life cycle analysis on using transported water to germinate and establish seed growth; find out project area thresholds for watering.			X	X	X	Evaluate uses of irrigation to establish plants
Evaluate seed imprinting success			X	X		Good potential for improvement; limited number of vendors having this equipment
Grading control and design coordination			X		X	Establish maximum slope when possible to allow revegetation; coordination between landscaping and design engineer is not clear
WPCM needs a checklist and direction on how to sample and monitor before and after construction completed			X		X	Seed viability testing a potential
Contractors need to prepare soil as per specifications via soil ripping for hard compacted soils and disking			X		X	Revegetation issues discussed by Water Quality Committees
Project phasing may need to happen to plant seed at optimum times			X		X	
Consider using non-natives that are not noxious for hard to revegetate areas			X	X		Non natives not a general CDOT approach but could evaluate differences in growth over time between the native versus non-natives
Maintenance and Water Pollution Control Manager (WPCM) needs to work together with PE and Maintenance at sites			X		X	Maintenance punch list needs to be closely reviewed before acceptance; seed viability and other monitoring parameters could be tested before handing over to maintenance; revegetation status evaluated before project take over
Soil preparation performed by one subcontractor (during grading) and separate revegetation subcontractor used for planting and landscaping			X		X	Could use a NPS contractor or the prime contractor
Have contractor hold the stormwater permit until 70% achieved			X		X	
Water Pollution Control Manager in region reviews revegetation status during monthly inspections			X		X	
Establish planting and species selection with consideration for carbon sequester			X	X		Evaluate seed mixes and other variables to address climate change
Evaluate native salt tolerant plant species for revegetation near roadway due to deicing agents			X	X	X	Could evaluate use and success of salt tolerant species
Seed mixes could be combination of non native and natives to promote faster revegetation			X	X	X	Could do a growth comparison and dominance emergence study over time
Final site inspection needs to take into account noxious weed density for acceptance			X		X	Unclear if there is a specification on this as a metric
Consider asking for an exception/variance for required percent vegetative coverage during drought years			X		X	Does not promote revegetation
Reduce site monitoring away from monthly to quarterly or yearly			X		X	Does not promote revegetation
Look at it in terms of square feet. 3.62 Acres = 157,687.2 SF. 104# over this area is .000659533557574 # / SF. Can't comprehend that? How about .0105525369212 oz. / SF. Ridiculously low. Evaluate seeding more along the lines of 10 # / 1000 SF or 435.6 # / acre.			X	X	X	
Identify ways to increase and measure optimum soil to seed contact			X	X	X	

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CDOT could buy the seed and be better manage for viability accountability	Reve		X		X	
Evaluate how much native plant establishments slows down the stabilization process			X		X	
Determine if soil salvaging may be counter production due to poor quality from scraping, storage and soil mixing			X	X	X	Evaluate soil salvaging process and success
Develop a life cycle cost for improved process and new specifications to obtain buy in			X	X	X	Need to show cost savings and effectiveness; reduced risk and liability has a cost
Perform proper salvage top soil management with soil testing		X			X	If project is large enough to salvage top soil
Inspection and enforcement of topsoil salvage specifications		X			X	KDOT has implemented a new 2 day training program that is focused on the importance of topsoil and the proper methodologies for salvaging, stockpiling and placing.
Plant establishment study		X				NDOR going back to construction sites revegetated 15 years ago and studying what plants within the seed mix were successful; brome seems to be dominant
Develop checklist to monitor contractors revegetation		X			X	Some monitoring guidance established; look at the web site
Selecting seed in anticipation of increasing average temperatures (climate change)		X		X	X	Need to select seeds that will be more drought tolerant that will be successful as warmer temperatures set in
Evaluate use of organic amendments such as manure, bio-solids, etc.		X		X	X	Biosolids may have odors that may be a problem for the public
Eliminate soil fertilizer		X		X	X	Usually does not use fertilizer during revegetation that increases water demand
Rock mulch		X			X	Used on bridge abutments and steep slopes; use local gravel sources; tough to get the aesthetic color desired; used by CDOT only in Pueblo; more BMP in nature
Timing of seeding		X		X	X	Timing of seeding in relation to mother nature. They like to go with the fall seeding window.
Use of cool weather grasses		X		X		Annual rye and oats to address weather extremes
Evaluate bio-mulch with microrizo		X		X		Class A seeding standard treatment- sent pdf of specification
Compost Application		X		X	X	Compost can successfully amend a site and has seen positive results from the use of compost but does not think it is a realistic cost effective amendment
Specifications need to flexible		X			X	Add flexibility in specifications and make the SOW elements in the RFP more concise and detailed about approaches and expectations; make adjustments for increased material and water costs and avoid specifications that are impediments to revegetation
Herbicide application		X			X	Herbicide applications during revegetation can cause big problems; maintenance or subcontractors not aware of impacts
Bio-mulch using green waste material		X		X		Seed placed under mulch; current study project; originally material was not tilled in and failed.
Using yard waste for highway compost near urban areas		X		X		Under consideration by NDOR
Certification or prequalification of CDOT Revegetation Contractors	X					Create a prequalification or certification process for Revegetation Contractors. Try to filter out companies that cannot perform proper revegetation. Increased success by experienced companies with proper revegetation equipment. Qualified contractors would increase positive results and would create a sense of accountability to CDOT.
Inspection of Material Application and evaluate seed viability	X					Ensures the proper application and rate of amendment, seed, mulch etc. Increased effectiveness of existing specifications
Reclamation Specialist inspector during revegetation installation	X				X	Assign a qualified representative to the project area during revegetation; provide direction to Contractor; daily oversight; Better revegetation results and less Contractor short cutting

