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GLOF II
PAKISTAN
SCALING-UP OF GLACIAL LAKE OUTBURST FLOOD RISK REDUCTION IN NORTHERN PAKISTAN

PMCC
PREMIER MOUNTAIN COMMUNITIES CONSULTANTS

PLANNING AND DESIGNING CLIMATE-RESILIENT INFRASTRUCTURE THROUGH BIOENGINEERING WORKS IN SELECTED VALLEYS UNDER GLOF-II PROJECT IN GILGIT-BALTISTAN

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Conducted under UNDP GLOF-II Project

FOREST, PARKS & WILDLIFE DEPARTMENT
GOVERNMENT OF GILGIT BALTISTAN

PMCC
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Gilgit-Baltistan Forest Department

Authority/Disclaimer:

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Cover photo: GLOF-II Project Site Arindu Valley District Shigar, Gilgit Baltistan

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Acronyms and Abbreviations

ADP	Annual Development Plan
ALF	Agriculture Livestock and Forestry
CEO	Chief Executive Officer
DoF	Department of Forest
FGD	Focus Group Discussion
GLOF	Glacier Lakes Outburst Floods
HHs	Households
KIIs	Key Informant Interviews
LEK	Local Ecological Knowledge
NGOs	No for Profit Organizations
NTFP	Non Timber Forest Products
PES	Payment for Eco system Services
PMCC	Premier Mountain Communities Consultants

Study Team

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We are also thankful and acknowledge the following team members who have walked from river bed to top of mountains in disaster prone environment and in freezing cold temperature. The team included; Mr. Altaf Hussain Bio-engineering Specialist, Mr. Masood Ahmed Mir Social Development Expert, Mr. Kamal Uddin Geologist, Mr. Jamil Hussain Surveyor and Designer. Mr. Muhammadi Sherazi Civil Engineer, Miss Rashida and Mrs. Shehnaz Rani Baig from administration who visited to field sites and provided information, reports, drawing designs; and the drivers, who worked hard to transport us safely to challenging locations in the region during rains even.

This assignment was one of most challenging assignments we have done so far and there was a great learning and exposure to new dynamics of Bioengineering. We, once again thankful to all whose names are mentioned here, and also those who are not mentioned here, we owe to all who made this assignment possible.

Shahid Hussain

Director PMCC Gilgit Baltistan

Gilgit, 2021

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Chapter One

Introduction

1. Background of the Study

Government of Gilgit-Baltistan through Forest, Parks and Wildlife Department has hired the services of PMCC as Consultancy Company after a competitive bidding process for "planning and designing climate-resilient infrastructure through bio-engineering works" in 16 selected valleys under UNDP-GLOF-II project of Gilgit-Baltistan. The project is funded by GCF under project titled 'Scaling-up of GLOF risk reduction in Northern Pakistan (GLOF-II)". PMCC has signed a contract agreement with Chief Conservator Department of forest parks and wildlife to assess sites for identification of stability and erosion issues of each site carefully and study the slopes and stream banks of selected valleys and recommend the practical bio-engineering technique for effective and sustainable slope and stream bank protection and stabilization.

PMCC has accepted the need for coherent understanding and application of slope stability analysis for climate resilient infrastructure in every GLOF_II site in Gilgit Baltistan. This document provides general background information of the selected sites, common stability and erosion issues, and proposing climate-resilient bio-engineering techniques for vulnerable sites. PMCC has prepared this document to provide detailed drawing and specifications of selected bio-engineering techniques to protect and increase the resilience of slopes and stream banks against surface erosion and shallow failure for each site.

There are different bio-engineering techniques recommended for each and every site according to physical topography, slope vulnerability, stream bank phenomenon, weather patterns, and elevation of the slope. It is to provide designs implementation methods types of vegetation and material that can be used during the physical construction and implementation of the project activities related to slope and stream bank stabilization, sustainable bioengineering infrastructure development. A team of dedicated consultants of PMCC has studied each and every project site and presents its recommendations in dedicated sections and chapters for every district and sites.

1.1. OVERALL OBJECTIVES:

There are two main purposes for the use of bio-engineering on slopes and stream banks are:

- ***Protection*** of surfaces against erosion and shallow land sliding under normal conditions.
- ***Resilience*** against damage by exceptional GLOF, rainstorms, floods or other climatic events, either now or in the future.

Therefore the aim of the consultancy is to provide technical inputs to assist the department of forest, parks and wild life to identify and present prevailing issues such as slope failure, and stream bank erosion in 16 GLOFF sites of Gilgit Baltistan. Furthermore, the extended aim is to recommend well-developed, cost-effective bioengineering techniques to counter these issues by proposing bioengineering techniques to increase their resilience. Although the report's guidance is aimed primarily for selected sites' infrastructure, but these techniques may be tailored for use in other slope protection environments in Gilgit Baltistan with base study and detail assessment of the sites to develop resilient and sustainable infrastructure.

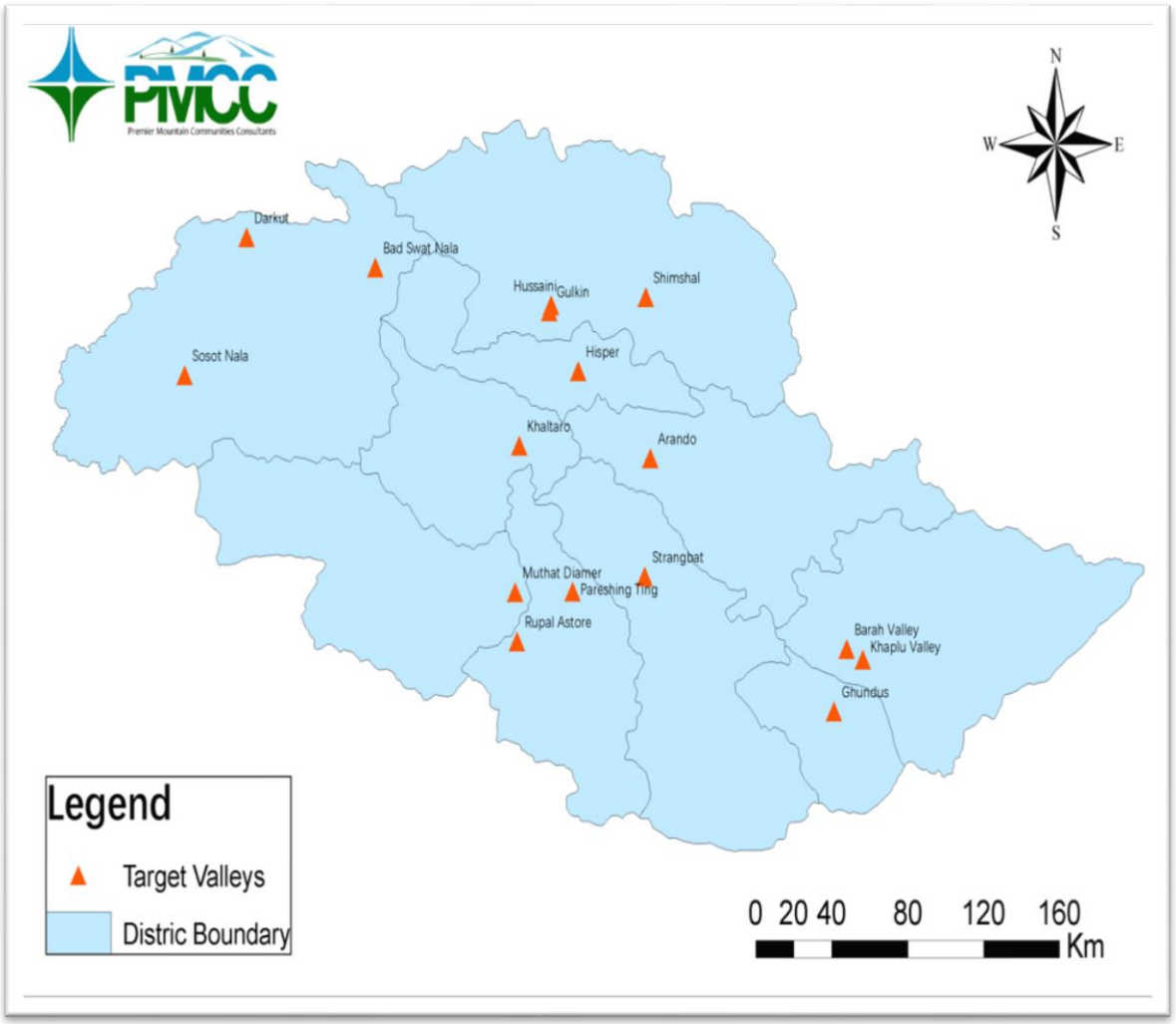
These low cost bioengineering techniques presented in this report are generally appropriate for immediate protection of both cut and fill slopes and stream banks against surface erosion and shallow mass movement of the GLOF-II selected sites in Gilgit Baltistan but in the longer term, they increase the resilience of the sites to withstand current and future extreme climatic events.

1.2. Specific Objectives

1. To study the GLOF-II selected site, potential of GLOF hazards and physical environment and terrain conditions in all selected valleys for initiating/implementing bio-engineering works.
2. To analyze the socio-economic and socio-cultural practices in the valleys in order to propose the most feasible and socially acceptable means of bio-engineering works to ensure adaptability and sustainability.
3. To select and recommend the most suitable and cost effective bioengineering works/designs, methods and measures at valley basis for all selected valleys.

1.3. Study Sites

This document includes the maps and specifications for bioengineering techniques that were recommended for 16 GLOF-II project sites in ten districts of Gilgit Baltistan namely: **Khaltaro** Hiramosh in District Gilgit, **Hassanabad, Gulkin/Husaini**, and **Shimshal** in District Hunza, **Hisper** in District Nagar, **Rupal Tareshing** and **Pareshing** in Astore district, **Darkut, Badsuwat**, and **Sosat** in Ghizer district, **Muthat** valley in Diamer District, **Satrungbat** in Skardu, **Barrah and Khapulo** Nallah in Ghanche District, and **Ghundus** Nullah in Kharmang District and **Arindu** in Shigar District that shown in Figure 1.1.



2: Introduction of UNDP GLOF-II project

Project brief published on website of the UNDP GLOF-II Project mentioned about that due to rising temperatures, glaciers in Pakistan's northern mountain ranges (the Hindu Kush, Himalayas and Karakorum) are melting rapidly and a total of 3,044 glacial lakes have developed in Gilgit-Baltistan (GB) and Khyber Pakhtunkhwa (KP). Of these, 33 glacial lakes have been assessed to be prone to hazardous glacial lake outburst flooding (GLOF). GLOF are sudden events which can release millions of cubic meters of water and debris, leading to the loss of lives, property and livelihoods amongst remote and impoverished mountain communities. Over 7.1 million people in GB and KP are vulnerable; in these areas, 26.7 percent and 22 percent of the population, respectively, are below the poverty line.

Figure 1 GLOF Site Darkut, District Ghizer, Lake with Glacier

The Scaling-up of GLOF risk reduction in Northern Pakistan (GLOF-II) project is a continuation of the four-year 'Reducing Risks and Vulnerabilities from GLOF in Northern Pakistan' (GLOF-I) project. GLOF-I helped vulnerable communities prepare for and mitigate GLOF risks through early warning systems, enhanced infrastructure and community-based disaster risk management.

2.1. Objectives of GLOF-II Project

GLOF-II builds on the measures piloted by GLOF-I and aims to empower communities to identify and manage risks associated with GLOFs and related impacts of climate change, strengthen public services to lower the risk of disasters related to GLOF, and improve community preparedness and disaster response. The project will also support the development of sustainable options for livelihoods in project areas, with a particular focus on the participation of women in ensuring food security and livelihoods.

Figure 2: GLOF event has destructed the Darkut valley

2.2. Expected results of GLOF-II Project

GLOF-II will scale up GLOF-I from its original two districts (one each in KP and GB) to cover 10 districts, benefiting 29 million people or 15 percent of the population of Pakistan. Expected results by the end of the project are

- At least two policies reviewed and/or revised to address or incorporate GLOF risk reduction.
- In target communities, 95 percent of households able to receive and respond to early warnings and take the appropriate action.

- At least 250 small-scale engineering structures established to reduce the effects of GLOF events on livelihoods, such as tree plantation, controlled drainage and mini dams.
- Fifty weather monitoring stations to collect meteorological data in catchment areas; 408 river discharge sensors to collect river flood data. This data will inform hydrological modeling and help develop village hazard watch groups.
- To improve food security and reduce flood risks due to deforestation and inefficient water use, 65,000 women will be trained in home gardening, 240 water-efficient farming technologies will be installed and 35,000 hectares of land will be reforested

3. Technical Descriptions of the Assignment

3.1. Bioengineering

Bioengineering provides a number of stabilization methods to solve the stabilization problems and making vulnerable slopes more resilient for both current and possible future climatic challenges. Slope stability problems have been faced throughout history when human or nature has disrupted the delicate balance of natural soil slopes. Slope stabilization through bioengineering method involves specially construction techniques that must be understood and modeled in realistic way. There are several ways in which this can be done, but the common theme is that any bare soil surface must be treated with bioengineering techniques. Bioengineering techniques are very affordable within the overall scope of infrastructure project budgets.

Figure 3: Bioengineering in Bhar Valley Nagar for Slope stabilization (PMCC, 2019)

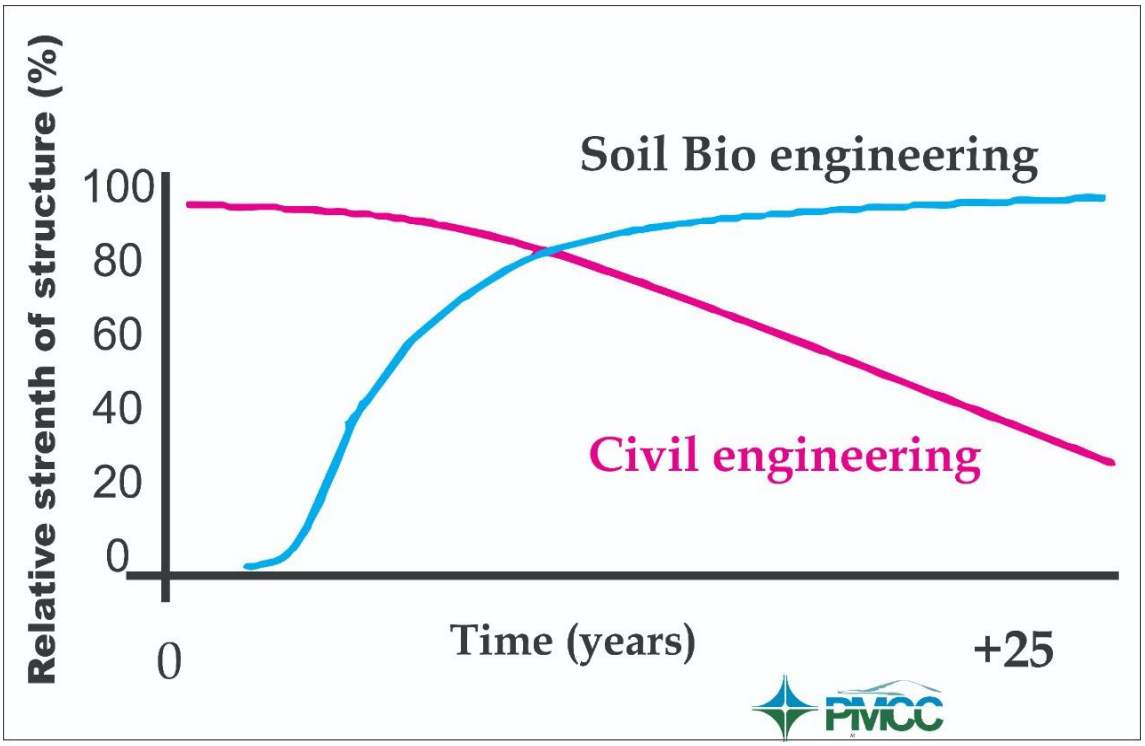
Beyond small areas, the only way to protect slope surfaces from erosion is through the use of vegetation. In most cases, plants will gradually colonize bare surfaces, and eventually a full cover of vegetation will be achieved. One of the purposes of bioengineering is to engineer the vegetation so that it is as strong as possible. To do this usually requires more than one technique to be used. That is why it is important to assess each site carefully and to implement a range of measures. To do this usually requires more than one technique to be used. That is why it is important to assess each site carefully and to implement a range of measures. An example might be for an embankment to have a cover of planted grass to armour the surface against erosion, and also to have live poles inserted, from which will come strong, woody roots that reinforce the soil and increase its resistance to shear. What this means is that the incorporation of vegetation in engineering – bioengineering is not just good in protecting stream banks from current climatic problems like heavy rainfall, but also important to make them more resilient against greater extremes of rainfall, drought or flood.

The use of vegetation for slope stabilization and erosion control can be referred to as bioengineering. Bioengineering and biotechnical engineering are terms which are commonly found in the literature, but there is much confusion as to their precise definitions. In this report, **bioengineering** refers to the use of any form of vegetation, whether a single plant or a collection of plants, as an engineering material (i.e. one that has quantifiable characteristics and behavior). **Biotechnical engineering** refers to techniques where vegetation is combined with inert structures such as crib walls, so combining the structural benefits of both the vegetative and non-vegetative components of the scheme. We, in this study focus on bioengineering and recommend bioengineering techniques as per ToR of the assignment for slope and embankment stabilization.

3.2. Rationale for Bioengineering:

Traditional civil engineering techniques (‘grey solutions’, such as concreting of welded wire walls for slope stabilization) may not be sustainable in the long term due to high initial capital expenditure and (more importantly) increasing maintenance requirements over time. Carefully selected and implemented bioengineering techniques are bound to be more sustainable over time as vegetation is self-regenerating and able to respond dynamically and naturally to changing site conditions, ideally without compromising or losing the engineering properties of that selected vegetation. Indeed, there are examples where a grey solution to a landscaping problem has been wholly replaced with a more natural, environmentally sensitive vegetative approach. Schürholz (1992) outlines a

scheme for river channelization using vegetation and natural geotextiles, which were shown to have significant advantages hydraulically, aesthetically and financially compared with the original, concrete-based channelization scheme.



The Diagram shows that over time conventional engineering loose its strengths and increasing maintenance requirements. While carefully selected and implemented bioengineering techniques are bound to be more sustainable over time as vegetation is self-regenerating and able to respond dynamically and naturally to changing site conditions, ideally without compromising or losing the engineering properties of that selected vegetation. Moreover, bioengineering requires no any maintenance requirements in shape of budget and efforts over the time period.

3.3. Climate Resilient Infrastructure

Climate change is a global issue and constantly occurred at different time scales, severity and probable in future is to be a rising characteristic of global environmental conditions. Though the nature of enhanced climate change is very difficult to determine, there is enough evidence that the variability of weather patterns is changing. Even without that, much of human life is already sometimes affected by climatic-induced events

(rainstorms, floods, GLOF Events, etc.) of exceptional severity, and at levels occasionally experienced historically.

Figure 4: A Vegetated Slope in Pareshing Astore

It is obvious that, even if future climate changes are not significantly more severe, the future management of infrastructure will benefit from greater in-built resilience to the kind of events already seen. If that can be achieved in a cost-effective way, then the benefits will be greater.

Bioengineering offers a number of opportunities to make infrastructure more resilient for both current and possible future climatic extremes. There are several ways in which this can be done, but the common theme is that any bare soil surface must be treated with bioengineering techniques. As this study report shows, these are very affordable within the overall scope of infrastructure project budgets. Beyond small areas, the only way to protect slope surfaces from erosion is through the use of vegetation. In most cases, plants will gradually colonize bare surfaces, and eventually a full cover of vegetation will be achieved. Left to itself, this vegetation will be random. One of the purposes of bioengineering is to engineer the vegetation so that it is as strong as possible to protect infrastructure and properties of the target communities of GLOF-II sites.

This document provides the detailed technical designs of selected bioengineering and associated engineering options used to protect and increase the resilience of stream side

slopes and stream banks against surface erosion and shallow failure in high altitude mountain slopes in Gilgit-Baltistan in general and for GLOF-II selected valleys in particular.

3.4. Methodology of Study

3.4.1. Decision-Making Process for Slope and Embankment

Slope stabilization need to start with understanding the nature of any actual or potential slope and embankment problems, its causes and most possible solutions. PMCC conducted initial site inspection to identify the slope problem. The local representatives of the communities have been consulted during initial site inspection to identify vulnerable slope sites.

Gilgit Baltistan is a mountainous region where there slopes and embankment issues are existed in every site. However, to build up a comprehension of the issue, slope inspection is conducted cautiously and systematically, to identify the basis for the next steps. Detail assessment and careful examination of each site is critical part of this study. The intention is to understand what processes are causing the problems that are making the site or slope unstable, and working out how they can be resolved most cost effectively.

