APPENDIX J

RESTORATION TECHNIQUES APPLICABLE TO THE NOSE CREEK WATERSHED
Restoration Techniques in Aquatic and Riparian Habitats

Cows and Fish (2001) identified the need and potential to recover shrub communities, particularly the dominant sandbar willow community, for livestock forage, shelter and flood protection along Nose Creek and West Nose Creek. In West Nose Creek, there were many tree and shrub communities that indicate the potential for restoring these communities. The goal would be to achieve this healthy condition in those sites that do not have tree and shrub communities or have them in lesser numbers and poorer health.

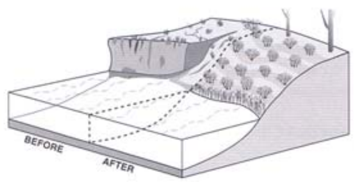
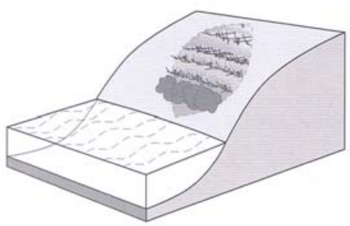
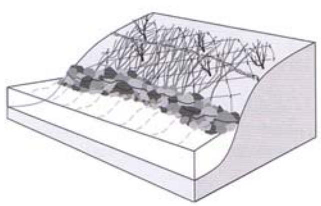
Tree and shrub communities along Nose Creek and West Nose Creek can be improved. The level of browse utilization of trees and shrubs is fairly heavy in both Creeks. Within West Nose Creek, continued moderate to heavy utilization of preferred trees and shrub could pose long-term reproduction problems. Within Nose Creek, sustained long-term browse utilization has removed many shrub communities and it is unknown to what extent these shrubs could be recovered. Increasing rest periods from grazing during the growing season can improve regeneration and improve future reproduction and establishment. Livestock management options, BMPs, such as distribution, timing and rotation should enable preferred trees and shrubs to be maintained and increased. Not addressing browsing pressure could reduce existing tree and shrub communities and increase lesser palatable species (e.g. snowberry and rose).

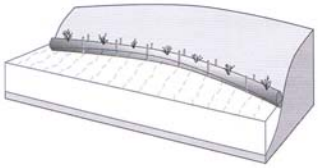
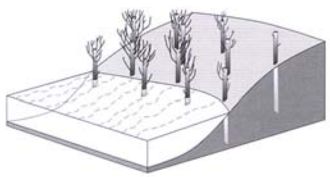
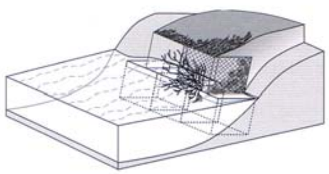
Where natural flows have been altered due to stormwater inputs from urban and country-residential developments, bioengineering may be required to stabilize streambanks. River, creek and stream shorelines are constantly changing due to stream flow (velocity and volume) and wave action interacting with substrate and vegetation. Although erosion is a natural process, forming undercut banks and important habitat areas for many aquatic species, changes to natural flow characteristics and degradation of riparian areas can increase erosion beyond the systems natural ability to restore balance (Polster Environmental Services Ltd. 2003).

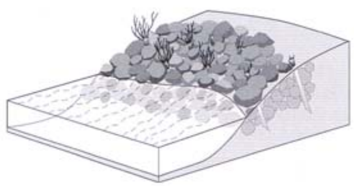
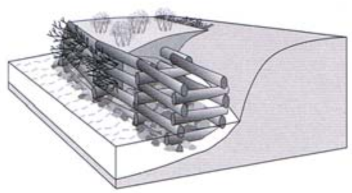
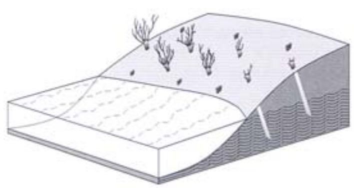
There are many conventional ways to prevent erosion, including rip-rap, gabion baskets and cast concrete, but these solutions do not provide ancillary benefits beyond those of erosion control. Bioengineering uses a combination of biological and engineering principles. There are two types of bioengineering practices that can be considered, which are biotechnical systems and soil bioengineering systems. Biotechnical systems use living materials along with non-living structural elements for stabilization. Soil bioengineering systems use lining plant materials to create the structures that stabilize the eroded area (Polster Environmental Services Ltd. 2003). Bioengineered systems provide cover, shade and food sources for aquatic life, improving the habitat quality of the river system.