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On-Call Revegetation Maintenance Contractors	x				x	Have prequalified and contracted revegetation contractors hired to be on call for touch up seeding and reveg maintenance items. Take some pressure off of CDOT's maintenance crews and have qualified firms evaluating and maintaining challenging sites.
Ability to evaluate if correct equipment being used for the revegetation project	x				x	Spec equipment: Drill seeders, crimpers, deep rippers, cultivation, etc.; Increase efficiency of contractors and ensure that proper equipment is being used
Develop a revegetation plan with the CDOT SWMP	x				x	Revegetation objectives, description and map of each revegetation unit, desired outcomes, noxious weed management, laws and regulations, project background, analysis and limiting factors, mitigation measures, strategy methodology, key contracts and responsibilities, budget, schedule, monitoring approach, corrective actions based upon monitoring. Region specific plans developed for reference. A management tool for the Project Manager as well as DOT landscape/environmental representatives; identifies expected outcomes and responsibilities at a minimum. Regional plans could be more cost effective solution than site-specific plans
Project contains enough financial funding to stabilize soils and provide sustainable revegetation	x				x	Ensures revegetation and water quality is being protected for several years after construction
Split Reveg Contract separate from general	x				x	Temporary seeding through general on larger projects and final seeding completed by qualified revegetation contractor.
Get Revegetation Contractor involved early on in the process.	x				x	Get the Revegetation Contractor involved during pre-construction and lean on their knowledge of the area for value engineering or input to increase success. More ownership to the project and allows the inspectors and engineers to set the stage for process and expectations.
Early revegetation planning	x				x	Early in the construction process and revegetation is not an afterthought
Communication and cooperation among reclamation scientist with design engineers	x				x	Reclamation Scientists and environmental representatives talk about revegetation with design engineers early in the process
Reclamation planning at the front end of projects	x				x	Use qualified reclamation scientists to evaluate the sites soils and vegetation prior to construction to establish a reclamation plan; Site specific reclamation plans will increase reveg success and in some cases save money on costly operations that are not needed (i.e.. compost)
Identify clear objectives with benchmarks	x				x	Ensure there are objectives with performance metrics to manage revegetation; Ability to measure success or provide adaptive management for corrective actions
Companion crop seeding	x				x	Determine if companion crops help or hinder seed establishment; reduce expensive straw mulch and erosion (9,12)
Equipment Calibration Inspection	x				x	Ensures the proper application of amendment, seed, mulch etc. This is needed to make sure existing specifications will be effective. This goes for any future specs as well.
Document revegetation progress and projects via GIS	x				x	Inspectors and maintenance crews inspecting and cataloging a project. GIS can map and create logs of reveg diaries.
Seed harvesting by botanist for native planting in project area	x				x	Collect native seed from local reference area
Inventory project site for native plants, shrubs and trees for replanting	x			x		Identify plant native species specific to project area. Use inventory to establish seed mixes. Identify native, local plants that fit the region ecology and stabilize soils; shown successful in oil and gas applications (16)