Therefore, recognizing which bioengineering technique is suitable for each slope problem is imperative for applying this approach. Each slope problem requires one or more solutions to perform different functions. To select the best bioengineering technique, we assessed the site carefully and systematically in collaboration with the communities to get indigenous knowledge, native plants, and history of slope. Mostly the professionals of PMCC strongly recommend using local and native species of vegetation in bioengineering as they are already adapted to the growing conditions especially as the targets sites are situated at more than 2000 meters or higher than that. Local and native plants can be more resistant to local diseases, are more readily available, and are likely to

be available at lower cost options. However, most of the sites have different time for planting of these trees and vegetation as compare to the main cities and surrounding areas. Site specific recommendations will be discussed in relevant chapters.

3.4.2. Resource Allocation Process

Risk-based approach is used to determine the best way to allocate resources between different sites. We tried to get a deep, clear and common understanding of the risk exposure for the communities, lives, properties, infrastructure, and means of communication. Analyzed the data with communities to know about what is working and what is not to stabilize the slopes, stream banks and bioengineering infrastructure. Determining and allocating the resources to each site by setting the frequency and depth of the exposed slope, vulnerability of stream bank and erosion threat. When getting data from the community representatives we tried to counteract cognitive biases to underestimate or overestimate the particular type of slope erosion threat.

3.4.3. Costing Norms

To supporting the department and implementers of the recommended bioengineering techniques in estimating the labor and material requirements for constructing bioengineering infrastructure in different sites, the staff recorded in detail the labor and material inputs required to build at the sites. As GLOF sites mostly are at the highest and in far flung areas of Gilgit Baltistan.

These figures need to be treated with caution, for the following reasons.

- The findings are based only on current market situation, and we practically implemented no any technique on ground.
- For no activity was there as a sample to be implemented by the consultants.
- All the sites have different geographical characteristics
- All GLOF-II Project's sites are totally different in availability of material and skilled and semi-skilled labors.
- Site conditions vary considerably between locations, so that bids and costs are also likely to have varied between the sites.
- Contractors could be new to these activities, and so the bidding rates might not be particularly representative of the actual true costs.
- The GLOF-II Project's sites were individual locations in different valleys, and so there could be no economy of scale for the contractors' mobilization to cover a number of sites.
- We strongly recommend to implement the activities at district level through divisional forest offices for effective utilization of funds at GLOFF sites

It also gives the upper and lower limits that might be expected, giving relevant implementers of the department at least some guidance in calculating the inputs required. To support executing department's staff in estimating the labour requirements for constructing bioengineering techniques in different locations and GLOF-II Project's sites of different areas, the financial budgets are presented on sites to site basis which can be different from each other.

3.4.4. Selected Bio-engineering Options for Slope, Surface and Stream Bank Stabilization

Bioengineering offers a number of opportunities to make infrastructure more resilient for both current and possible future climatic extremes. There are several ways in which this can be done, but the common theme is that any bare soil surface must be treated with bioengineering techniques. As this document shows, these are very affordable within the overall scope of bioengineering infrastructure project budgets. Beyond small areas, the only way to protect slope surfaces from erosion is through the use of vegetation. In most cases, plants will gradually colonize bare surfaces, and eventually a full cover of vegetation will be achieved. To do this usually requires more than one technique to be

Recommended Bio-engineering Techniques for Stabilization of Slope and Stream Banks				
S. No	Option	Locations for use		
		Cut Slope	Slopes	Stream Bank
01	Large and local grass planting		√	√
02	Short cover grass planting		√	
03	Grass seed + mulch + mesh		√	
04	Brush layers	√		√
05	Palisades	√		√
06	Live fences	√		√
07	Fascines		√	
8	Live poles and truncheons	√		√
9	Shrub or tree planting	√	√	
10	Vegetated rip rap		√	
11	Vegetated gabions	√		√

used. That is why it is important to assess each site carefully and to implement a range of measures.

Because bioengineering structures are flexible, capable of absorbing movement, and capable of recovering from damage, they should be seen as part of sustainable asset and infrastructure management. The practice helps to ensure the long life of physical structures and reduces overall maintenance costs. Where a slope is subject to erosion or very shallow slope failure, vegetative methods of slope protection are appropriate. This involves the use of living plants or cuttings to reduce erosion and shallow-seated instability on slopes. In these applications, while there is an element of slope stabilization, the primary focus is on slope surface protection through strengthening. Plants and their roots armour the slope surface and reinforce the soil.

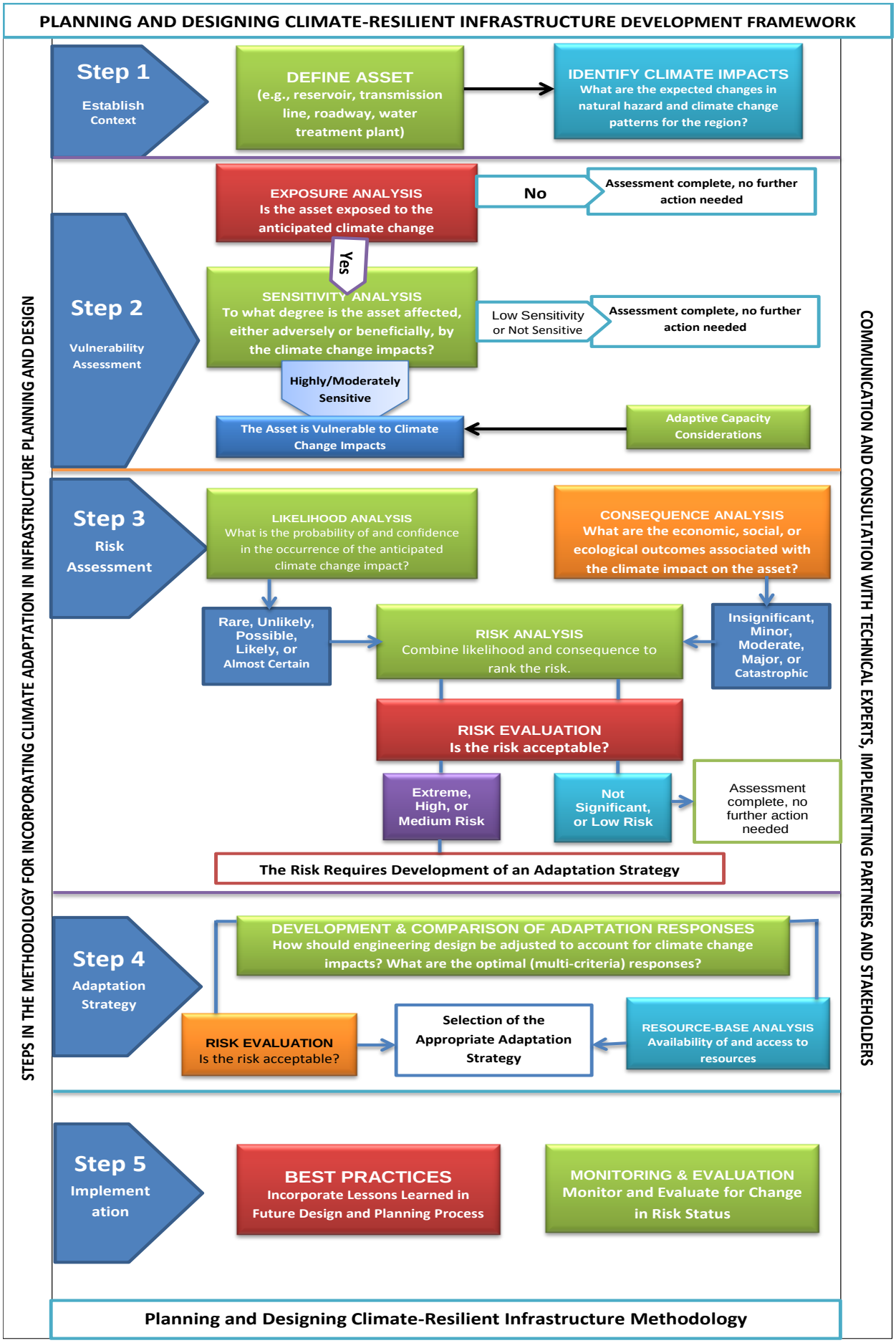
3.5. General Procedures, Planning and designing climate resilient infrastructure

Effective and sustainable slope protection, stabilization and embankment erosion control need to start with understanding the nature of any actual or potential slope and embankment problems and their causes. To identify and build up an understanding of the problem, slope, embankment inspection has been conducted carefully and systematically, to identify the basis for the next steps. Risk based approach has been used to determine the best way to allocate the resources according to site's vulnerability, availability of essential material for required techniques.

Taking an appropriate bioengineering technique depends on the slope or embankment conditions. Each issue of the site needs one or more solutions to perform different functions such as there could be one or more causes of the slope failure or embankment erosion.

For dry surface instability and slope slumping primarily we recommend diagonal lines for large grass planting and secondary technique crosswise palisades at wide spacing. While damp surface slumping and erosion, primarily downslope grass lines and vegetated stone pitched rills are recommended.

Common types of erosion and slope failure affecting hilly slopes, and surface erosion are listed in below table.


PLANNING AND DESIGNING CLIMATE-RESILIENT INFRASTRUCTURE DEVELOPMENT FRAMEWORK
STEPS IN THE METHODOLOGY FOR INCORPORATING CLIMATE ADAPTATION IN INFRASTRUCTURE PLANNING AND DESIGN
COMMUNICATION AND CONSULTATION WITH TECHNICAL EXPERTS, IMPLEMENTING PARTNERS AND STAKEHOLDERS
Step 1
Establish Context
DEFINE ASSET
(e.g., reservoir, transmission line, roadway, water treatment plant)
IDENTIFY CLIMATE IMPACTS
What are the expected changes in natural hazard and climate change patterns for the region?
Step 2
Vulnerability Assessment
EXPOSURE ANALYSIS
Is the asset exposed to the anticipated climate change
No
Assessment complete, no further action needed
Yes
SENSITIVITY ANALYSIS
To what degree is the asset affected, either adversely or beneficially, by the climate change impacts?
Low Sensitivity or Not Sensitive
Assessment complete, no further action needed
Highly/Moderately Sensitive
The Asset is Vulnerable to Climate Change Impacts
Adaptive Capacity Considerations
Step 3
Risk Assessment
LIKELIHOOD ANALYSIS
What is the probability of and confidence in the occurrence of the anticipated climate change impact?
CONSEQUENCE ANALYSIS
What are the economic, social, or ecological outcomes associated with the climate impact on the asset?
Rare, Unlikely, Possible, Likely, or Almost Certain
RISK ANALYSIS
Combine likelihood and consequence to rank the risk.
Insignificant, Minor, Moderate, Major, or Catastrophic
RISK EVALUATION
Is the risk acceptable?
Extreme, High, or Medium Risk
Not Significant, or Low Risk
Assessment complete, no further action needed
The Risk Requires Development of an Adaptation Strategy
Step 4
Adaptation Strategy
DEVELOPMENT & COMPARISON OF ADAPTATION RESPONSES
How should engineering design be adjusted to account for climate change impacts? What are the optimal (multi-criteria) responses?
RISK EVALUATION
Is the risk acceptable?
Selection of the Appropriate Adaptation Strategy
RESOURCE-BASE ANALYSIS
Availability of and access to resources
Step 5
Implement ation
BEST PRACTICES
Incorporate Lessons Learned in Future Design and Planning Process
MONITORING & EVALUATION
Monitor and Evaluate for Change in Risk Status
Planning and Designing Climate-Resilient Infrastructure Methodology

Common types of erosion and slope failure[1]

Mechanism	Depth
Surface erosion Dry ravel, rain splash, surface runoff causing rills and gullies. Affects bare slopes	Surface and top 0.1 m, deeper if uncontrolled
Gully erosion Surface runoff concentrates and cuts into slopes forming steep-sided gullies	Top 1.0 m, may become much deeper if uncontrolled
Planar sliding Mass slope failure on a shallow slip plane parallel to the surface. Small to large	Often in only the top 0.5 m, may be deeper
Shear failure Rotational mass slope failure, on a curved slip plane. May be deep or very deep	Usually > 1.5 m deep
Slumping Failure of slope when wet and weak - material may flow downslope	Usually < 0.5 m deep, sometimes deeper

To counter these processes, the eight functions are suggested for slope and embankment protection sites as per requirement of the site; its vulnerability and causes, techniques are

- Anchoring
- Armouring
- Reinforcing
- Catching
- Draining
- Supporting
- Restraining

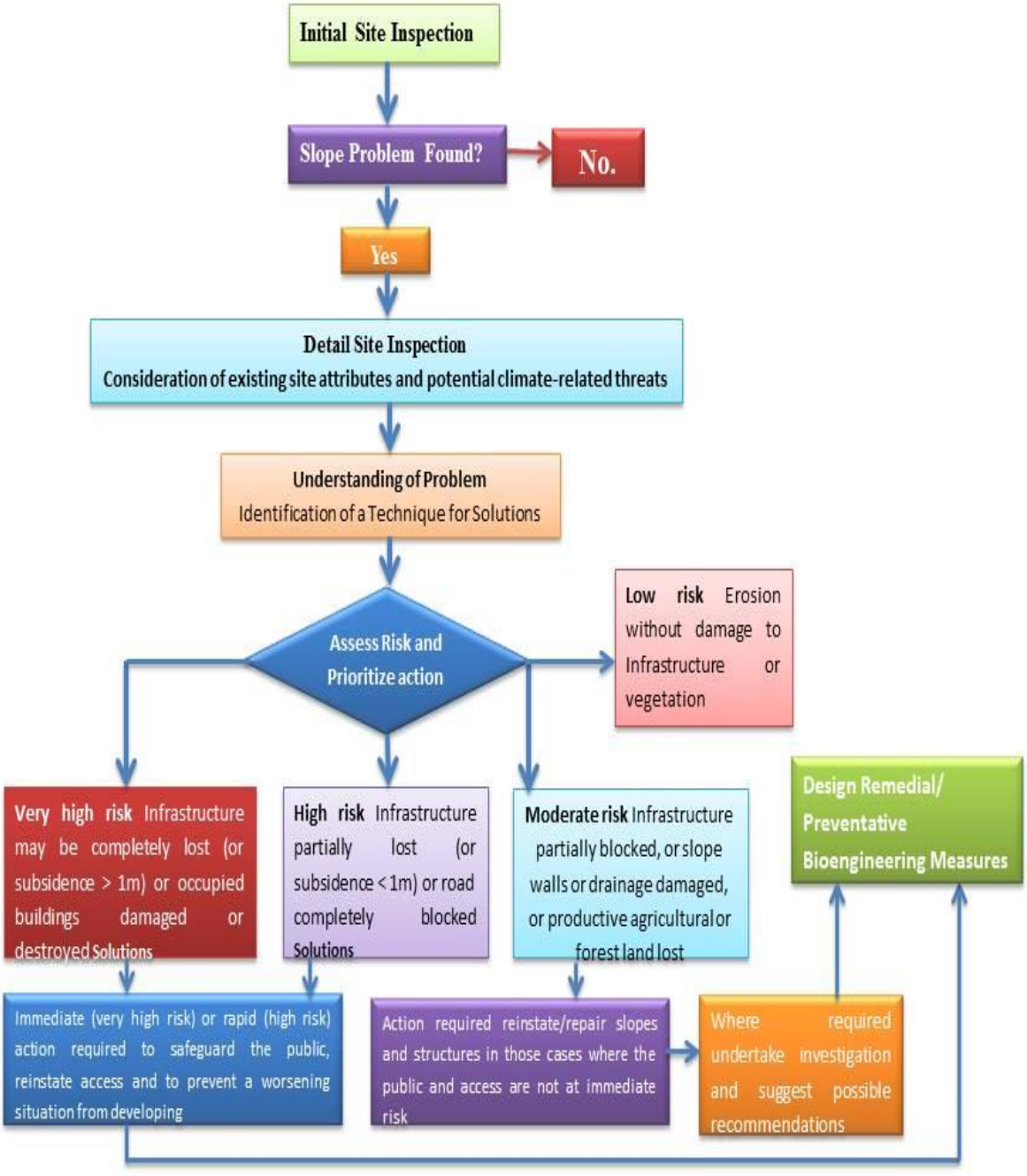
[1] **Table derived from information in Howell, J. 1999.**

3.5.1. Decision-Making Process for Site Inspection

After identification of potential slope and embankment problem, it was important to carry out detailed planning of the necessary steps to address the problem. Professionals of PMCC conducted detailed assessment of each vulnerable site and embankment. Through this approach we carefully inspected the site, embankment, and slope completing and data collection exercise. The objective of this exercise was to understand what processes are causing the problems that are making the site, slope and embankment unsafe, unstable and vulnerable. This exercise worked out how these issues can be resolved through which technique most cost effectively and sustainably.

Following diagram presents the steps we followed to select a site for bioengineering infrastructure development.

Systematic Assessment and Site Treatment of Sites.



Choosing the appropriate bioengineering techniques depends on site conditions. Each slope problem requires one or more solutions to perform different functions. Bioengineering can deal with surface protection and shallow slope instability. Therefore, knowing which bioengineering technique is suitable for each slope problem is crucial for applying this approach.

The recommended approach for this involves a careful inspection of the site, completing a data collection exercise. The intention is to understand what processes are causing the problems that are making the site unstable, and working out how they can be resolved most cost effectively.

SITE ASSESSMENT PROFORMA			
SITE LOCATION			
Date of assessment		**Assessor's name**	
SITE TYPE [_] Above road [_] Below road [_] Foothills [_] Stream bank [_] Other (specify)			
Sketch of site			**[Label Segments]**
(a) Segment number	**(1)**	**(2)**	**(3) can add more pages**
(b) Slope length			
(c) Slope angle(s)			
(d) Erosion and failure processes			
(e) Material drainage			

(f) Segment moisture				
Assessment criteria				
(a) Slope segments.	Identify each part of the slope with a uniform angle, material and failure process (es).			
(b) Slope length	Measure and place in one of 2 classes <20 meters or > 20 meters.			
(c) Slope angle(s).	Measure and place in one of 3 classes < 30º, 30 – 45º, or > 45º.			
(d) Erosion and failure processes	List the erosion or failure processes. State their size and severity.			
(e) Material drainage.	Assess and place in one of 2 classes good or poor.			
(f) Segment moisture.	Assess and place in one of 4 classes.			
	Wet	**Moist**	**Dry**	**Very dry**

Site Moisture during assessment of the sites it was determined into the following four categories each segment falls

- Wet permanently damp sites (e.g. north facing gully sites).
- Moist sites those are reasonably well shaded or moist for some other reason.
- Dry generally dry sites
- Very dry sites that are very dry; these are usually quite hot (e.g. south facing cut slopes).

Site Treatment Proforma

SITE TREATMENT PROFORMA	
SITE LOCATION	
Date of assessment	**Assessor's name**
Sketch of proposed treatment – Segment 1	**Treatment list**
Sketch of proposed treatment – Segment 2	**Treatment list**
Sketch of proposed treatment – Segment 3	**Treatment list**
Additional notes on site treatment	

Site Segments. A slope segment was defined as a length of slope with a uniform angle and homogeneous material that is likely to erode or fail in a uniform manner. In most cases, the bioengineering response will be different for different parts of a site. The segment is the unitary area of treatment on the site.

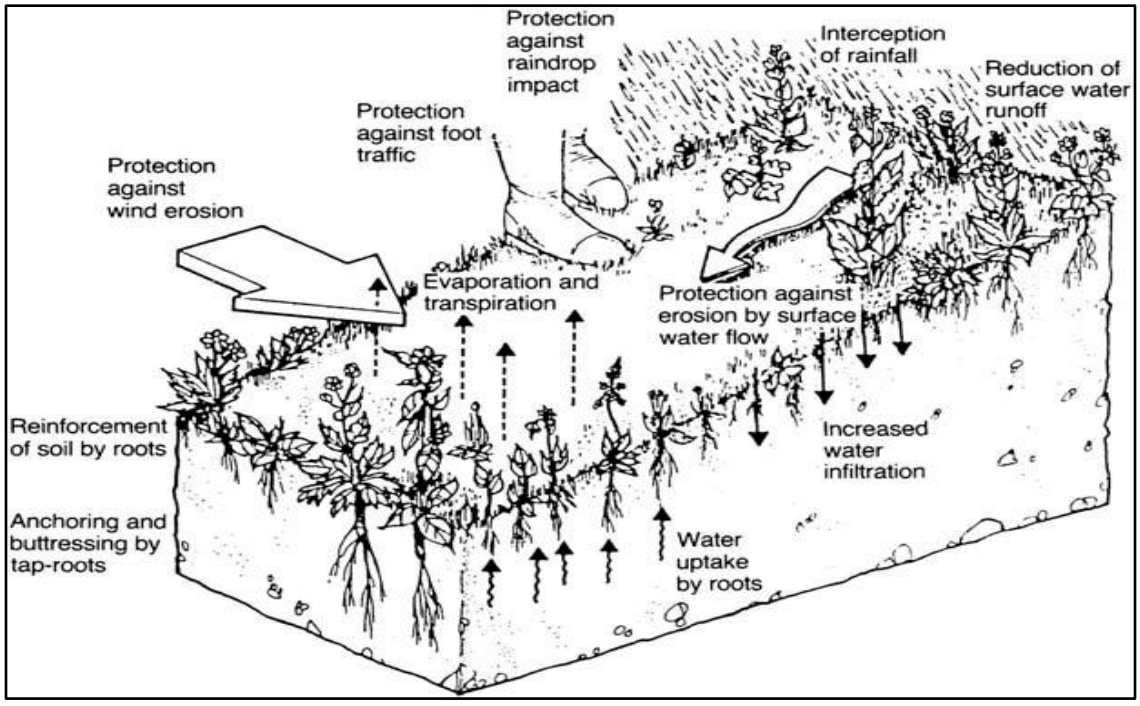
4. RECOMMENDED BIOENGINEERING TECHNIQUES

Following are some specific bioengineering techniques considered for slope stabilization, surface slumping, cutting of stream banks & water ways and resilient infrastructure development.