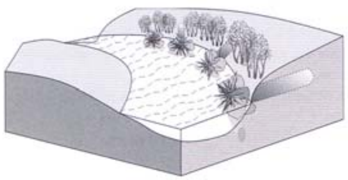
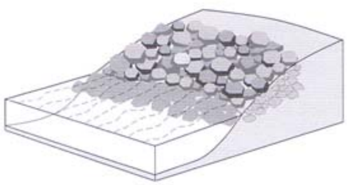
Where possible, bioengineering options should be employed in the Nose Creek watershed to restore streambanks and reduce/prevent further occurrence of erosion. Table D1 summarizes some soil bioengineering and bioengineering techniques.

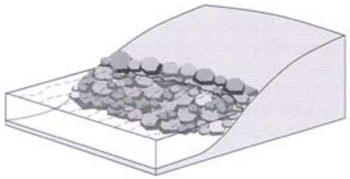
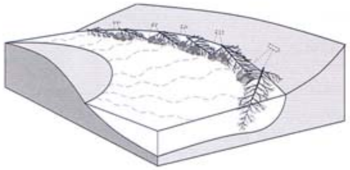
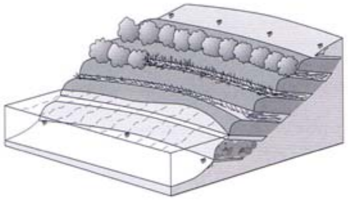
Table D1. Bioengineering techniques for stabilizing and restoring eroded streambanks. Source: The Federal Interagency Stream Restoration Working Group, 1998.

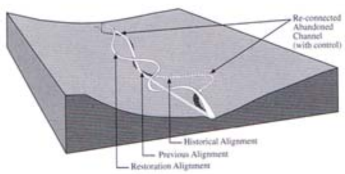
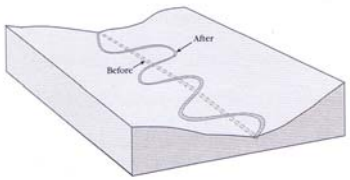
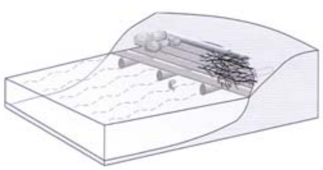
Streambank Treatment	**Description**	**Applications and Effectiveness**
Bank Shaping and Planting  	Regrading streambanks to a stable slope, placing topsoil and other materials needed for sustaining plant growth, and selecting, installing and establishing appropriate plant species.	• Where moderate erosion and channel migration are anticipated. • Reinforcement at the toe is often needed. • Use with other protective practices where flow velocities exceed the tolerance range for available plants, and where erosion occurs below base flows. • Streambank soil materials, probable groundwater fluctuation, and bank loading conditions are factors for determining appropriate slope conditions. Slope stability analyses are recommended.
Branch Packing 	Alternate layers of live branches and compacted backfill which stabilize and revegetate slumps and holes in streambanks.	• Where patches of streambank have been scoured out or have slumped leaving a void. • Appropriate after stresses causing the slump have been removed. • Produces a filter barrier that prevents erosion and scouring from streambank and or overbank flows. • Rapidly establishes a vegetated streambank and provides immediate soil reinforcement • Not effective in slump areas greater than four feet deep or four feet wide.
Brush Mattresses 	Combination of live stakes, live facines, and branch cuttings installed to cover and physically protect streambanks; eventually to sprout and establish numerous individual plants.	• Where exposed streambanks are threatened by high flows prior to vegetation establishment. • Form an immediate protective cover over the streambank, capture sediment during flood flows, provide opportunity for rooting of the cuttings over the streambank, rapidly restores riparian vegetation and habitat • Limited to the slope above base flow levels and toe protection is required where toe scour is anticipated. • Not to be used on slopes experiencing mass movement or other slope instability.