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Obtain initial site/soil conditions (see soil testing)	x			x		Evaluate soil types, chemistry, existing vegetation, solar exposure, slope, precipitation, and other limiting factors (deicing); Provides more data to select the correct native seed species along with necessary soil augmentation elements (1, 6, 11)
Salvage topsoil	x			x		Provides native soils from project area; Salvage topsoil prior to construction Topsoil salvage has shown to increase reclamation results in the mining industry and is a BMP for most industries. Topsoil is a BMP and likely does not need further testing.
Evaluate Site specific amendment rates	x			x		Base reclamation plan on site specific conditions; Improved conditions for reclamation
Application of amendments based upon soil chemistry	x			x		If amendments are being applied make sure they are being applied in the most effective manner (topical or incorporated); Increased effectiveness of costly amendments; Take advantage of amendments that are currently being used
Evaluate use of organic fertilizers	x			x		There is a cost benefit to using amendments in some situations if applied properly. This would be a great test plot at a BMP or maintenance facility. Are organic fertilizers working and at what rates are they effective? Are they all created equal?
Use stockpiled soils	x			x		Mostly flat areas; stockpiled top soil to depth of 6 inches and tacked with heavy equipment; native seed mix from local reference site; Use stockpiled soils with organic matter to promote revegetation; reduce import costs and noxious weed introduction (1)
Use of cover crops in off season seeding	x			x		Utilize cover crops to stabilize site and then interseed into stubble in following years
Topographical planting along roadway	x			x		Change seed mix based on distance from road and soil moisture regime; Likely not feasible due to increase cost and time. May speed reclamation and save money if done properly; Improve reclamation success due to better plant selection (17)
Organic Amendment applications (Compost and BioChar)	x			x		Add organic material to reestablish soil characteristics, microbial activity, soil moisture characteristics and aggregate stability; Increased seedling establishment; Up and coming research has a sustainability aspect (10, 11, 13, 14)
Soil Pitting/Micro Pocketing on Steep Slopes	x			x		Creating micro environments to hold water and shade seedlings to increase revegetation success; Increased success in some challenging sites; Increased success in some challenging sites.
Supplemental Watering	x				x	Addition of watering in contracts to help establish cover quickly. Utilize temp irrigation to increase reveg. Success and decrease amount of time needed for 70% establishment; Increased up front cost with quicker permit release. Would need to look at ROI. This could be practical on some sites and impractical on others; This would be an effective but expensive way to quickly establish cover. Temp irrigation can range between \$.06 a sf to \$.30 a sf based on location.
Mycorrhizae Inoculation	x			x		Inoculate soil with mycorrhizae; Increased reclamation success for plants that are susceptible to mycorrhizae invasion; Has shown good results in many studies (8,11)

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Weed Free Straw Specifications	X			X		Ensure all weed free straw meets minimum requirements for use. Wheat straw with sufficient length to crimp is becoming difficult to find due to the advent and use of rotary combines. Need to make sure all straw length is a minimum of 6 inches; Increase reclamation success and stabilization; It is known that straw less than 6 inches in length can be difficult to adequately crimp.
Blown in place compost over rip-rap	X			X		Used for steep slopes; compost can be made up of recycled organics containing beneficial bacterial and mycorrhizal fungi, and binding agent; mixed with native seed, tackifier use
Rock mulch	X			X		Promote short and long term stabilization especially on steep slopes On steep slopes, 4-6 inch diameter rocks spread over the entire slope; depth of rock was 12 inches; hydro seed mixture of woody shrubs; 30#/acre; annual grasses at 8#/acre; bonded fiber matrix sprayed to secure seeds. Perennial grasses suggested. Flush slope with water to fill voids with applied dirt/compost
Polyacrylamide Polymer (PAM) for stabilization	X			X		Help aggregate soil and stabilize site until vegetation can be established. Add PAM to other soil amendments to increase site stabilization

References:

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- 2- United State Department of Agriculture. 1979. User Guide to Soils. Mining and Reclamation in the West General Technical Report INT-68. Ogden Utah,
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- 7- Norton and Storm. 2011 Successful restoration of severely disturbed lands: Identify suitable soil for salvage prior to disturbance
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