4.1. Vegetated Techniques

In the valleys, slopes are subject to erosion or very shallow slope failure, vegetated methods of slope protection is appropriate. This involves the use of living plants or cuttings and large and local small grasses to reduce erosion and shallow-seated instability on slopes. In these applications while there is an element of slope stabilization the primary focus is on slope surface protection.

Vegetation is a highly appropriate means of providing slope protection for reasons of its availability, relatively low cost, local plants and grasses based installation techniques and compatibility with a mountainous environment. It is particularly recommended in situations where there large areas of slope are affected a common situation on unstable hill terrain. The enhancement of vegetation increases resilience to extreme climatic events, and can also have a positive affect both visually and through economic returns from plant usage. Vegetation is a very desirable means of providing surface and slope



protection for reasons of availability, relatively low cost, relatively low design requirements, simplicity of installation techniques, and increasing strength over time,

ongoing local benefits such as fodder and fuel wood, ease of maintenance, and compatibility with a rural and mountainous environment. A range of vegetation also increases the biodiversity. This is not so much through the vegetation itself. Only a few species are used in bioengineering works but more through the encouragement of colonization of the site by other plants and animals which can come into the habitat created by the initial bioengineering species. Greater biodiversity is a benefit in itself, but it is also important to achieve it wherever possible because healthy ecosystems contribute to environmental resilience in the wider landscape.

4.2. Functions of Vegetation

4.2.1 Hydrological Functions

Plants play a significant role in slope stabilization of vulnerable sites by influencing hydrological process through intercepting raindrops; restrain soil particles; absorbs the surface and underground water and reduces saturation level of soil particles.

The functions of vegetation can be summarized as under:

- **Interception** the vegetation canopy intercepts raindrops and reduces their size and mechanical strength, thus protecting the soil from erosion caused by the rain and floods.
- **Restrain** the dense network of coarse and fine roots physically binds and restrains soil particles in the ground while the above ground portions filter the sediment out of runoff.
- **Absorption** Roots of the plants absorb surface and underground water thus reducing the saturation level of soil.
- **Infiltration** Plants and their residues help to maintain soil porosity, thereby

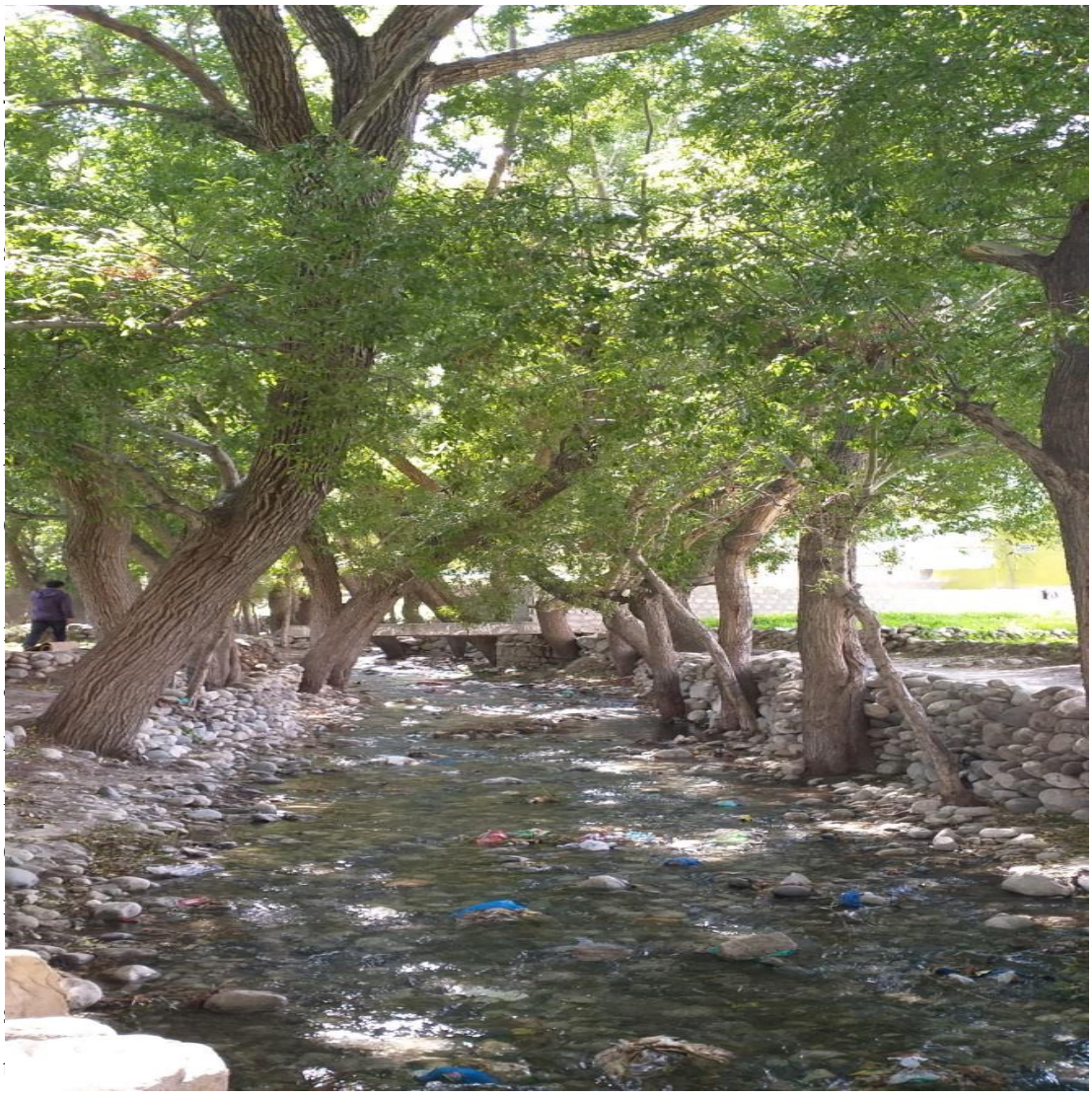
increasing retention and delaying the onset of surfeit.

- **Surface runoff reduction** Stems and roots can reduce the velocity of surface runoff by increasing surface roughness.
- **Stem Flow** A portion of rainwater is intercepted by the plants and flows along the branches and stem to the ground at low velocity. Some rainwater is stored in the canopy and stems.

4.2.2. Engineering Functions

- **Catching** Catch eroding loose material moving down the slope as gravity alone and reduce the tendency to roll down a slope because of the gravity and erosion, and this can be controlled by planting vegetation. The stems and roots can catch and hold loose material.
- **Armouring** Armour the slope against surface erosion from both runoff and rain splash. However, some slopes are very water sensitive. They start moving or are easily liquefied when water falls on them. Vegetation can protect the surface from water infiltration and erosion by rain splash.
- **Reinforcing** reinforce the soil by providing a network of roots that increases the resistance of soil to shear. The shearing strength of the soil can be increased by planting vegetation.

- **Anchoring** Anchor the surface material by extending roots through potential failure l



rata below. Layers with a tendency to slip over each other can be pinned to each other and stable underlying layer by penetration of woody taproots from vegetation which functions as anchor.

- **Supporting** water flow and pressure of floods causes erosion of stream banks and outward movement of water from sideways and large plants can provide support and prevent movement and erosion.
- **Restraining** Dense network of coarse and fine roots physically binds and restrains soil particles in the ground, while the above ground portions filter sediment out of runoff.

5. BEST TECHNIQUE SELECTION CRITERIA FOR SLOPE AND STREAM BANK STABILIZATION

Following table provided us criteria for selection of suitable bioengineering techniques for slope stabilization.

Choosing Bioengineering Techniques For Slope Stabilization And Protection							
Start (A) Slope Angle	(B) Slope Length	(C) Material Drainage	(D)Site Moisture	(E) Previous / Potential Problems	(F) Functions Required	(G) Primary Techniques Protection	**(G) Secondary Techniques – Resilience**
> 45 0	> 15 Meters	Good	Damp	Erosion, Slumping	Armour, Reinforce, Drain	Diagonal Lines Of Large Grass Planting	**Diagonal Palisades At Wide Spacing**
			Dry	Erosion	Armour, Reinforce	Contour Lines Of Large Grass Planting	**Contour Palisades At Wide Spacing**
		Poor	Damp	Surface Slumping, Erosion	Drain, Armour, Reinforce	**1.** Downslope Grass Lines And Vegetated Stone Pitched Rills Or **2.** Chevron Grass Lines And Vegetated Stone Pitched Rills	**None Available – Consider More Hard Engineering Measures With Good Drainage**
			Dry	Erosion, Surface Slumping	Armour, Reinforce, Drain	Diagonal Lines Of Large Grass Planting	**Diagonal Palisades At Wide Spacing**
	< 15 Meters	Good	Any	Erosion	Armour, Reinforce	**1.** Diagonal Lines Of Large Grass Planting Or **2.** Bamboo Mesh And Planted Grass	**Diagonal Palisades At Wide Spacing**
		Poor	Damp	Surface Slumping, Erosion	Drain, Armour, Reinforce	**1.** Downslope Lines Of Large Grass Planting Or **2.** Diagonal Lines	**None Available – Consider More Hard Engineering Measures**

						Of Large Or Short Grass Planting	**With Good Drainage**
			Dry	Erosion, Surface Slumping	Armour, Reinforce, Drain	**1.** Bamboo Mesh And Short Grass Planting Or **2.** Contour Lines Of Large Grass Planting Or **3.** Diagonal Lines Of Large Grass Planting	**Contour Palisades At Wide Spacing**
30^0 - 45^0	> 15 Meters	Good	Any	Erosion	Armour, Reinforce, Catch	**1.** Downslope Grass Lines And Vegetated Stone Pitched Rills Or **2.** Site Planted Grass, Mulch And Jute Or Bamboo Mesh	**Live Poles Or Truncheons**
		Poor	Any	Surface Slumping, Erosion	Drain, Armour, Reinforce	Site-Specific Drainage System And Shrub/Tree Planting	**Nothing Further Required**
	< 15 Meters	Good	Any	Erosion	Armour, Reinforce, Catch	**1.** Brush Layers Of Woody Cuttings Or **2.** Contour Lines Of Large Or Short Grass Planting Or **3.** Contour Fascines Or **4.** Palisades Of Woody Cutting Or **5.** Large Grass Planting And Jute Or Bamboo Mesh	**Short Cover Grass Planting Between Brush Layers, Palisades And Fascines** **Live Poles Between Grass Lines**

		Poor	Any	Surface Slumping, Erosion	Drain, Armour, Reinforce	**1.** Diagonal Large Grass Planting Lines Or **2.** Diagonal Brush Layers Or **3.** Site-Specific Drainage System And Shrub/Tree Planting	**Shrub Or Tree Planting**
< **30**^{0}	Any	Good	Any	Erosion	Armour, Catch	Contour Lines Of Large Grass Planting	**Shrub Or Tree Planting** **Live Poles Or Truncheons**
		Poor	Any	Surface Slumping, Erosion	Drain, Armour, Catch	Diagonal Lines Of Large Grass Planting	**Shrub Or Tree Planting** **Live Poles Or Truncheons**
Special Conditions							
Any Loose Sand		Good	Any	Erosion	Armour	Bamboo Mesh And Planted Grass	**Live Poles Or Truncheons**
Any "Laterite"		Poor	Any	Erosion, Surface Slumping	Armour, Drain	Diagonal Lines Of Grass And Shrub/Tree Planting	**Nothing Further Required**
Gullies ≤ **45**^{0}		Any Gully		Erosion (Major)	Armour, Reinforce, Catch	**1.** Live Check Dams Or **2.** Vegetated Stone Pitching	**Nothing Further Required**

≠ Only the common potential problems are given here. "Any loose sand" is defined as any slope in a weak, unconsolidated sandy material; such materials are normally stream deposits of recent geological origin. "Any laterite" covers any reddish soil with a high clay content. it is normally of clay loam or clay texture, and formed from prolonged weathering; it may not show all the characteristics of laterite. Techniques in bold type are preferred.

Site Moisture. The moisture routine of the entire site was considered, although in the field this can only be estimated. In assessing sites, it was necessary to determine into which of four categories each segment falls.

Wet permanently damp sites (e.g. usually north-facing gully sites).

Moist sites those are reasonably well shaded or moist for some other reason.

Dry generally dry sites. (Usually south-facing cut slopes).

Very dry sites that are very dry; these are usually quite hot as well (e.g. south-facing cut slopes).

6. Structure of Report

The report is divided mainly in eleven sections 18 chapters, Section one covers the introduction, background, methodology and general procedure and remaining ten sections cover each district and each chapter covers a GLOF-II site.

Section #	Chapter #	Description
01	01	Introduction, Background and Methodology of Study
02	02	**GLOF-II Site** Khaltaro Hiramosh, District Gilgit
03	03	**GLOF-II Site** Rupal Tareshing, District Astore
	04	**GLOF-II Site** Pareshing, District Astore
04	05	**GLOF-II Site** Hassan Abad District Hunza
	06	**GLOF-II Site** Gulkin-Husani District Hunza
	07	**GLOF-II Site** Shimshal District Hunza
05	08	**GLOF-II Site** Hisper District Nagar
06	09	**GLOF-II Site** Badswat District Ghizer
	11	**GLOF-II Site** Sosat District Ghizer
	12	**GLOF-II Site** Darkut District Ghizer
07	13	**GLOF-II Site** Muthat District Diamer
08	14	**GLOF-II Site** Arindu District Shigar
09	15	**GLOF-II Site** Barrah District Ghanche
	16	**GLOF-II Site** Khapulo Nallah District Ghanche
10	17	**GLOF-II Site** Ghundus District Kharmung
11	18	**GLOF-II Site** Satrungbat Basho District Skardu

Section II: District Gilgit.

Chapter Two: GLOF-II Site Khaltaro Hiramosh, District Gilgit, Gilgit-Baltistan

1. Description of the Site

Khaltaro Valley Hiramosh is located at a high altitude with a central geographical coordinate of 35.91681898 N 74.71430093E 2609.75294166a, 392.26608186d, 35y,-73.98799215h in the district Gilgit. It can be accessed from the Gilgit Skardu Road some 30 KM away from Gilgit city. Being situated at high altitude and under glaciers, it is vulnerable for erosion landslide and stream bank issues. The site faces slope stability, and stream bank erosion issues for many years as mentioned by the community members during FGD and observed during field visits. Mr. Behram Khan, a middle age man mentioned that we faced the increased erosion challenges after deforestation and construction of roads and water channels. The valley is intersected with ridges and stream banks and landscape features are prone for slope stability issues.

The natural slopes and stream banks of Khaltaro stabled for centuries fail because of deforestation, construction, weathering, flush flood and glacier outbursts. Stream bank's erosion problem is persistently increasing when temperature in summer increases; streams receive more floods because of glacier outburst and flush flood. In many instances, significant uncertainty exists about the stability of the natural slopes and agricultural land nearby the streams and gaps of Khaltaro Hiramosh.

However, our study could be more fruitful if the area under study was been studied previously. But there we got no any study clue from community and secondary data. However, some natural old slip surfaces exist in natural slopes of Khaltaro valley. These slip surfaces may also be caused by the glacier shove. The shearing strength along these slip surfaces is often very low because prior movement has caused resistance to peak and gradually reduce to residual values.

2. Site Assessment

2.1. Site Type

The sites in the Khaltaro valley are situated in between the foothills and stream banks in two different water streams of the valley. The valley is surrounded by the huge mountains. In both two water streams there is continuous water flow which increases in summers, rainy seasons and during GLOF events. These both water streams merge at the end of village and flows downstream. The valley has multiple faces from north to south and east to west. The erosion mostly occurs as a result of GLOF and flash floods.

Moreover, water channels and pony tracks usually damage because of land sliding during rainy and snow melting seasons.

2.2 Topography (Slope, Angle and Moisture)

Slopes in Khaltaro Hiramosh valley are of different sizes and lengths. The western site is of different portions and every portion is more than fifty meters in length and twenty to thirty meters in width. Slopes of "Parkuy" are more than two hundred of meters and fifty to sixty meters in width. These slopes have debris flow and landslide issues as well as surface erosion during extreme climatic conditions. The slopes facing south in "Parkuy" are in between 20 to 45 degree of angle. The slopes facing north wards are below 30 degree in angle.

These slopes typically have extreme variety of material types, sizes and characteristics. These materials are mostly consisted of debris, dry soil, roots of plants and cohesion less soil. The slopes of ‘Umkote” facing north are moist and damp. There are cut and filled areas or newly exposed area on slope which requires reinforcing and restraining treatment.

2.2.1. Material Drainage

The mud and debris fell downwards from the venerable slopes of site and fell into water channels due to gravitational forces during rainy, snow melting seasons and other events causing destruction of water channels and infrastructure as well. The debris moves further into adjacent water streams which lastly plunge into the Indus River.

2.2.2. Stream Bank

In the stream banks on both sides of two water streams, there is earth-rock mixture mostly very dry. Furthermore, heavy rains and floods increase the moisture of the stream banks and increases erosion. Heavy floods had eroded the main village and houses, forest and fruit trees and agricultural land is highly vulnerable for future catastrophes.

3. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

After initial site inspection the team has found slope problems in the Khaltaro GLOF Site. During initial visit of the site team has recommended the site for detail site inspection. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the problem and prioritized some sites as high risks and some had moderate risks.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development.

3.1. Grass Planting

This technique is recommended to the above water streams and in the foothills of Parkio, Umkot and Bar areas in Khaltaro village where there are slopes already vegetated in many chunks. Alfalfa and local species of grasses are recommended as these species are

widely used for slopes and surface stabilization in many parts of the area. Alfalfa has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. These grasses will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. These will have stabilization and economic impact for the vulnerable slopes and community. Contour Planting and sowing of Alfalfa and other

grasses can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.1.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.1.2. Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the large grasses however, we recommend at the right and left bank of both Nallahs of Khaltaro village where there slopes mostly are below 30 degree angle and water facility is available for irrigation.

- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

3.1.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds	200kgs	2000	400000
03	Labor for site preparation & seeding	120 men days	1000	120000
04	Transportation to site	01	20000	20000
	Total			**510000**

3.2. Sea buckthorn Plantation

Sea buckthorn plays a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.2.1. Site Preparation

Sea buckthorn is recommended at the embankments of the both Nallahs in to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier. Picked out Sea buckthorn plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.2.2. Special Instructions for Plantation

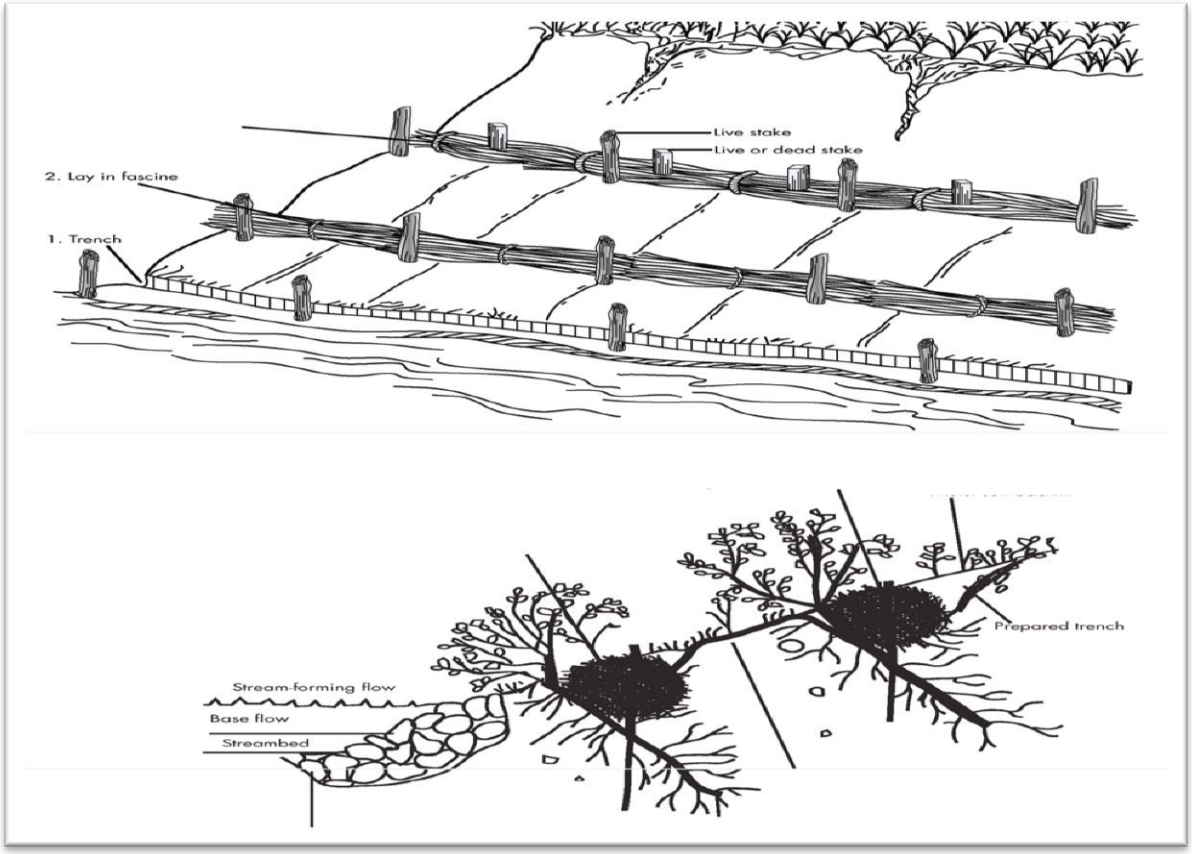
- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Sea buckthorn plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height
- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

3.2.3. Budget Estimate

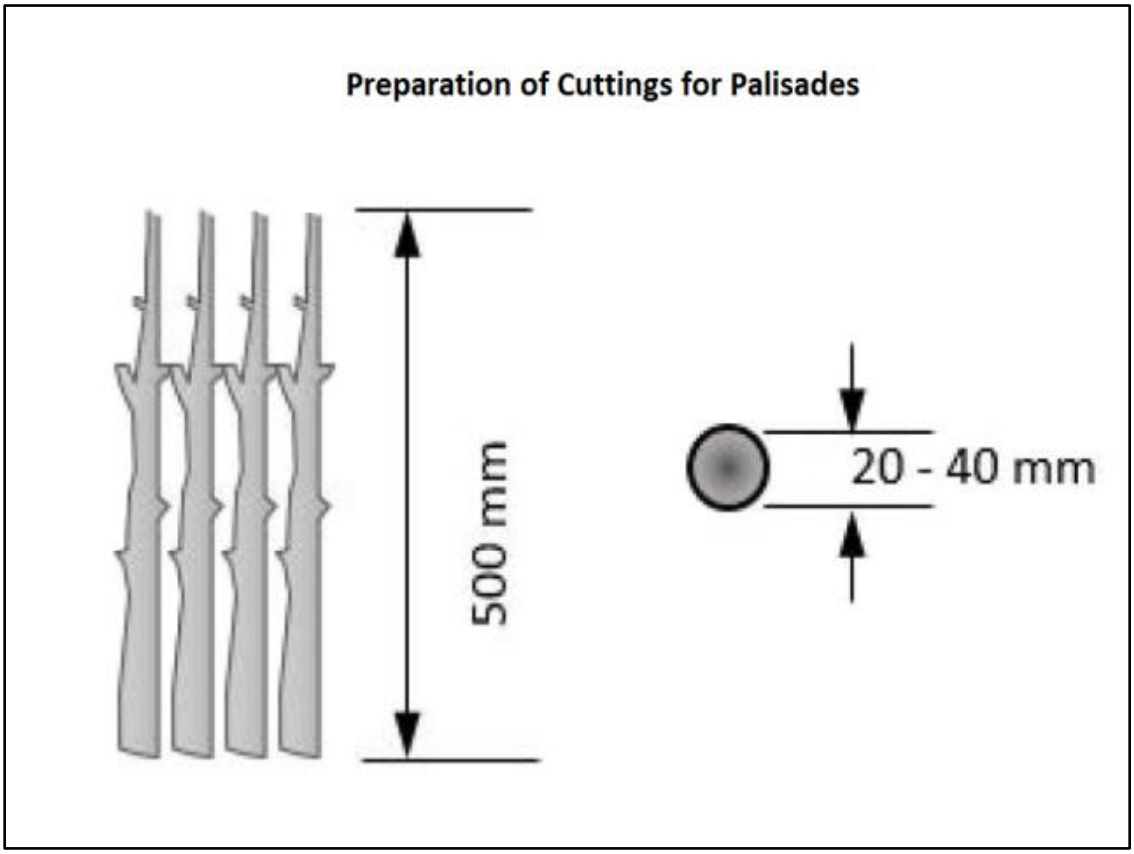
S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants	8000 plants	50 Rs.	400000
02	Transportation	8000 plants	10	80000
03	Labor for digging pits and plantation	8000 plants	15	120000
	Total			**600000**

3.3. Live Fascines

This procedure applies to the use of cuttings of willow, popular, other indigenous and local species of plants which are commonly available in Gilgit Baltistan. It is best to use local species as they are already adapted to the growing conditions; are more like to be resistant to local diseases; are more readily available; and are likely to be on lower cost options. Live hardwood willow, popular, shrub cuttings are laid in successive shallow



trenches, in lines across the slope, usually following the contour. The tips of the cuttings protrude just beyond the face of the slope, where they grow buds and leaves that intercept rainfall, slow runoff and filter sediments. In addition to the exposed stems catching surface debris, as the roots develop they reinforce the upper soil layers. This techniques are used to stabilize embankments (fill slopes) or less steep cut-slopes. The roots add tensile reinforcement to the slope and provide a measure of frictional resistance to shallow sliding. The protruding brush retards runoff and reduces surface erosion. Brush wood layers give both immediate and increasingly strong protection and reinforcement to newly constructed fill and cut slopes. They are also a good remedial measure for repairing eroded gullies. The perpendicular orientation of brush layering to the slope is effective in terms of earth reinforcement and near-surface stabilization of the slope.



3.3.1. Site Preparation

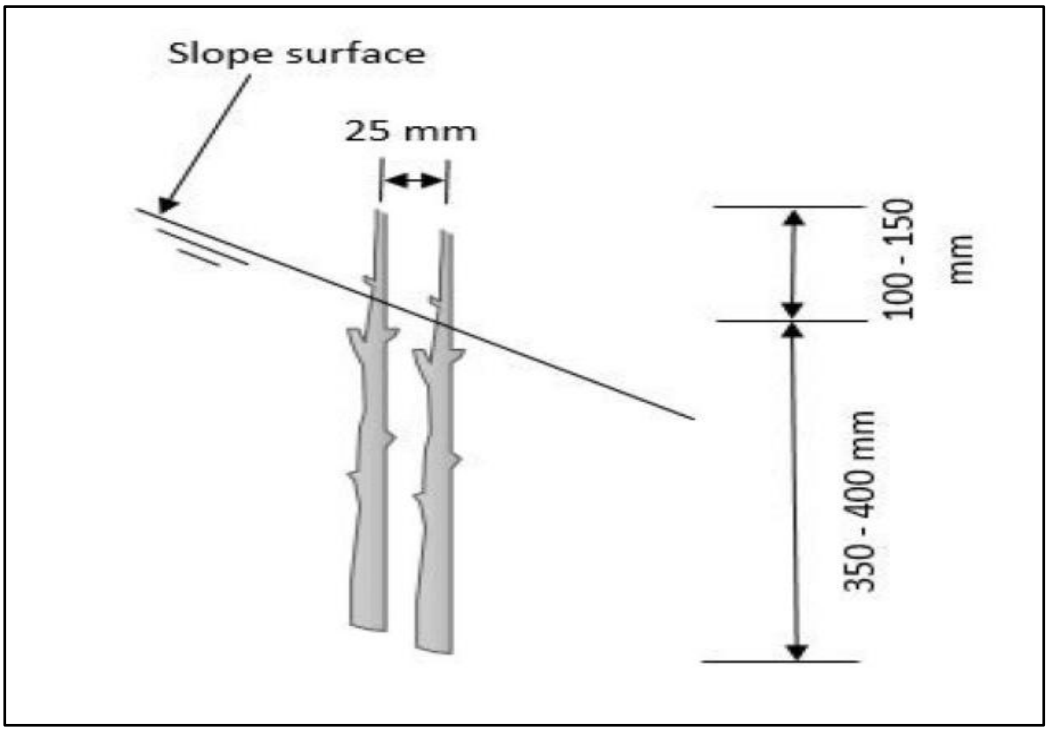
The site above the right hill of the Khaltaro village should be prepared before planting the cuttings of willow, popular, shrubs and other local species. Debris must be removed, depressions should be filled and humps should be leveled off to attain a linear profile. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 250mm above the toe of the slope, and 1000mm centers up the slope.

3.3.2. Special Instructions

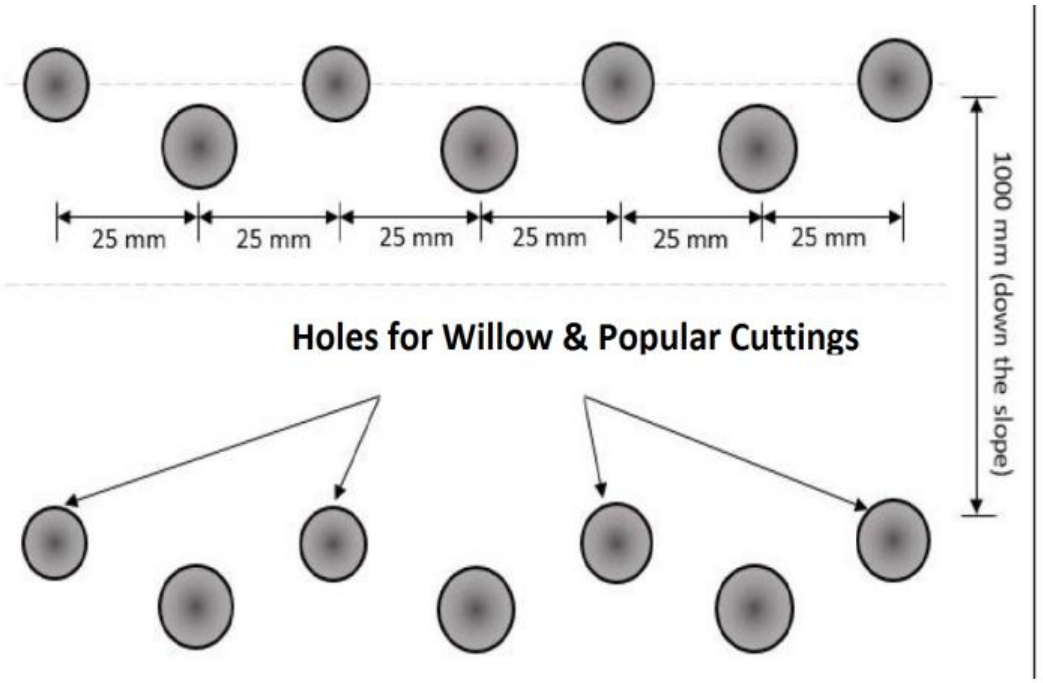
- Plant cuttings must be prepared from the woody material of 6 to 18 months in age.
- Cuttings should be approximately 20 mm dia., 500 mm length. They are laid in shallow trenches.
- These cuttings should be buried in moist soil for 3 to 7 days
- These cuttings may be immersed in water for two or three days
- When land is prepared plant the cuttings within 12 hours
- Cuttings from willow, popular and shrubs are more feasible for the local environment however; any other plant cutting must be suited to the site and shows

the correct habit for an ability to grow from the cuttings. For example many shoots coming from the stems.

- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- Side branches shall be trimmed off carefully with a sharp tool.

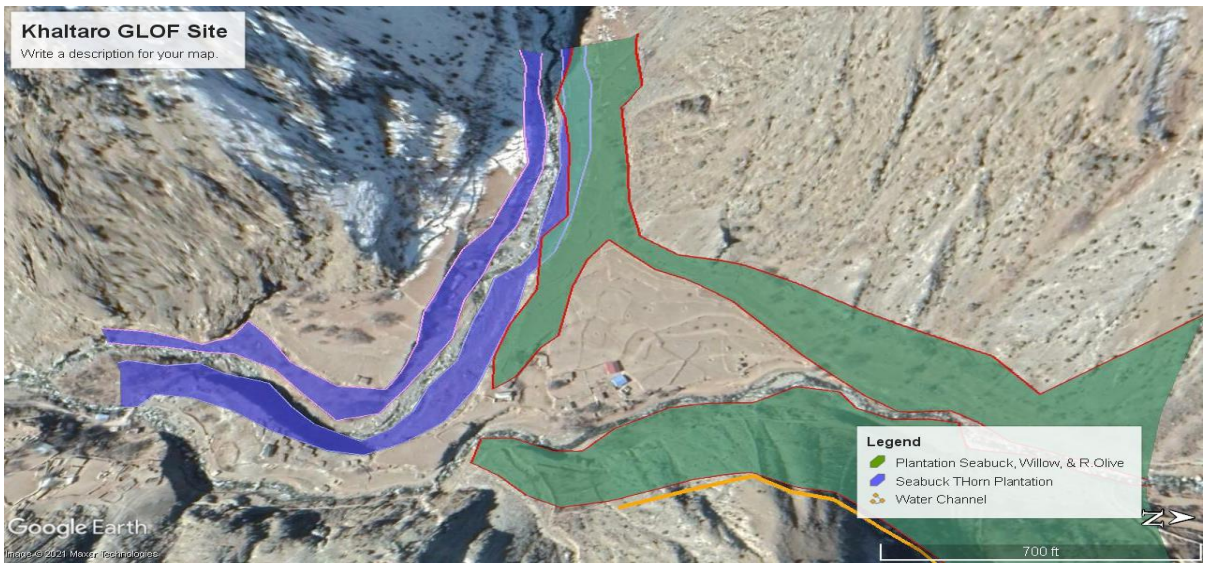


- The cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- As with grass planting, the brush layers can also be angled to enhance drainage.
- Planting should be by experienced agricultural labor with technical supervision.
- Always start at the top of the slope and work downwards
- Using a pointed bar, make a hole that is bigger than the cutting
- Carefully place the cutting in the hole so that two third is buried, firm the soil around it, taking care not to damage the bark
- Make the next hole 50mm along the row



3.3.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Plant cuttings	20000 cuttings	50 Rs.	1000000
02	Transportation, land preparation & Plantation	20000 cuttings	20 Rs.	300000
	Total			**1400000**



3.4. Compact Planting of Rooted and Cuttings of Plants

Khaltaro village in Hiramosh valley has a vast scope for compact plantation and vegetated Rip Rap. This procedure applies to use long cuttings or rooted trees of willow, popular and other indigenous plants on the slopes, ditches, valleys and gullies. Willow, popular and other local plants are easily available in every valley of Gilgit Baltistan. Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. Furthermore, roots absorb surface and underground water thus reducing the saturation level of soil and the associated risks of slope failure. It can also stabilize the slope and reduce the risk of landslides and debris flows occurring. Plants intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as allows it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap is strongly recommended.

3.4.1. Site Preparation

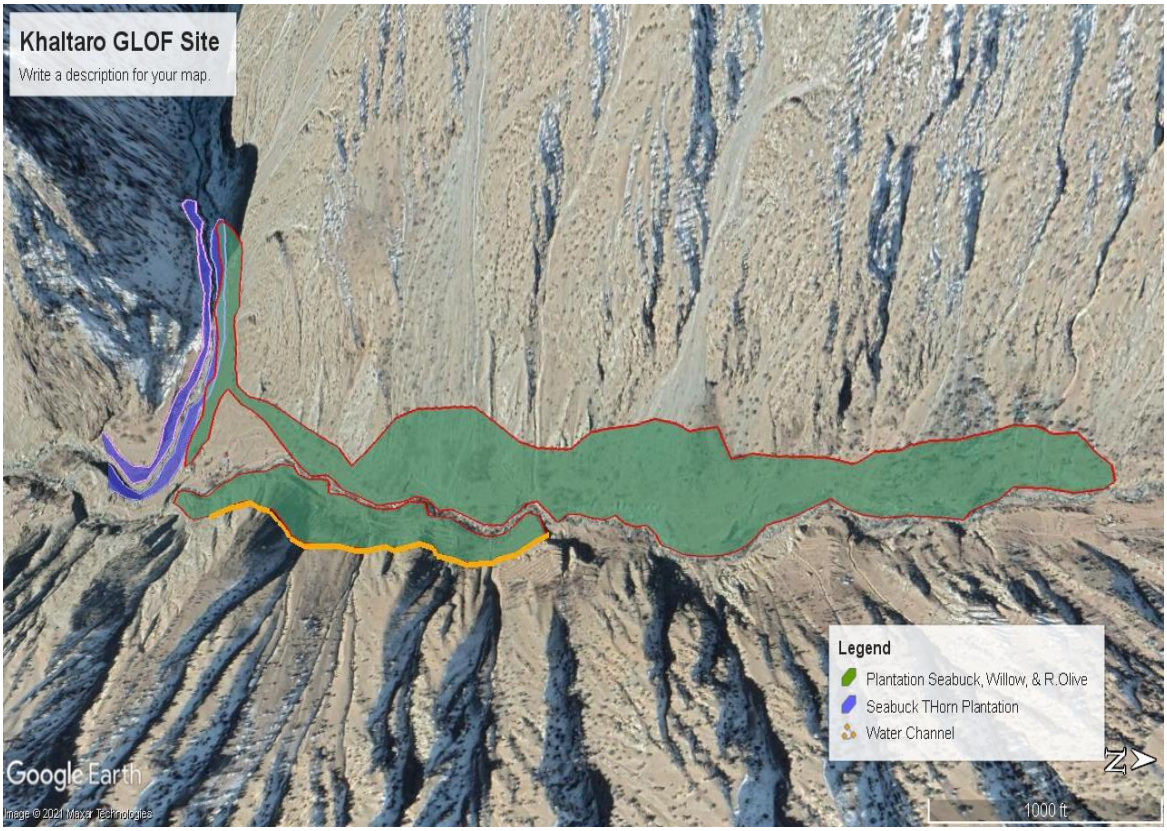
In Khaltaro village there is vast scope for compact planting and Rip Rap vegetation in valleys, slopes, ditches, and gullies. For compact planting and Rip Rap vegetation plants require trenches. It requires no any special preparation of land.

3.4.2. Special Instructions for Planting Process

- Long cuttings of willow and popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five or ten days
- Cuttings from Russian olive, willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labour with experienced supervision.

3.4.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings of willow, Russian Olive and popular (all inclusive)	20000 cuttings	90 Rs.	1800000
02	Rooted Plants of Russian Olive, Ailanthus and Popular (all inclusive)	25000	100	2500000
	Total			**4100000**



3.5. Repair and extension of existing water channels

There are three water channels traditionally for agricultural and watering the fruit and forest trees. These water channels require maintenance, improvement and extension to irrigate the newly planted trees and grown forest. These channels will provide irrigation water for vegetated riprap plantation, compact planting and long grass planted areas.