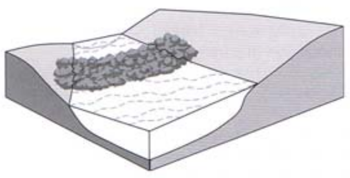
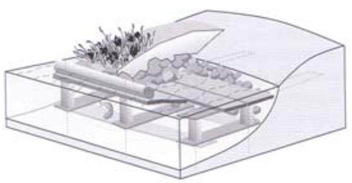
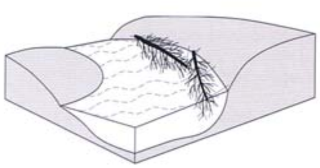
Streambank Treatment	Description	Applications and Effectiveness
Coconut Fibre Role 	Cylindrical structures composed of coconut husk fibres bound together with twine woven from coconut material to protect slopes from erosion while trapping sediment which encourages plant growth within the fibre roll.	• Where moderate toe stabilization is required in conjunction with restoration of the streambank and the sensitivity of the site allows for only minor disturbance. • Not appropriate for sites with high velocity flows or large ice build up • Staked near the toe of the streambank with dormant cuttings and rooted plants inserted into slits cut into the rolls. • Provides excellent medium for promoting plant growth at the water's edge.
Dormant Post Plantings 	Plantings of cottonwood, willow, poplar, or other species embedded vertically into streambanks to increase channel roughness, reduce flow velocities near the slope face, and trap sediment.	• Used as live pilings to stabilize rotational failures on streambanks where minor bank sloughing is occurring. • Best suited to non-gravely streams where ice damage is not a problem. • Will reduce near bank stream velocities and cause sediment deposition and reduce erosion
Vegetated Gabions 	Wire-mesh, rectangular baskets filled with small to medium size rock and soil and laced together to form a structural toe or sidewall. Live branch cuttings are placed on each consecutive layer between the rock filled baskets to take root, consolidate the structure, and bind it to the slope.	• Used to protect steep slopes where scouring or undercutting is occurring or there are heavy loading conditions. • Useful when design requires rock size greater than what is locally available. • Effective where bank slope is steep and requires moderate structural support. • Appropriate at the base of a slope where a low toe wall is needed to stabilize the slope and reduce slope steepness. • Appropriate where channel side slopes must be steeper than appropriate for riprap or other material, or where channel toe protection is needed, but rock riprap of the desired size is not readily available. • Will not resist large, lateral earth stresses, and is not appropriate in heavy bedload streams or those with severe ice action because of serious abrasion damage potential. • Requires a stable foundation.

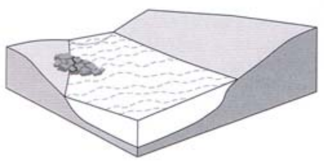
Streambank Treatment	Description	Applications and Effectiveness
Joint Plantings 	Live stakes tamped into joints or openings between rock which have previously been installed on a slope or while rock is being placed on the slope face.	• Appropriate where there is a lack of desired vegetative cover on the face of existing or required rock riprap. • Root systems provide a mat upon which the rock riprap rests and prevents loss of fines from the underlying soil base. • Root systems improve drainage in the soil base. • Have few limitations and can be installed from base flow levels to top of slope, if live stakes are installed to reach ground water. • Survival rates can be low due to damage to the cambium or lack of soil/stake interface, and thick rock riprap layers may require special tools for establishing pilot holes.
Live Cribwalls 	Hollow, box-like interlocking arrangements of untreated log or timber members filled above baseflow with alternate layers of soil material and live branch cuttings that root and gradually take over the structural functions of the wood members.	• Provides protection to streambank in areas with near vertical banks where bank sloping is an option. • Effective on outside bends of streams where high velocities are present. • Appropriate at the base of a slope where a low wall might be required to stabilize the toe and reduce slope steepness. • Appropriate above and below water level where stable streambeds exist. • Afford a natural appearance, immediate protection and accelerate the establishment of woody species. • Don't adjust to toe scour.
Live Stakes 	Live, woody cuttings which are tamped into the soil to root, grow and create a living root mat that stabilizes the soil by reinforcing and binding soil particles together, and by extracting excess soil moisture.	• Effective where site conditions are uncomplicated, construction time is limited, and an inexpensive method is needed. • Appropriate for repair of small earth slips and slumps that are frequently wet. • Can be used to stake down surface erosion control materials. • Requires toe protection where toe scour is anticipated.

Streambank Treatment	Description	Applications and Effectiveness
Live Fascines 	Dormant branch cuttings bound together into long sausage-like, cylindrical bundles and placed in shallow trenches on slopes to reduce erosion and shallow sliding.	• Effective stabilization technique for streambanks requiring a minimum amount of site disturbance. • Not appropriate for treatment of slopes undergoing mass movement. • Can trap and hold soil on streambank by creating small dam-like structures and reducing the slope length into a series of shorter slopes. • Facilitate drainage when installed at an angle on the slope. • Requires toe protection where toe scour is anticipated.
Log, Rootwad, and Boulder Revetments 	Boulders and logs with root masses attached placed in and on streambanks to prevent streambank erosion, trap sediment, and improve habitat diversity.	• Suited to streams where fish habitat deficiencies exist. • Use of native materials can sequester sediment and woody debris, restore streambanks in high velocity streams, and improve fish rearing and spawning habitat. • Will tolerate high boundary of shear stress if logs and rootwads are well anchored. • Site must be accessible to heavy equipment. • Can create local scour and erosion.
Riprap 	A blanket of appropriately sized stones extending from the toe of slope to a height needed for long term durability.	• Appropriate where long term durability is needed, design discharge are high, there is significant threat to life or high value property, or there is no practical way to otherwise incorporate vegetation into the design. • Can be vegetated (see joint plantings). • Flexible and not impaired by slight movement or settlement or other adjustments. • Should not be placed to an elevation above which vegetative or soil bioengineering systems are an appropriate alternative.

Streambank Treatment	Description	Applications and Effectiveness
Stone Toe Protection 	A ridge of quarried rock or stream cobble placed at the toe of the streambank as an armor to deflect flow from the bank, stabilize the slope and promote sediment deposition.	• Used where streambanks are being undermined by toe scour, and where vegetation cannot be used. • Stone prevents removal of failed streambank material that collects at the toe, allows revegetation and stabilizes the streambank. • Can be placed with minimal disturbance to existing slope, habitat, and vegetation.
Tree Revetments 	A row of interconnected trees attached to the toe of the streambank to reduce flow velocities along eroding streambanks, trap sediment, and provide a substrate for plant establishment and erosion control.	• Best on streambank heights under 12 feet and bankfull velocities under 6 feet per second. • Limited life and must be replaced periodically, might be severely damaged by ice flows. • Not appropriate for installation directly upstream of bridges and other channel constrictions because of the potential downstream damages should the revetment dislodge. • Should not be used if they occupy more than 15% of the channel's cross sectional area at bankfull level. • Wire anchoring systems can present safety hazards.
Vegetated Geogrids 	Alternating layers of live branch cuttings and compacted soil with natural or synthetic geotextile material wrapped around each soil lift to rebuild and vegetate eroded streambanks.	• Can be installed on steeper and higher slope and has a higher initial tolerance of flow velocity than brush layering. • Produce a newly constructed, well-reinforced streambank. • Useful in restoring outside bends where erosion is a problem. • Slope stability analyses recommended. • Requires a stable foundation.