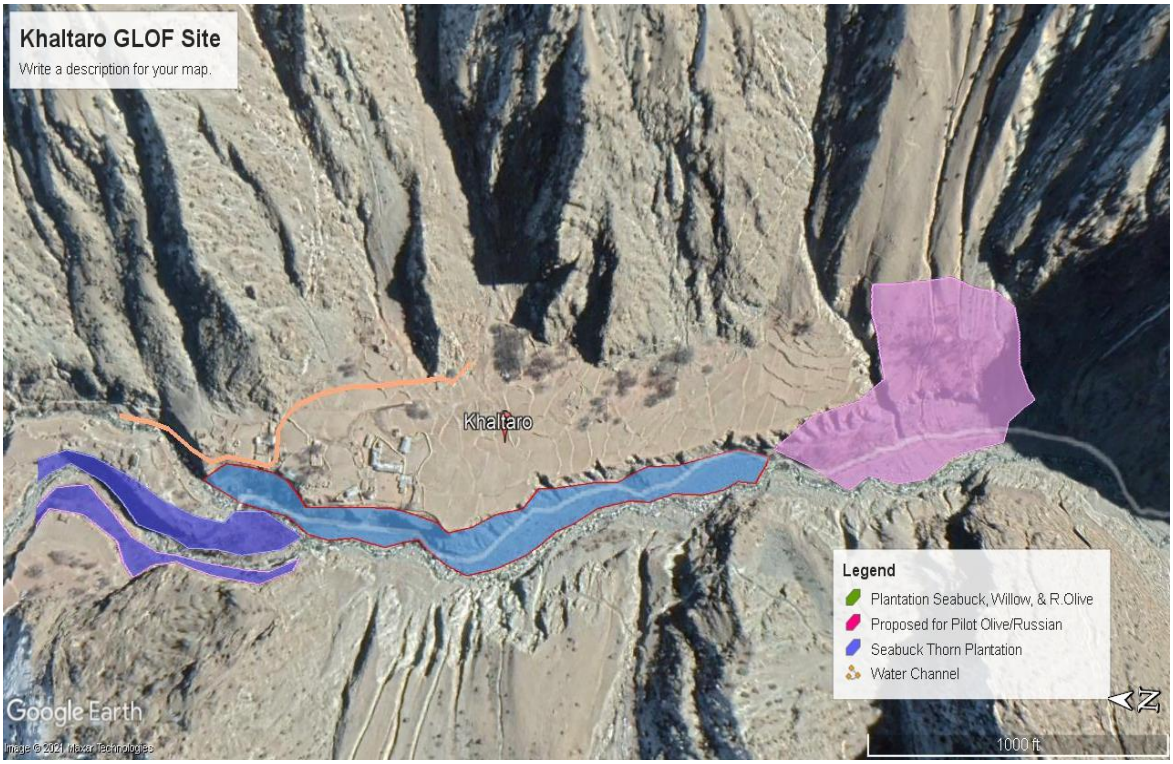
3.5.1. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of existing water channels	03	250000.	750000
Total				**750000**

Summary of Budget for GLOF-II Site (Khaltaro Hiramosh)

Activity No	Bioengineering Technique	Total
01	Large and local grass planting	590000
02	Sea buckthorn & willow Plantation	600000
03	Palisades, Live Fascines, live spurs	1400000
04	Poplar, Russian olive, ailanthus Plantation	4100000
05	Repair, and extension of water channels	750000
Grand Total		**7440000**

Site and Bioengineering Specific Maps Of Khaltaro GLOF Site



Section III: District Astore,
Chapter 03 GLOF-II Site Rupal Tareshing, District Astore, Gilgit-Baltistan

1. Introduction & Description of Site

Rupal Valley in District Astore is located at a high altitude with a central geographical coordinate of 35.2199055.E, 74.7035868.N at world geographical Globe. It is 142 km from Gilgit city and can be accessed from Astore valley road in District Astore some 30 km away from district headquarter. The Rupal valley faces heavy rain and snow in summer and winter respectively. The melting of heavy snow of winters and heavy rains of spring causes erosion in the valley. The site faces slope stability issues for many years as mentioned by the community members during FGD, consultants practically observed during field visits to site. Vegetation on the slopes has been seriously and continuously deforested because of cold weather for heating, construction of houses, schools, health centers and tourism facilities, urban occupation, adjacent land use, irrigated agriculture, livestock grazing, and the extraction of wood and minerals.

Open grazing of livestock on slopes and mountains in summer season harm living vegetation and regrowth is seriously in hazard. Rupal Community is an agrarian and mostly depends upon livestock and agricultural products therefore; they farm livestock throughout the year on mountain slopes. The valley is intersected with ridges and stream banks and landscape features are prone for slope stability issues. Stabled natural slopes for centuries fail because of deforestation, construction, weathering, flush flood and glacier outbursts. Stream bank's erosion problem is persistently increasing when temperature in summer increases; streams receive more floods because of glacier outburst and flush flood. In many instances, significant uncertainty exists about the stability of the natural slopes and agricultural land nearby the streams and gaps of the site. It has damaged multiple times the agricultural land, houses and livestock in the recent past.

In addition to mitigating the negative impacts of erosion, control is often needed to satisfy therefore, use of live plants and plant parts, in which live cuttings and stems are placed in the ground of slopes or in earthen structures, where they provide additional support to soil, act as hydraulic drains, barriers to earth erosion and will provide a sustainable ecosystem that benefits both human society and the natural environment.

However, this study could be more productive if the area was been studied previously in the context of bioengineering. The shearing strength along the slip surface is often very

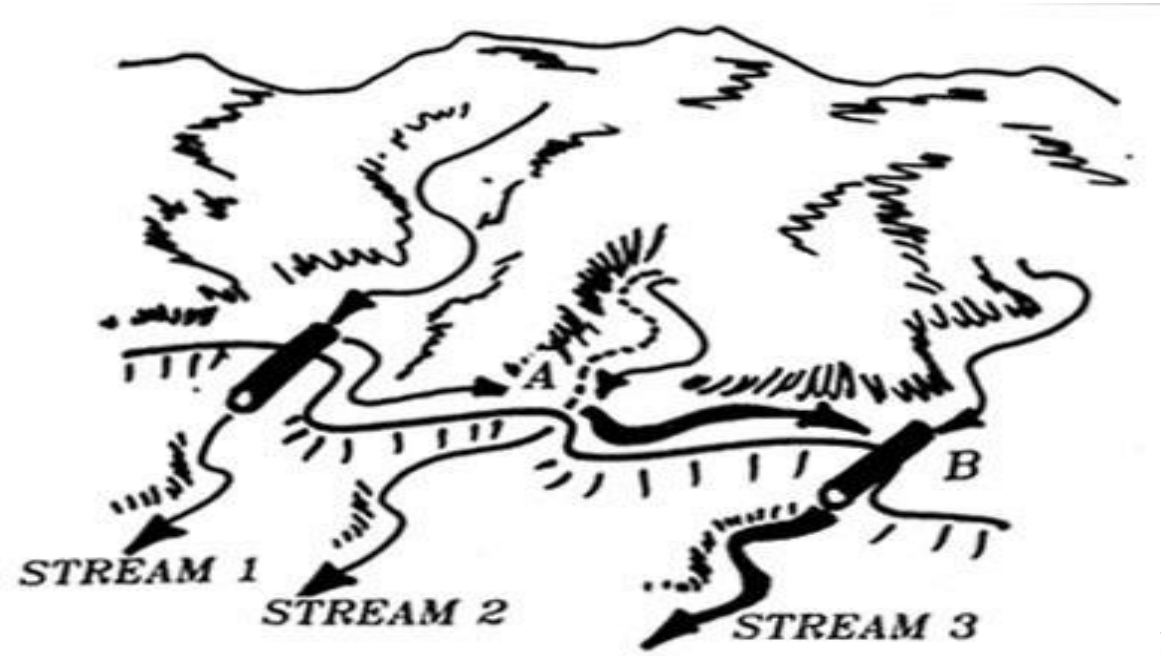
low because prior movement has caused resistance to peak and gradually reduce to residual values.

2. SITE ASSESSMENT

2.1. Site Type

Slopes in the Rupal valley are situated above the valley, agricultural land, forest cover, and settlement of the village. Pony tracks are existed on both sides of the valley across the water stream. Around 97 percent of this mountainous area has steep slopes, glaciers and water streams. The valley is located in areas of steep, unstable and erodible. The area usually affected by the extreme rainfall, snow melting, GLOF events and found the area difficult to supply and maintain critical small scale infrastructure, agricultural land and in more intensive situations even houses of the communities. Poor condition of the road is the major constraint to local development and mitigation of natural disasters. The access road to Rupal valley is damaged therefore, local transport cross the Rupal glacier from Tarishing village that can be an enormous cause to trigger the GLOF events rapidly. Climate related risks especially GLOF events, floods, erosion and landslides can severely damage agricultural land, forest, fruit trees, water supply system, roads, livestock, fodder, houses impacting community livelihoods and the socioeconomic development of the valley.

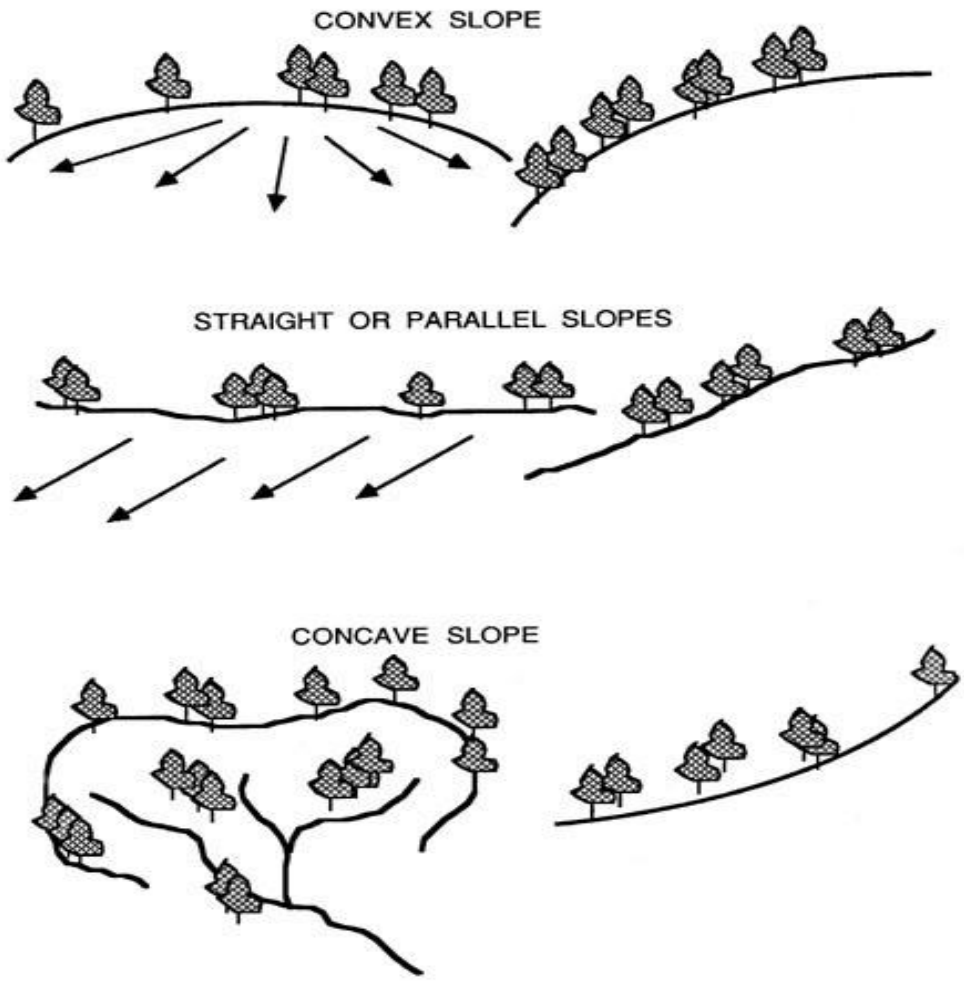
More resilient infrastructure means protection of agricultural land for farming; roads to transport their products to market; forest to slow down the erosion and mitigate climate change phenomenon. Stronger stream bank defenses mean that communities are protected from flood. Better and resilient water supply systems help grow more crops and people are spending less time to collect and transporting water from long distances for domestic uses especially in winters.



Erosion of the slopes and stream banks in the valley is befalling because of the deforestation and earth disturbing projects as mentioned earlier. Erosion from the slopes above the valley damage the ecosystem and visual environment, increase agricultural cost, and leave the land susceptible to harmful weeds. Following bioengineering projects can be significant, cost effective and necessary to mitigate the impacts of the erosion as part of caring for the land.

GLOF events and floods damage harshly their infrastructure and communication system. Mostly their communication system such as road infrastructure and agricultural land gets damaged. Moreover, water channels and pony tracks usually damage because of loss material above the hills during rainy and snow melting seasons.

Slopes of the Rupal valley Tarishing are bare slopes that easily effects during rainy and snow melting seasons leading to heavy erosion and destruction of agricultural land below the footings of the mountain in the valley. The surface runoff rate is very high and the flowing water carries the soil particles away and triggers a debris flow. A dense cover of vegetation will protect the soil from splash effects and reduce runoff velocity, while the roots will bind the soil particles to hinder surface erosion.



2.2. Slope Length

Main slope of the Rupal valley is situated above the village and hundreds of meters long in length and hundreds of meters in width. However, some other slopes of different sizes and lengths are situated across the main stream. The opposite site of the village is of different portions and every portion is more than thirty meters in length and twenty to thirty meters in width. These slopes have debris flow and landslide issues as well as surface erosion during climatic conditions.

2.3. Topography Slope, Angle and Material Drainage

Main slope of the Rupal valley Tareshing is of 30 to 45 degree of angle. The slopes situated across the water stream are of different angles varying from 30 to more than 45 degree. Material drainage of the main slope during the disaster runoff towards the agricultural land below the foothills in the village causing the damage of agricultural land, trees, infrastructures such as irrigation channels, tracks, road and houses of the inhabitants. There is no any specific or single Nallah for drainage of the flood water and material. Surface water of the opposite site of the water stream slopes drain directly into the water stream which damages forest trees, fodder and pony tracks. The surface water and floods drain into stream water which has high flow therefore it removes the material downwards in Nallah.

2.4. Moisture

The bare soil-covered slope above the village is dry and becomes wet during rainy and snow melting seasons. It's easily erodible during rains and splash of water. Intense rain leads to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. The surface runoff rate is also very high, and the flowing water carries the soil particles away and triggers debris flow from the slope. Because of no vegetation cover on the slope, roughness of slope surface increases and rain and melting snow easily erode through the gaps and near the village it becomes a disaster for community by destructing agricultural land, trees, forests, pastures, livestock and lives of the community. Dense cover, if forest trees are grown on the slope, may protect the soil splash effects and can reduce runoff velocity, while roots of the plants may bind the soil particles, resulting to hinder surface erosion.

2.2. Stream Bank

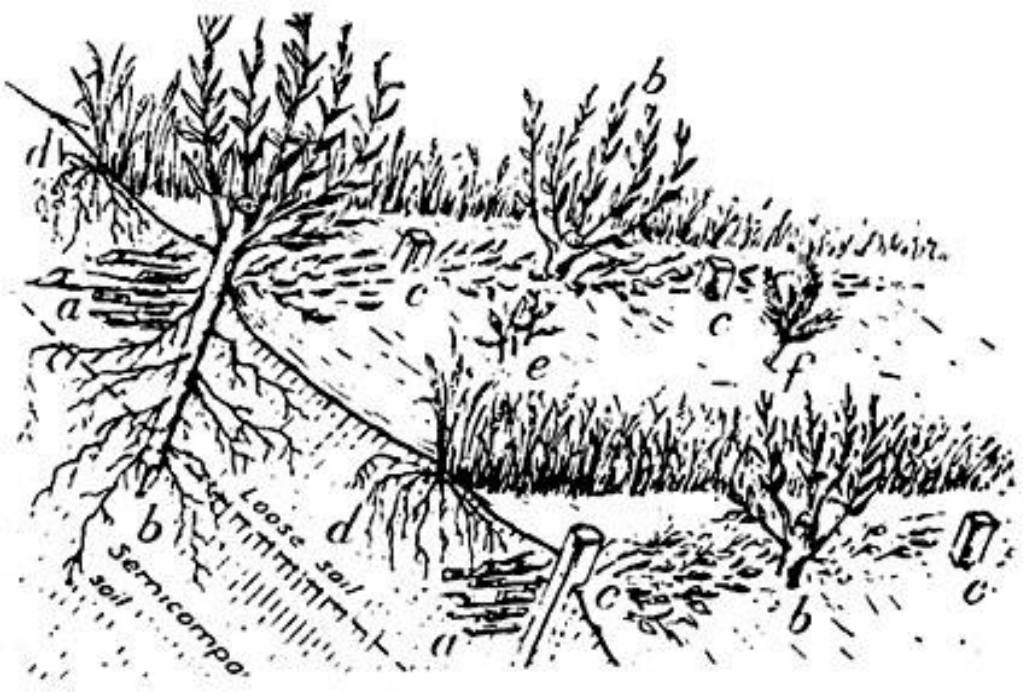
Stream banks on both sides are is earth-rock mixture mostly very dry. Furthermore, heavy rains and floods increase the moisture of the stream banks and erosion increases.

Heavy floods had eroded the main village and houses, forest and fruit trees and agricultural land is vulnerable.

3. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment exposed slope problems in the Rupal area Tareshing GLOF Site. The team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the problem and prioritized some sites as high risks and some had moderate risks.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area.



3.1. Compact Planting and Vegetated Rip Rap

Rupal valley has scope for compact plantation and vegetated Rip Rap. This procedure applies to use long cuttings or rooted trees of Juniper, willow, popular and other indigenous plants on the slopes, ditches, valleys and gullies. Willow and long cuttings of popular and other local plants are easily available in Rupal and Tareshing valley of Astore District. But Juniper, Cedar, Spruce and Pine can be supplied from the forest nurseries and suppliers of the forest plants. Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. Furthermore, roots absorb surface and underground water thus reducing the saturation level of soil and the associated risks of slope failure. It can also stabilize the slope and reduce the risk of landslides occurring. Plants intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as allows it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap is strongly recommended. Plants canopy will intercept the rain drops and reduce their size and mechanical strength resulting to protect the surface soil from erosion caused by the rain splash.

3.1.1. Site Preparation

The site has vast scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and Rip Rap vegetation plants require trenches. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of Rupal valley are 30 to 50 degree angle.

3.1.2. Special Instructions for Willow and Popular Cuttings

- Long cuttings of willow and popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants (willow and popular) are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.

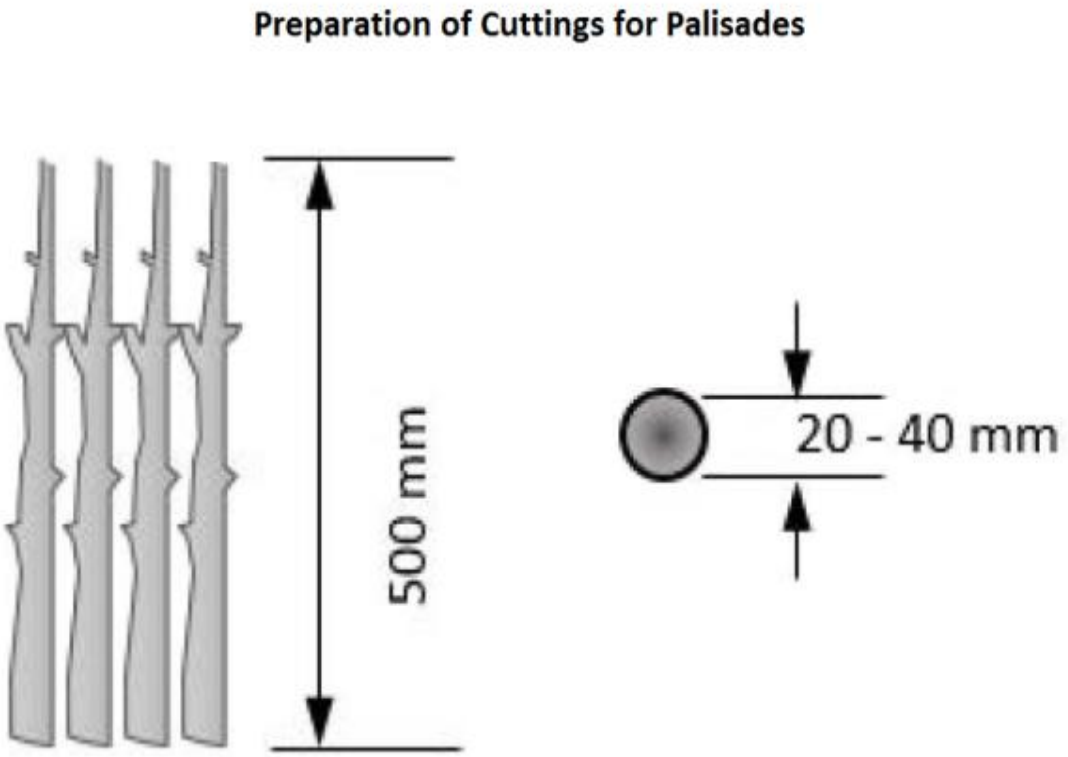
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred

3.1.3. Budget Estimates

S.NO	Item	Unit	Unite price	Total
01	Long cuttings of willow, Russian Olive and popular (all inclusive)	20000 cuttings	80 Rs.	1600000
02	Rooted Plants of Popular, Russian Olive Ailanthus (all inclusive)	25000	100	2500000
	Total			**4100000**

3.2. Live Fascines

This procedure applies to use live cuttings of willow, popular, other indigenous and local species of plants which are commonly available in Rupal valley in District Astore of Gilgit Baltistan. It is best to use local species as they are already adapted to the growing



conditions; are more like to be resistant to local diseases; are more readily available; and are likely to be on lower cost options. Live hardwood willow, popular, shrub cuttings are laid in successive shallow trenches, in lines across the slope, usually following the contour. The tips of the cuttings protrude just beyond the face of the slope, where they grow buds and leaves that intercept rainfall, slow runoff and filter sediments. In addition to the exposed stems catching surface debris, as the roots develop they reinforce the upper soil layers. This techniques are used to stabilize embankments (fill slopes) or less steep cut-slopes. The roots add tensile reinforcement to the slope and provide a measure of frictional resistance to shallow sliding. The protruding brush retards runoff and reduces surface erosion. Brush wood layers give both immediate and increasingly strong protection and reinforcement to newly constructed fill and cut slopes. They are also a good remedial measure for repairing eroded gullies. The perpendicular orientation of

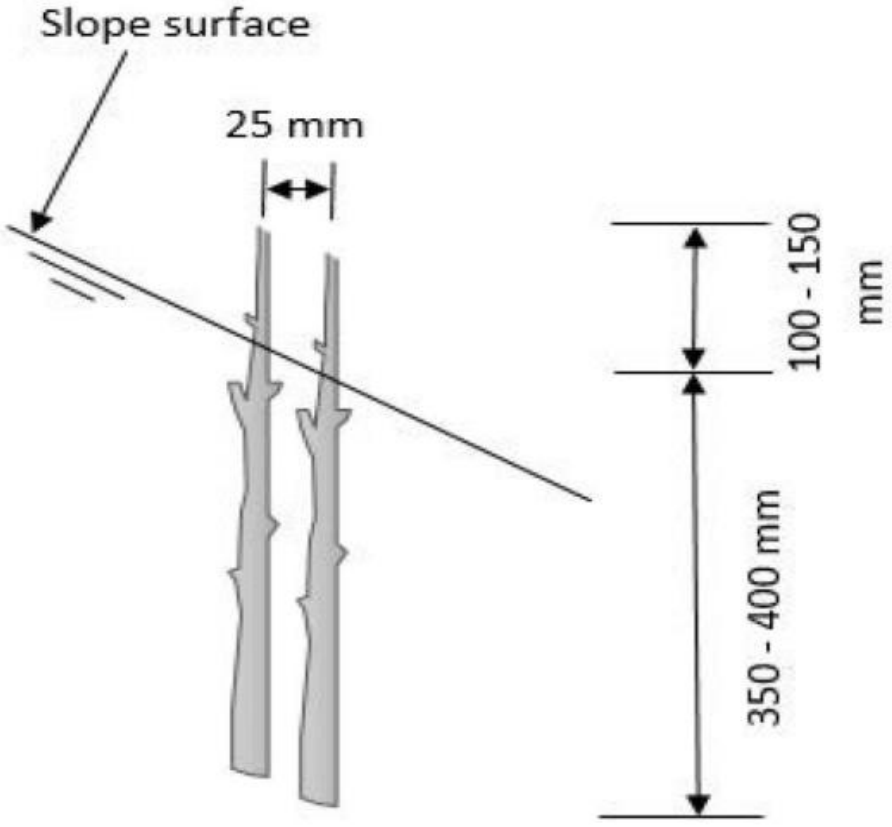
brush layering to the slope is effective in terms of earth reinforcement and near-surface stabilization of the slope.

3.2.1. Site Preparation

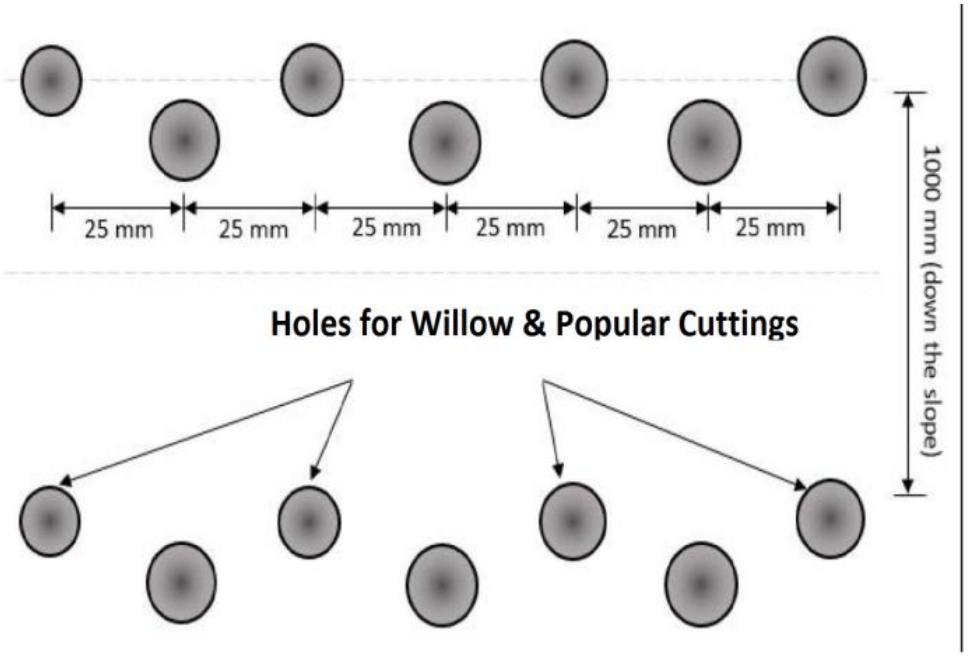
The site above the main Rupal village should be prepared before planting the cuttings of willow, popular, shrubs and other local species. Debris must be removed, depressions should be filled and humps should be leveled off to attain a linear profile. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 250mm above the toe of the slope, and 1000mm centers up the slope.

3.2.2 Special Plantation Instructions

- Plant cuttings must be prepared from the woody material of 6 to 18 months in age.
- Cuttings should be approximately 20 mm dia., 500 mm length. They are laid in shallow trenches.
- These cuttings should be buried in moist soil for 3 to 7 days
- These cuttings may be immersed in water for two or three days



- When land is prepared plant the cuttings within 12 hours
- Cuttings from willow, popular and shrubs are more feasible for the local environment however; any other plant cutting must be suited to the site and shows the correct habit for an ability to grow from the cuttings. For example many shoots coming from the stems.
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- Side branches shall be trimmed off carefully with a sharp tool.
- The cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- As with grass planting, the brush layers can also be angled to enhance drainage.
- Planting should be by experienced agricultural labor with technical supervision.
- Always start at the top of the slope and work downwards
- Using a pointed bar, make a hole that is bigger than the cutting
- Carefully place the cutting in the hole so that two third is buried, firm the soil around it, taking care not to damage the bark
- Make the next hole 50mm along the row



3.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Local live Plant cuttings	30000 cuttings	40 Rs.	1200000
02	Transportation, land preparation & Plantation	30000 cuttings	20 Rs.	600000
	Total			**1800000**

3.3. Sea buckthorn & Willow Plantation

Sea buckthorn and Willow plays a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.3.1. Site Preparation

Sea buckthorn is recommended at the embankments of the Rupal water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier. Picked out Sea buckthorn plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.3.2. Special Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Sea buckthorn plant will take place.

- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn thorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height
- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

3.3.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants	10000 plants	50 Rs.	500000
02	Transportation	10000 plants	20	200000
03	Labor for digging pits and plantation	10000 plants	15	150000
	Total			**850000**

3.4. Repair and extension of existing water channels

There are two traditional water channels for agricultural and irrigation of fruit and forest trees. These water channels require repair and extension to irrigate the newly planted trees and grown forest. These channels will provide irrigation water for vegetated riprap plantation, compact planting and long grass planted areas.

3.4.1 Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of existing water channels	02	400000.	800000
	Total			**800000**

3.5. Local Grass Planting

This technique is recommended to the above water streams and in the foothills of Rupal Tareshing valley in Astore where there are slopes already vegetated in many chunks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.5.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.5.2. Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the large grasses however, we recommend at the right and left bank of Rupal valley Nallah where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation.

- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.

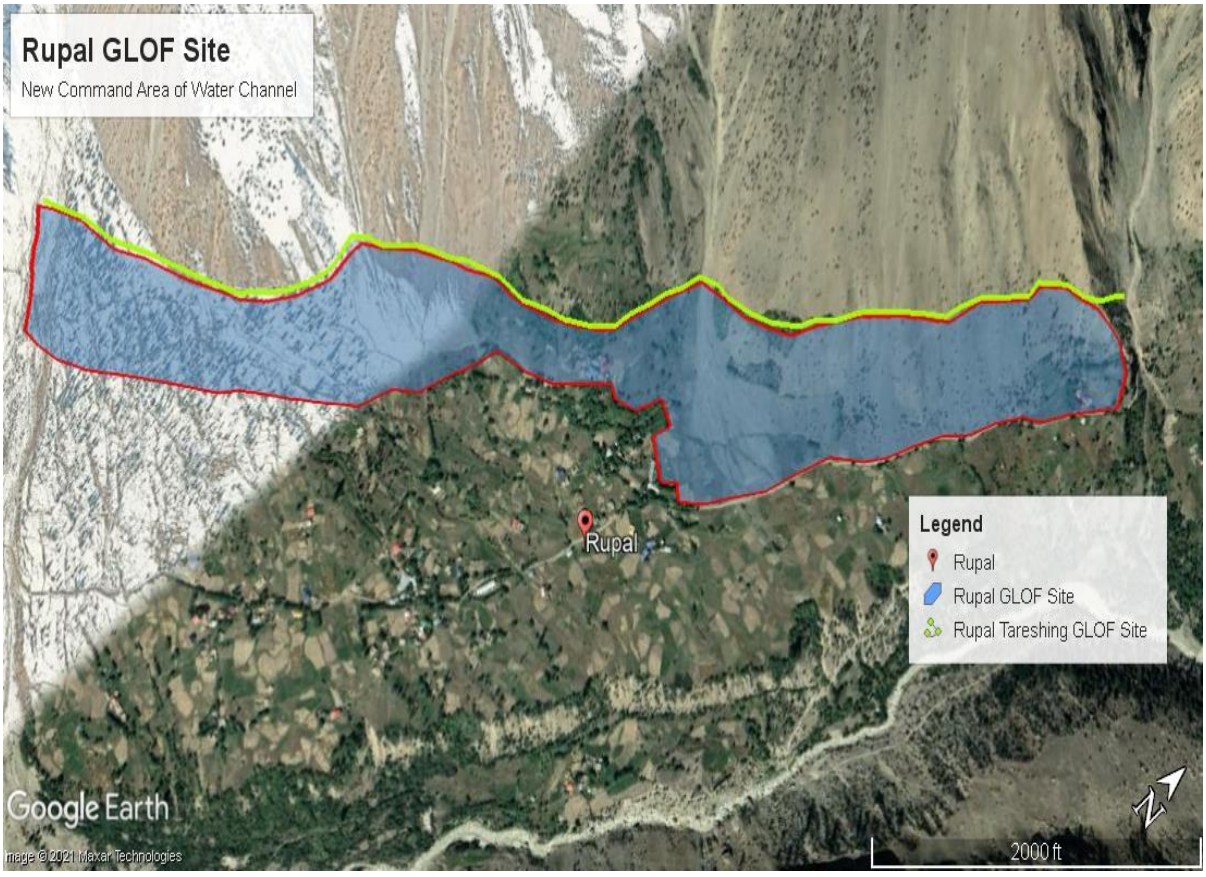
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

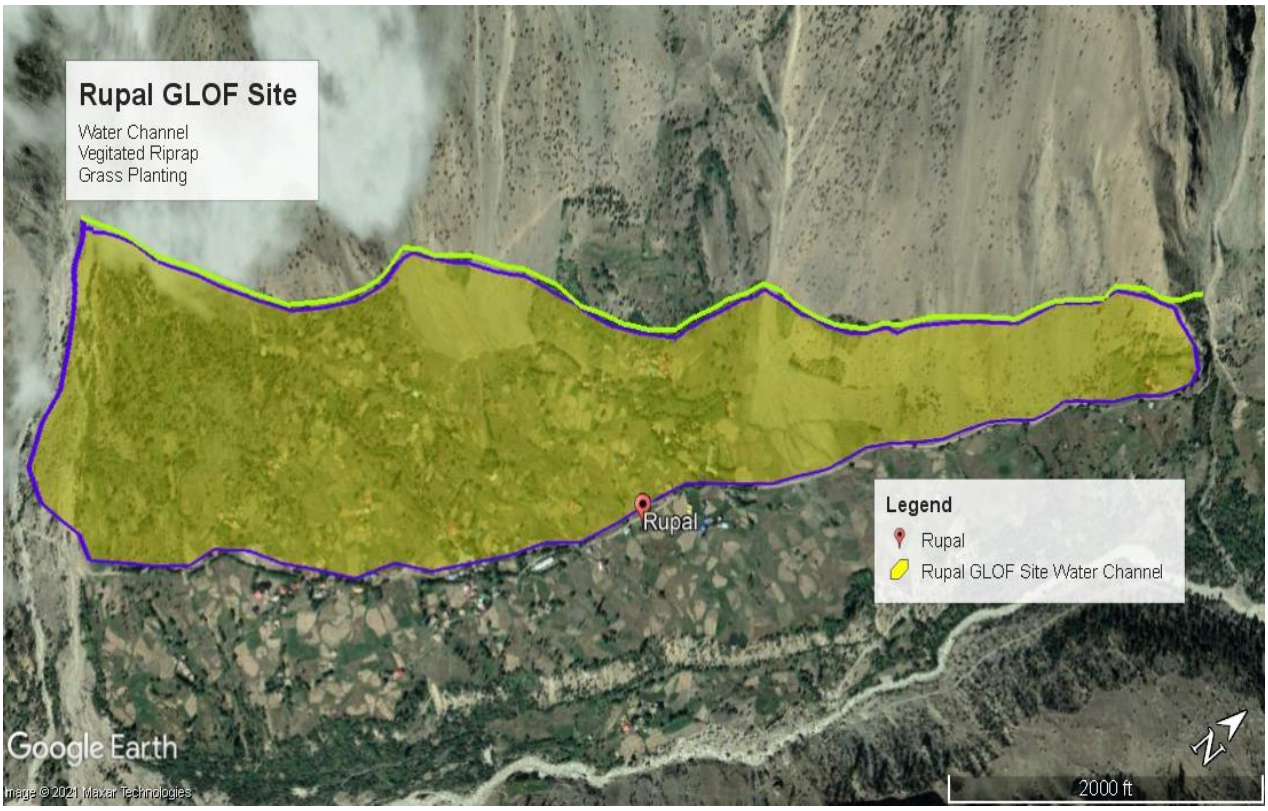
8.4. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds	200kgs	3000	600000
03	Labor for site preparation & seeding	100 men days	1000	100000
04	Transportation to site	01	20000	20000
	Total			**720000**

Summary of Budget for GLOF-II Site (Rupal Valley Tareshing Astore)		
Activity No	**Bioengineering Technique**	**Total**
01	Compact Planting and Vegetated Rip Rap	4100000
02	Live Fascines,	1800000
03	Sea buckthorn Plantation	850000
04	Repair and extension of water channels	800000
05	Grass Planting	720000
	Grand Total	**8270000**

Maps of proposed activities in GLOF site Tareshing Astore District




Rupal GLOF Site
Water Channel
Vegitated Riprap
Grass Planting
Rupal
Legend
Rupal
Rupal GLOF Site Water Channel
Google Earth
Image © 2021 Maxar Technologies
2000 ft

Section III: District Astore,
Chapter Four: GLOF-II Site Pareshing, District Astore, Gilgit-Baltistan

1. Description of Site

Pareshing Valley in District Astore is located at a high altitude with a central geographical coordinate of 74°59'8.60"E, 35°23'58.71"N at world geographical Globe. It is 137 km from Gilgit city and can be accessed from Astore-Gilgit Road near district headquarter in District Astore. Pareshing valley faces heavy rain and snow in summer and winter respectively. The melting of heavy snow of winters and heavy rains of spring causes erosion and Pareshing stream erodes embankment erosion issues in the valley. Pareshing Nallah usually changes its direction during the season and huge area of the valley has been affected multiple times. The site faces slope instability and erosion issues for many years as mentioned by the community members during FGD, consultants practically observed during field visits to site. Vegetation on the slopes has been seriously and continuously deforested because of cold weather for heating, construction of houses, schools, health centers and tourism facilities, urban occupation, adjacent land use, irrigated agriculture, livestock grazing, and the extraction of wood and minerals.

Open grazing of livestock on slopes and mountains in summer season harm living vegetation and regrowth is seriously in hazard. Pareshing Community is an agrarian and mostly depends upon livestock and agricultural products therefore; they farm livestock throughout the year on mountain slopes. The valley is intersected with ridges and stream banks and landscape features are prone for slope stability issues. Stabled natural slopes for centuries fail because of deforestation, construction, weathering, flush flood and glacier outbursts.

Stream bank's erosion problem is persistently increasing when temperature in summer increases; streams receive more floods because of glacier outburst and flush flood. In many instances, significant uncertainty exists about the stability of the embankment and agricultural land nearby the streams and gaps of the site. It has damaged multiple times the agricultural land, houses and livestock in the recent past.

In addition to mitigating the negative impacts of erosion, control is often needed to satisfy therefore, use of live plants and plant parts, in which live cuttings and stems are placed in the ground of slopes or in earthen structures, where they provide additional support to soil, act as hydraulic drains, barriers to earth erosion and will provide a sustainable ecosystem that benefits both human society and the natural environment.

However, this study could be more productive if the area was been studied previously in the context of bioengineering. The shearing strength along the slip surface is often very low because prior movement has caused resistance to peak and gradually reduce to residual values.

2. Site Assessment

2.1. Site Type

Embankments of the Pareshing water stream in Pareshing valley are vulnerable and continuously eroding during summer, rainy and snow melting seasons. The water stream usually changes its direction during floods and GLOF events that damages the agricultural land, forest, settlements, infrastructure specially roads, building and bridges. The slopes are situated above the valley and during GLOF events and floods; agricultural land; pony tracks and roads face damages. Around 97 percent of this mountainous area has steep slopes, glaciers and water streams.

The valley is located in areas of steep, unstable and erodible. The area usually affected by the extreme rainfall, snow melting, GLOF events and found the area difficult to supply and maintain critical small scale infrastructure, water supply system, irrigation channels, agricultural land and in more intensive situations even houses of the communities.

Poor condition of the road is the major constraint to local development and mitigation of natural disasters. Climate related risks especially GLOF events, floods, erosion and landslides can severely damage agricultural land, forest, fruit trees, water supply system, roads, livestock, fodder, houses impacting community livelihoods and the socioeconomic development of the valley.

More resilient infrastructure means protection of agricultural land for farming; roads to transport their products to market; forest to slow down the erosion and mitigate climate change phenomenon. Stronger stream bank defenses mean that communities are protected from flood. Better and resilient water supply systems help grow more crops and people are spending less time to collect and transporting water from long distances for domestic uses especially in winters.

Erosion of the slopes and stream banks in the valley is befalling because of the deforestation and earth disturbing projects as mentioned earlier. Erosion from the slopes above the valley damage the ecosystem and visual environment, increase agricultural cost, and leave the land susceptible to harmful weeds. Following bioengineering projects

can be significant, cost effective and necessary to mitigate the impacts of the erosion as part of caring for the land.

Slopes of the valley are bare slopes and comparatively vegetated in segments and still there is more area to vegetate. The bare slopes easily effects during rainy and snow melting seasons leading to heavy erosion and destruction of agricultural land below the footings of the mountain in the valley. The surface runoff rate is very high and the flowing water carries the soil particles away and triggers a debris flow. A dense cover of vegetation will protect the soil from splash effects and reduce runoff velocity, while the roots will bind the soil particles to hinder surface erosion.

2.2. Slope Length

There are multiple segments of the slopes and main slope of the valley is situated above the village and hundreds of meters long in length and hundreds of meters in width. However, there are small segments of slopes of different sizes and lengths are situated across the main stream. The opposite site of the main village there is a large portion and some portions exist and every portion is more than thirty meters in length and twenty to thirty meters in width. These slopes have landslide issues as well as surface erosion during climatic conditions.

2.3. Topography (Slope, Angle and Material Drainage)

Main slope of the Pareshing valley is of 35 to 55 degree of angle. The slopes situated across the water stream are of different angles varying from 30 to more than 55 degree. Material drainage of the main slope during the disaster runoff towards the agricultural land below the foothills in the village causing the damage of agricultural land, trees, infrastructures such as irrigation channels, tracks, roads and houses of the inhabitants. There is no any specific drainage way of the flood water and material. Surface water of the opposite site of the water stream slopes drain directly into the water stream in many segments but in most of the area it affects the infrastructure of the village by damaging irrigation channels, water supply, roads, forest trees, fodder and pony tracks.

2.4. Moisture

The bare soil-covered slope above the village is dry and becomes wet during rainy and snow melting seasons. It's easily erodible during rains and splash of rain in rainy seasons. Intense rain leads to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. The surface runoff rate is also very high, and the flowing water carries the soil particles away and triggers

debris flow from the slope. Because of no vegetation cover on the slope, roughness of slope surface increases and rain and melting snow easily erode through the gaps and near the village it becomes a disaster for community by destructing agricultural land, trees, forests, pastures, livestock and lives of the community. Dense cover, if forest trees are grown on the slope, may protect the soil splash effects and can reduce runoff velocity, while roots of the plants may bind the soil particles, resulting to hinder surface erosion.