Channel Reconstruction	Description	Applications and Effectiveness
Maintenance of Hydraulic Connections 	Maintenance of hydraulic connectivity to allow movement of water and biota between the stream and abandoned channel reaches.	• Used to prevent losses of aquatic habitat area and diversity. • Slack water areas adjoining the main channel have potential for spawning and rearing areas for many fish species and are a key component of habitat for wildlife species that live in or migrate through the riparian corridor. • Effective along reaches of realigned channel where cutoffs have been made. • Not effective in streams with insufficient stages or discharges to maintain satisfactory hydraulic connections to the abandoned channel reaches. • May require maintenance if sedimentation is a problem. • Requires high level of analysis.
Stream Meander Restoration 	Transformation of a straightened stream into a meandering one to reintroduce natural dynamics, improve channel stability, habitat quality, aesthetics, and other stream corridor functions or values.	• Used to create a more stable stream with more habitat diversity. • Requires adequate area where adjacent land uses may constrain locations. • May not be feasible in watersheds experiencing rapid changes in land use. • Streambank protection may be required on the outside bends. • Significant risk of failure and requires high level of analysis. • May cause significant increases in flood elevations. • Effective discharge should be computed for both existing and future conditions, particularly in urbanized watersheds.
Instream Practices		
Log/Brush/Rock Shelters 	Logs, brush, and rock structures installed in the lower portion of streambanks to enhance fish habitat, encourage food web dynamics, prevent streambank erosion, and provide shading.	• Most effective in low gradient stream bends and meanders where open pools are already present and overhead cover is needed. • Create an environment for insects and other organisms to provide and additional food source. • Can be constructed from readily available materials found near the site. • Not appropriate for unstable streams which are experiencing severe bank erosion and/or bed degradation unless integrated with other stabilization measures. • Important in streams where habitat deficiencies exist. • Not generally as effective on the inside of bendways.

Instream Practices	Description	Applications and Effectiveness
Grade Control Measures 	Rock, wood, earth, and other material structures placed across the channel and anchored in the streambanks to provide a “hard point” in the streambed that resists the erosion forces of the degradational zone, and/or to reduce the upstream energy slope to prevent bed scour.	• If a stable channel bed is essential to the design, grade control should be considered as a first step before any restoration measures are implemented. • Used to build bed of incised stream to higher elevation. • Can improve bank stability in an incised channel by reducing bank heights. • Man-made scour holes downstream of structures can provide improved aquatic habitat. • Upstream pool areas created by structures provide increased low water depths for aquatic habitat. • Potential to become low flow migration barrier, but can be designed to allow for fish passage. • Upstream sediment deposition may cause increased meandering tendencies. • Siting of structures is a critical component of design process, including soil mechanics and geotechnical engineering. • Design of grade control structures should be accomplished by an experienced river engineer.
Lunker Structures 	Cells constructed of heavy wooden planks and blocks which are imbedded into the toe of streambanks at channel bed level to provide covered compartments for fish shelter, habitat, and prevention of streambank erosion.	• Appropriate along outside bends of streams where water depths can be maintained at or above the top of the structure. • Suited to streams where fish habitat deficiencies exist. • Are often used in conjunction with wing deflectors and weirs to direct and manipulate flows. • Are not recommended for streams with heavy bed material loads. • Most commonly used in streams with gravel-cobble beds. • Heavy equipment may be necessary for excavating and installing the materials.
Tree Cover 	Felled trees placed along the streambank to provide overhead cover, aquatic organism substrate and habitat, stream current deflection, scouring, deposition, and drift catchment.	• Particularly advantageous in streams where the bed is unstable and felled trees can be secured from the top of bank. • Channels must be large enough to accommodate trees without threatening bank erosion and limiting needed channel flow capacity. • Not recommended if debris jams on downstream bridges might cause subsequent problems. • Require frequent maintenance.

Instream Practices	Description	Applications and Effectiveness
Wing Deflectors 	Structures that protrude from either streambank but do not extend entirely across a channel. They deflect flows away from the bank, and scour pools by constricting the channel and accelerating flow.	• Should be used in channels with low physical habitat diversity, particularly those with a lack of stable pool habitat. • Deflectors placed in sand bed streams may settle or fail due to erosion of sand, and in these areas a filter layer or geotextile might be needed under the deflector. • Should be designed and located far enough downstream of riffle areas to avoid backwater effects that would drown out or otherwise damage the riffle • Should be sized based on anticipated scour. • The material washed out of scour holes is usually deposited a short distance downstream to form a bar or riffle. These areas of deposition are often composed of clean gravels that provide excellent habitat for certain species. • Can be installed in series on alternative streambanks to produce a meandering thalweg and associated structural diversity.