2.5. Stream Bank

Pareshing Nallah is flowing through the middle of the main village dividing the village in two sub villages. The stream keeps changing its way in summer generally and during floods especially. Therefore, embankment erosion issue is persistently harms the infrastructure, roads, foot bridges, water supply and forest and agricultural land. Both sides of the water stream in the valley are dry and muddy which is susceptible for erosion. Furthermore, heavy rains and floods increase the moisture of the stream banks and erosion increases. Heavy floods had eroded the main village and houses, forest and fruit trees and agricultural land as well.

3. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment exposed slope and embankment problems in the Pareshing GLOF Site. The initial survey team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the problem and prioritized some sites as high risks and some had moderate risks.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

3.1. Vegetated Rip Rap and Compact Planting

Slopes of the Preshing valley are have loose material that have high tendency to roll down the slope because of the erosion caused by the rain, wind and weathering. This erosion of the slope can be controlled by the vegetated riprap and compact plating of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They

start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of Juniper, willow, popular and other indigenous plants on the slopes, in ditches, valleys and gullies. Willow and long cuttings of popular and other local plants are easily available in Pareshing valley of Astore District. But Juniper, Cedar, Spruce and Pine can be supplied from the forest nurseries and suppliers of the forest plants. Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil up to 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

3.1.1. Site Preparation

The site has vast scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of Pareshing valley are 30 to 50 degree angle.

3.1.2. Special Instructions for Willow and Popular Cuttings

- Long cuttings of willow and popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants (willow and popular) are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.

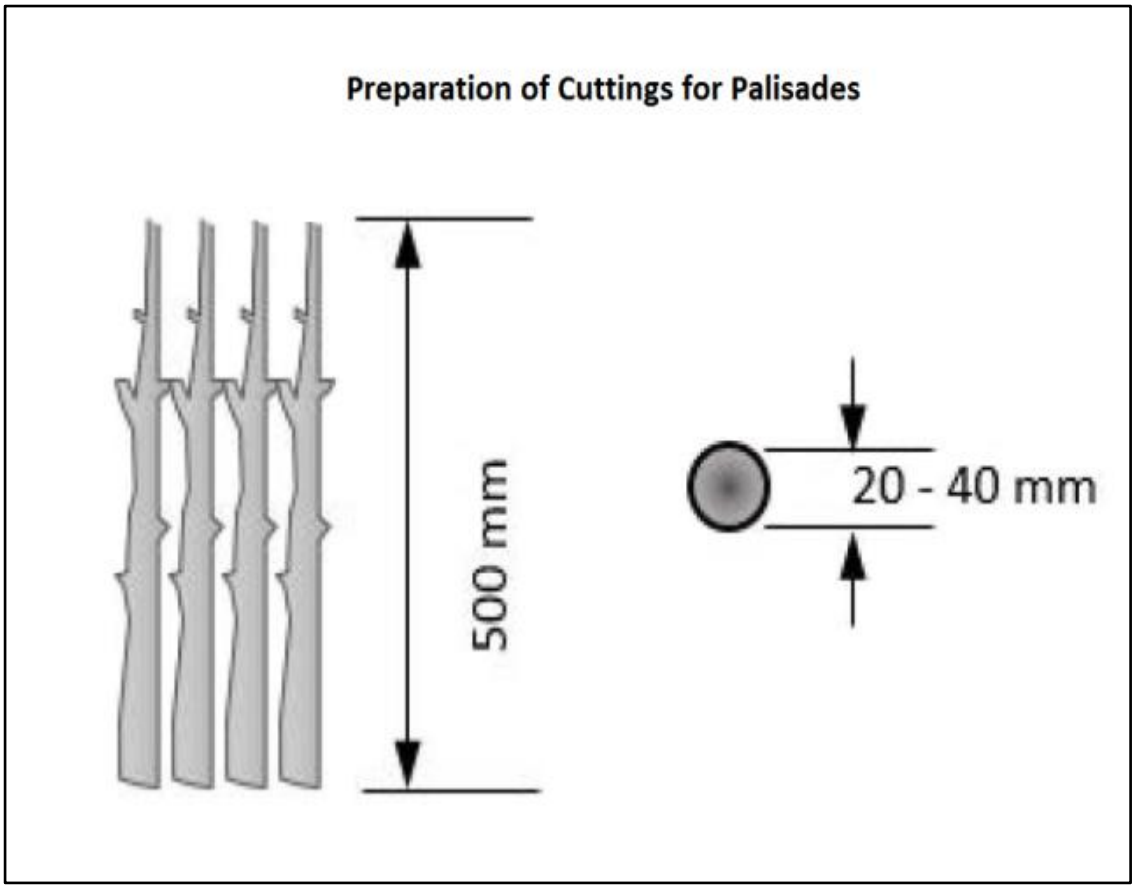
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

3.1.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings of Russian Olive, willow and popular (all inclusive)	15000 cuttings	90 Rs.	1350000
02	Rooted Plants of Ailanthus, Popular, and Russian Olive (all inclusive)	25000	100	2500000
	Total			**3850000**

3.2. Live Fascines

This procedure applies to use live cuttings of willow, popular, other indigenous and local species of plants which are commonly available in Pareshing valley in District Astore of Gilgit Baltistan. It is best to use local species as they are already adapted to the growing conditions; are more like to be resistant to local diseases; are more readily available; and are likely to be on lower cost options. Live hardwood willow, popular, shrub cuttings are laid in successive shallow trenches, in lines across the slope, usually following the contour.



The tips of the cuttings protrude just beyond the face of the slope, where they grow buds and leaves that intercept rainfall, slow runoff and filter sediments. In addition to the exposed stems catching surface debris, as the roots develop they reinforce the upper soil layers. This techniques are used to stabilize embankments (fill slopes) or less steep cut-slopes. The roots add tensile reinforcement to the slope and provide a measure of frictional resistance to shallow sliding. The protruding brush retards runoff and reduces surface erosion. Brush wood layers give both immediate and increasingly strong protection and reinforcement to newly constructed fill and cut slopes. They are also a good remedial measure for repairing eroded gullies. The perpendicular orientation of

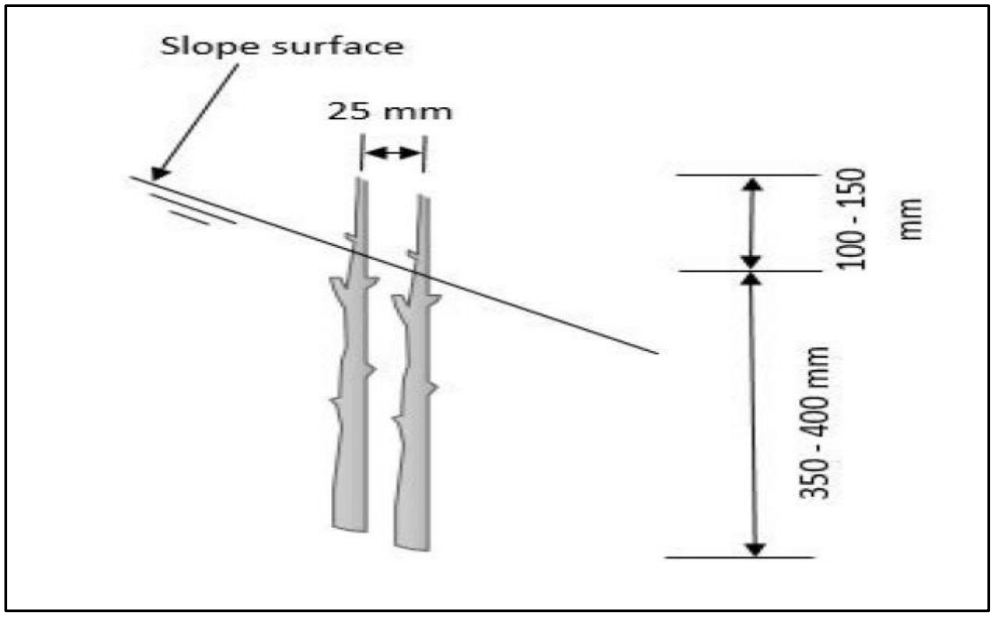
brush layering to the slope is effective in terms of earth reinforcement and near-surface stabilization of the slope.

3.2.1. Site Preparation

The site above the main village and along the water stream should be prepared before planting the cuttings of willow, popular, shrubs and other local species. Debris must be removed, depressions should be filled and humps should be leveled off to attain a linear profile. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 250mm above the toe of the slope, 1000mm centers up the slope and at the edge of the water stream 12 inches of distance from water level of summer season.

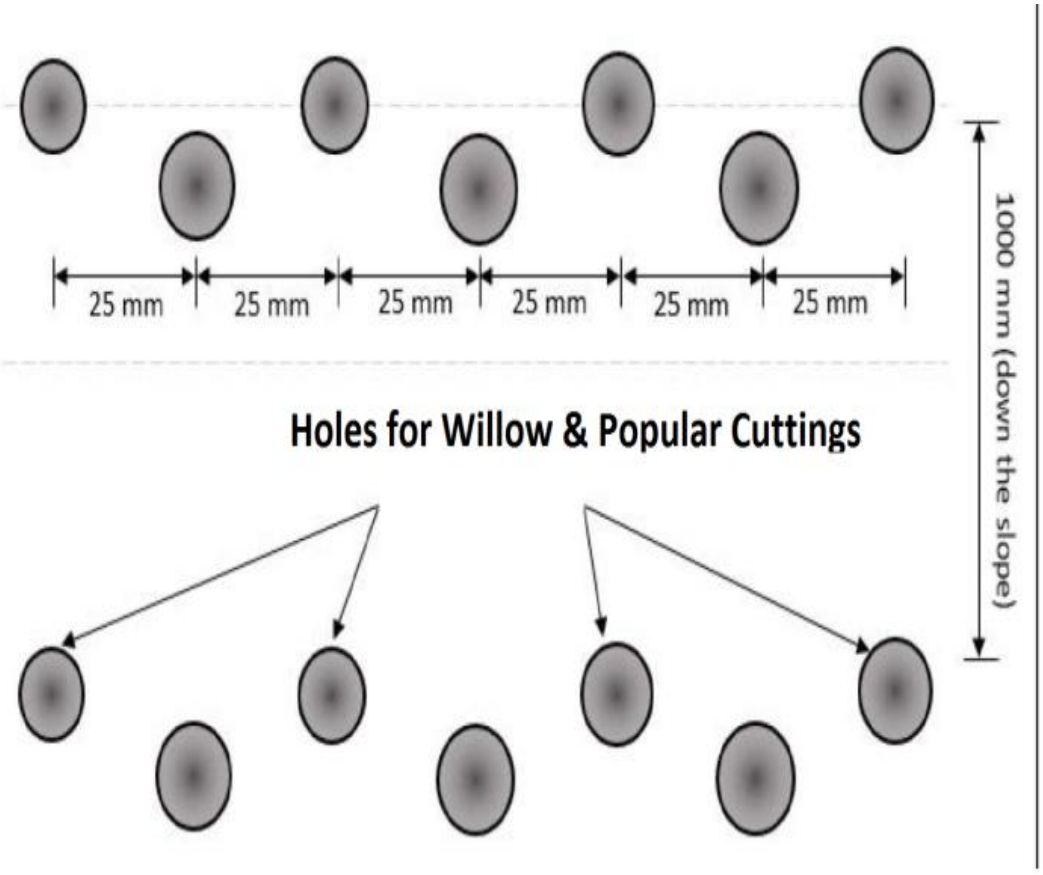
3.2.2. Special Instructions

- Plant cuttings must be prepared from the woody material of 6 to 18 months in age.
- Cuttings should be approximately 20 mm dia., 500 mm length. They are laid in shallow trenches.
- These cuttings should be buried in moist soil for 3 to 7 days



- These cuttings may be immersed in water for two or three days
- When land is prepared plant the cuttings within 12 hours Cuttings from willow, popular and shrubs are more feasible for the local environment however; any other plant cutting must be suited to the site and shows the correct habit for an ability to grow from the cuttings. For example many shoots coming from the stems.

- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- Side branches shall be trimmed off carefully with a sharp tool.
- The cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- As with grass planting, the brush layers can also be angled to enhance drainage.
- Planting should be by experienced agricultural labor with technical supervision.
- Always start at the top of the slope and work downwards
- Using a pointed bar, make a hole that is bigger than the cutting
- Carefully place the cutting in the hole so that two third is buried, firm the soil around it, taking care not to damage the bark
- Make the next hole 50mm along the row



3.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Local live Plant cuttings	30000 cuttings	40 Rs.	1200000
02	Transportation, land preparation & Plantation	30000 cuttings	20 Rs.	600000
	Total			**1800000**

3.3. Sea buckthorn and Willow Plantation

Sea buckthorn, willow and bush's roots mainly protect soil one meter deep and plays a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.3.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier. Picked out Sea buck plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.3.2. Special Planting Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Seabuck plant will take place.

- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height
- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

BOX 1. CASE STUDY-PASSU VALLEY

The Passu Valley was once bountiful. The Khunjerab and Shimshal rivers gradually eroded their banks, posing a very real threat to homesteads and agriculture/livestock-dependent livelihoods. To all locally active development partners, including government entities, the International Centre for Integrated Mountain Development (ICIMOD) and World Wide Fund for Nature (WWF), it was clear that erosion had to be curbed if any development activity was to be effective. Drawing on cross learning from effective river training efforts along the Yellow River in China, ICIMOD identified sea buckthorn plantation as a locally appropriate bioengineering measure, with the ability to withstand rough conditions and the potential to deliver multiple benefits.

3.3.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants	10000 plants	50 Rs.	500000
02	Transportation	10000 plants	20	200000
03	Labor for digging pits and plantation (200 Men days)	200 men days	1000	200000
	Total			**900000**

3.4. Repair and extension of existing water channels

There are two traditional water channels for agricultural and irrigation of fruit and forest trees. These water channels require repair and extension to irrigate the newly planted trees and grown forest. These channels will provide irrigation water for vegetated riprap plantation, compact planting and long grass planted areas. The channels are earthen irrigation channels therefore, they require not concrete work.

3.4.1. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of existing water channels	02	350000.	700000
	Total			**700000**

3.5. Local Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting and palisades on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.5.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.5.2. Special Planting Instructions for Plantation

There is hundreds of Kanals of sloppy land feasible for the large grasses along the trees and bushes however, we recommend at the right and left bank of Pareshing Nallah where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation.

- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

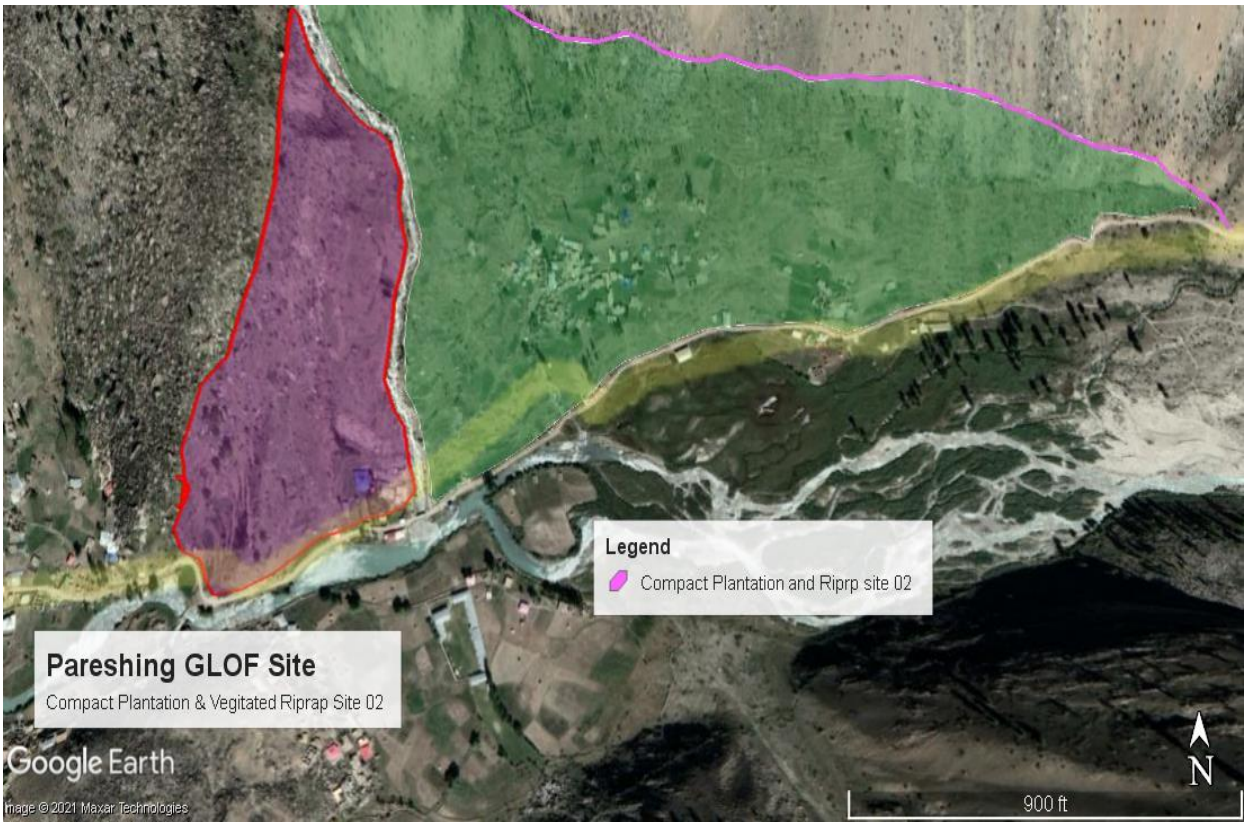
3.5.3. Budget Estimate

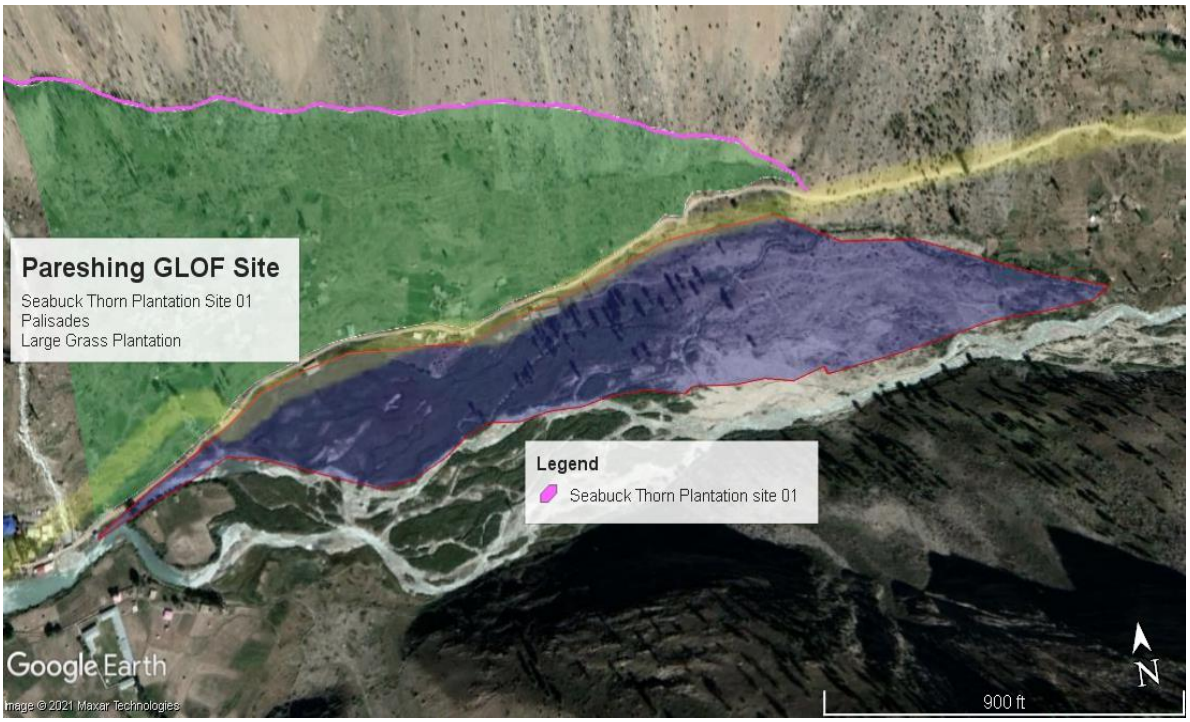
S.NO	Item	Unit	Unite price (PKR)	Total (PKR)
01	Alfalfa seeds	250kgs	3,000	750,000
03	Labor for site preparation & seeding	150 men days	1,000	150,000
04	Transportation to site	01	20,000	20.000
	Total			**920,000**

Summary of Budget for GLOF-II Site (Pareshing Valley Astore)

Activity No	Bioengineering Technique	Total (PKR)
01	Compact Planting and Vegetated Rip Rap	3,850,000
02	Live Fascines,	1,800,000
03	Sea buckthorn Plantation	900,000
04	Repair and extension of water channels	700,000
05	Grass Planting	920,000
Grand Total		**8,170,000**

Description: Water Channel **(Pink),** Plantation **(Green)** and seabuck thorn **(Light Pink)**




Pareshing GLOF Site
Seabuck Thorn Plantation Site 01
Palisades
Large Grass Plantation
Legend
Seabuck Thorn Plantation site 01
Google Earth
Image © 2021 Maxar Technologies
900 ft
N


Pareshing GLOF Site
Compact Plantation & Vegitated Riprap Site 03
Palisades
Large Grass Plantation
Legend
Compact Plantation and Riprap site 03
Google Earth
Image © 2021 Maxar Technologies
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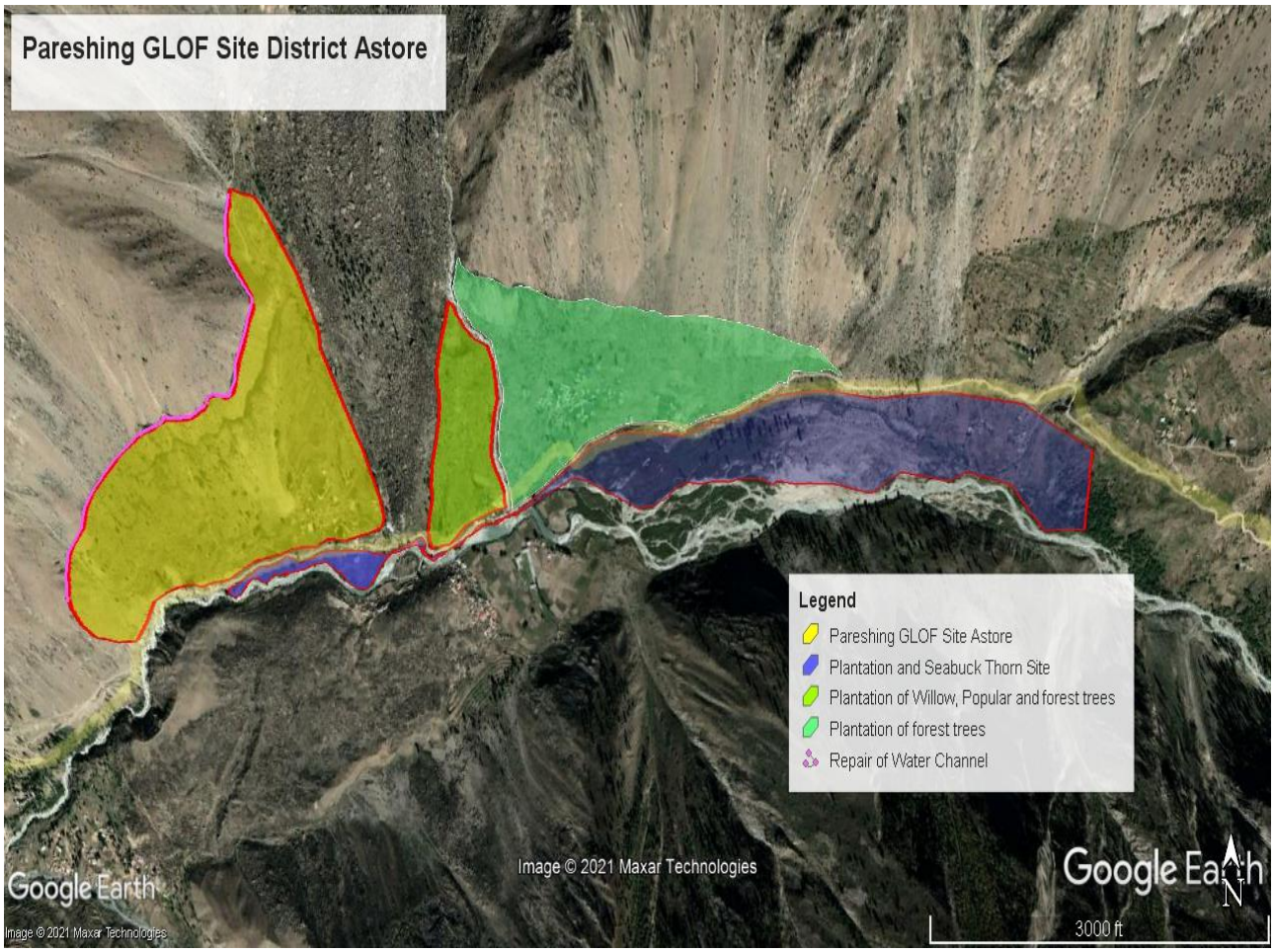

Pareshing GLOF Site District Astore
Legend
Pareshing GLOF Site Astore
Plantation and Seabuck Thorn Site
Plantation of Willow, Popular and forest trees
Plantation of forest trees
Repair of Water Channel
Image © 2021 Maxar Technologies
Google Earth
3000 ft
N

Section IV: District Hunza,
Chapter 05: GLOF-II Site Hassanabad, District Hunza, Gilgit-Baltistan

1. Description of the Site:

Hassanabad village, the most vulnerable and currently facing the challenges of GLOF in the mountains of Gilgit-Baltistan is located in Hunza district of Gilgit Baltistan. It is located at an elevation of 8093 with a central geographical coordinate of 36°18'7.01"N 74°35'10.33"E, at world geographical Globe. Shishper Glacier surged in 2018 and blocked the water stream starting from the snout of the Muchuhar glacier. The melting water formed a glacier lake and became one of the most dangerous glacier lakes of Gilgit Baltistan. It is almost 93 km from Gilgit, the capital city of Gilgit Baltistan and is situated at main KKH which connects Pakistan with China. Hassanabad is the very next village of Aliabad which is district headquarter of the Hunza district. The site is vulnerable because of the glacier surge of Shishper glacier and the community of around 170 households is living under consistent fear of outburst of the Glacier Lake.

During the early summer and in rainy seasons the Lake discharges water that erodes the embankments of the Nallah and causes heavy floods. The Nallah has loose material and debris which erodes and damages the agricultural land, orchards, fruit and forest trees, infrastructure such as water channels, houses of the community, power houses, roads and even threatens KKH. Above the Nallah there are barren slopes of loose material which shear in rainy and snow melting seasons; and because of weathering.

The valley is intersected with ridges and stream banks and landscape features are prone for slope instability issues. Stabled natural slopes for centuries fail because of deforestation, construction, weathering, flush flood and glacier outbursts.

Stream bank's erosion problem is persistently increasing when temperature in summer increases; streams receive more floods because of glacier outburst and flood. In many instances, significant uncertainty exists about the stability of the embankment and agricultural land nearby the streams and gaps of the site. It has damaged multiple times the agricultural land, houses and livestock in the recent past.

In addition to mitigating the negative impacts of erosion, control is often needed to satisfy therefore, use of live plants and plant parts, in which live cuttings and stems are placed in the ground of slopes or in earthen structures, where they provide additional support to soil, act as hydraulic drains, barriers to earth erosion and will provide a sustainable ecosystem that benefits both human society and the natural environment.

2. Site Assessment

2.1. Site Type

Hassanabad Nallah is located in areas of steep, unstable and erodible. The area usually remains affected by the extreme rainfall, GLOF events and found the area difficult to maintain critical infrastructure such as power houses and their supply system has been damaged; water supply system and irrigation channels were been disrupted; agricultural land and trees were smashed and in more intensive situations even houses of the communities were interrupted and families were dislocated.

Embankments of the water stream are vulnerable and continuously eroding during floods and GLOF events that carry filth, rocks and overflowing water have huge potential to cause damage to human settlements, land and infrastructure downstream. This is almost a regular annual feature especially in summer of this GLOF site.

The site is vulnerable for debris flow and situated in sediment producing zone. Both sides of the Nallah are dry and brunt but communities have planted trees and bushes in some patches. The use of bioengineering techniques alone is mainly confined to stream bank stabilization. By their nature, stream banks provide a good environment for growth of vegetation. Left alone, banks usually have dense vegetation as the stream provides nutrients in the form of silt and water to support growth. If vegetation is sufficient in the stream bed, it can stabilize the bank, lessen erosion, reduce the speed of flowing water, and reduce scouring by a flood wave. Where vegetation has been reduced or removed, it can be replaced by planting of appropriate species to achieve the desired effect. Structures formed from a combination of dead and living plant material can also be used to guide the river course and prevent flood entering into settlements and farmland. The plants can provide additional benefits for the local population like fodder, fruit, and firewood, but this is secondary to the protective function.

More resilient infrastructure means protection of agricultural land for farming; roads for easy communication; forest to slow down the erosion and mitigate climate change phenomenon. Stronger stream bank defenses mean that communities are protected from flood. Better and resilient infrastructure systems help to grow more crops and people are spending less time to collect and transporting water from long distances for domestic uses especially in winters.

2.2. Slope Length

Hassanabad Nallah is situated in narrow gorge of huge mountains on both sides. The village is situated on the footings of these mountains and at the edge of the water stream. There is hard rock, sandy soil, loose material slopes in patches on both sides of the water stream. The slopes are of very different sizes in length and width ranging from fifty to hundreds of feet long and wide. Stream bank is more than five KM long from Shishper Glacier to the snout of Hunza Nagar River. However, there are small segments of slopes of different sizes and lengths are situated across the main stream. The slopes have landslide issues as well as surface erosion during climatic conditions.

2.3 Topography (Slope, Angle and Material Drainage)

Hassanabad valley is situated between two high mountains different segments of the slopes vary from 30 to 70 degree angle. The main slop is of 20 to 35 degree angle. The stream flows in 10 to 20 degree angle downwards in the river. Material drainage of the main slope during the disaster drains in the water stream. It causes heavy floods in the stream that triggers embankment erosion and damage existing infrastructure. There is no any specific or single drainage way of the erosion and material. Surface water of the site slopes drain directly into the water stream in many segments but in most of the area it affects the infrastructure of the village by damaging irrigation channels, water supply, roads, forest trees, fodder and pony tracks.

3.4. Moisture

The bare soil-covered slope above the village is dry and becomes wet during rainy and snow melting seasons. It's easily erodible during rains and splash of rain in rainy seasons. Intense rain leads to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. The surface runoff rate is also very high, and the flowing water carries the soil particles away and triggers debris flow from the slope. Because of no vegetation cover on the slope segments, roughness of slope surface increases and rain and melting snow easily erode through the gaps and near the village it becomes a disaster for community by destructing agricultural land, trees, forests, pastures, livestock and lives of the community. Dense cover, if forest trees and vegetation are grown at the slope, may protect the soil splash effects and can reduce runoff velocity, while roots of the vegetation may bind the soil particles, resulting to hinder surface erosion.

2.5 Stream Bank

Hassanabad Nallah is flowing through the middle of the main village dividing the village in two sub villages. The floods in the stream cause heavy embankment erosion and put the village and infrastructure to damage. Therefore, embankment erosion issue is persistently harms the infrastructure, roads, bridges, water supply and forest and agricultural cover. Both sides of the water stream of the valley are dry and muddy which are susceptible for erosion. Furthermore, heavy rains and floods increase the moisture of the barren stream banks and erosion increases. Heavy floods had eroded the main village and houses, forest and fruit trees and agricultural land as well. More than 20 houses were migrated in recent past.

4. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment exposed slope and embankment problems in the Hassanabad GLOF Site. The initial survey team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the problem and prioritized some sites as high risks and some had moderate risks.

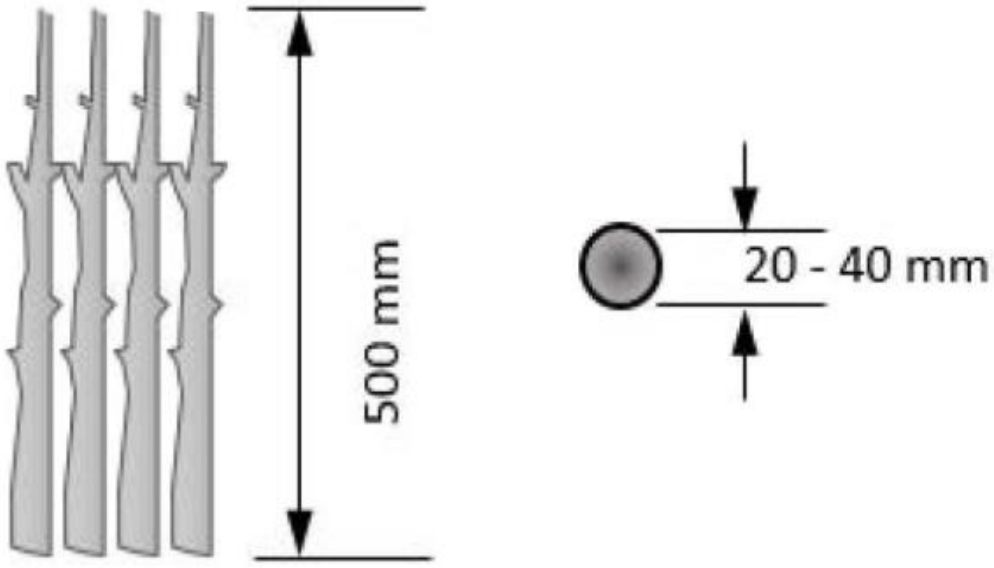
The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

4.1. Live Fascines

A palisade is a fence or wall made from wooden stakes or tree trunks. Palisades were used historically as a defensive structure. In slope and embankments' protection, palisades are barriers made from live wood cuttings installed across a slope following the contour in order to trap debris moving down the slope, to armour and reinforce the slope, and to increase the infiltration rate. Palisades are used to prevent the extension of deep, narrow gullies and the erosion of V-shaped rills by forming a strong barrier which stabilizes the gully floor and traps material moving downwards. They are also effective on steep landslide or debris slopes. Palisades can be used on a wide range of sites with slopes of up to about 60°.

This procedure applies to use live cuttings of willow, popular, other indigenous and local species of plants which are commonly available in Hassanabad valley in District Hunza of Gilgit Baltistan. It is best to use local species as they are already adapted to the growing conditions; are more like to be resistant to local diseases; are more readily available; and are likely to be on lower cost options. Live hardwood willow, popular, shrub cuttings are laid in successive shallow trenches, in lines across the slope, usually following the contour. The tips of the cuttings protrude just beyond the face of the slope, where they grow buds and leaves that intercept rainfall, slow runoff and filter sediments. In addition to the exposed stems catching surface debris, as the roots develop they reinforce the upper soil layers. This techniques are used to stabilize embankments (fill slopes) or less steep cut-slopes. The roots add tensile reinforcement to the slope and provide a measure of frictional resistance to shallow sliding. The protruding brush retards runoff and reduces surface erosion. Brush wood layers give both immediate and increasingly strong protection and reinforcement to newly constructed fill and cut slopes. They are also a good remedial measure for repairing eroded gullies. The perpendicular orientation of brush layering to the slope is effective in terms of earth reinforcement and near-surface stabilization of the slope.

Preparation of Cuttings for Palisades

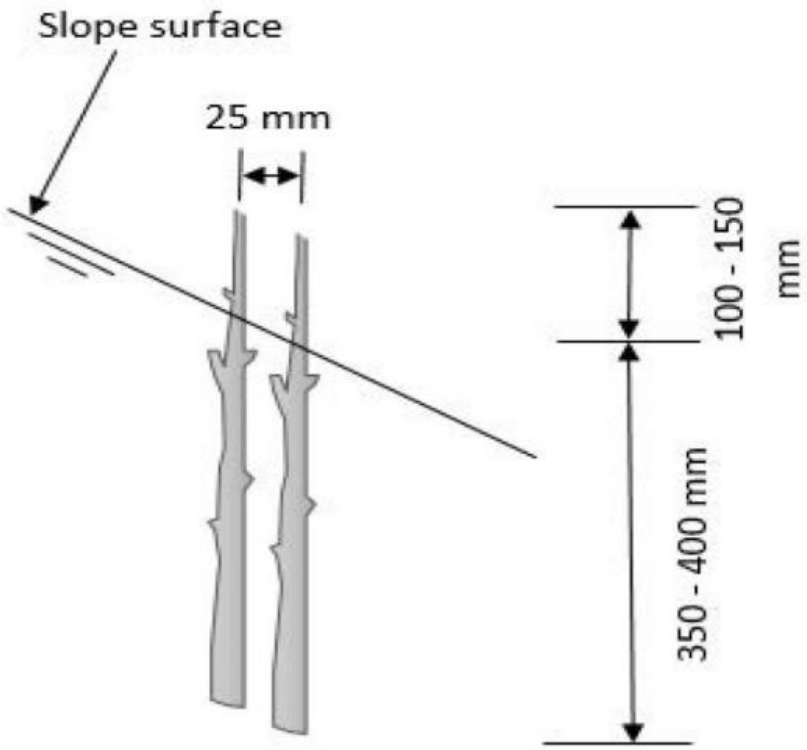


4.1.1. Site Preparation

The site along the water stream should be prepared before planting the cuttings of willow, popular, shrubs and other local species. Debris must be removed, depressions should be filled and humps should be leveled off to attain a linear profile. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 250mm above the toe of the slope, 1000mm centers up the slope and at the edge of the water stream 12 inches of distance from water level of summer season.

4.1.2. Planting Instructions

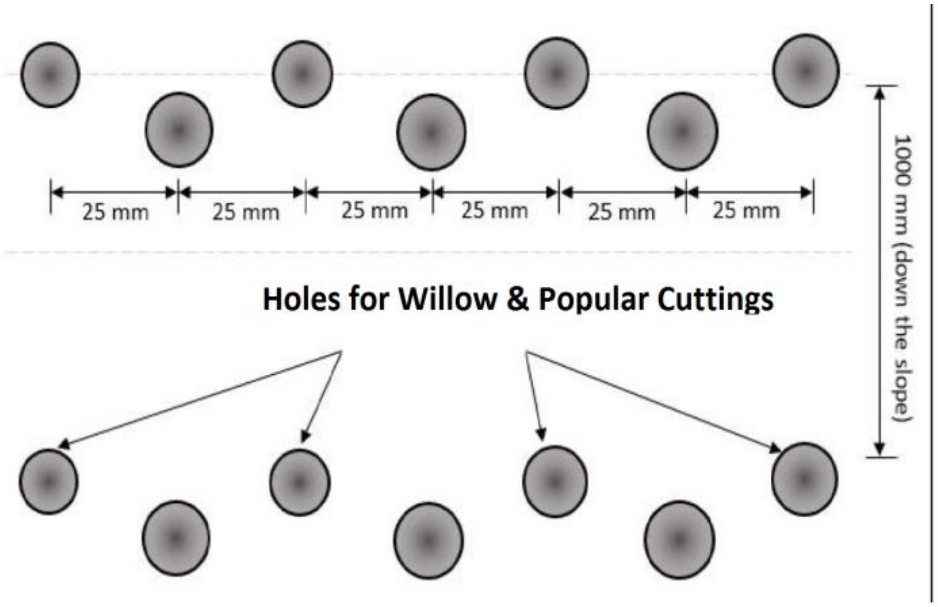
- Plant cuttings must be prepared from the woody material of 6 to 18 months in age.
- Cuttings should be approximately 20 mm dia., 500 mm length. They are laid in shallow trenches.
- These cuttings should be buried in moist soil for 3 to 7 days



- These cuttings may be immersed in water for two or three days
- When land is prepared plant the cuttings within 12 hours
- Cuttings from willow, popular and shrubs are more feasible for the local environment however; any other plant cutting must be suited to the site and shows

the correct habit for an ability to grow from the cuttings. For example many shoots coming from the stems.

- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- Side branches shall be trimmed off carefully with a sharp tool.
- The cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- As with grass planting, the brush layers can also be angled to enhance drainage.
- Planting should be by experienced agricultural labor with technical supervision.
- Always start at the top of the slope and work downwards
- Using a pointed bar, make a hole that is bigger than the cutting
- Carefully place the cutting in the hole so that two third is buried, firm the soil around it, taking care not to damage the bark
- Make the next hole 50mm along the row



4.1.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Local live Plant cuttings	30000 cuttings	40 Rs.	1200000
02	Transportation,	30000 cuttings	20 Rs.	600000
03	Laboring (Men days)	300 men days	1000	300000
	Total			**2100000**

4.2. Vegetated Rip Rap And Compact Planting

Slopes of the Hassanabad are have loose material that have high tendency to roll down the slope because of the erosion caused by the rain, wind and weathering. This erosion of the slope can be controlled by the vegetated riprap and compact plating of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of Juniper, willow, popular and other indigenous plants on the slopes, in ditches, valleys and gullies. Willow and long cuttings of popular and other local plants are easily available in Hunza District. But Juniper, Cedar, Spruce and Pine can be supplied from the forest nurseries and suppliers of the forest plants. Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil up to 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

4.2.1. Site Preparation

The site has vast scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of the valley are 30 to 50 degree angle.

4.2.2. Special Instructions for Willow, Russian Olive and Popular Cuttings

- Long cuttings of Willow, Russian Olive and Popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants (willow and popular) are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

4.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings & Rooted Plants of willow and popular (all inclusive)	30000 cuttings	90 Rs.	2700000
02	Plants of Juniper, spruce, Cedar and Pine (all inclusive)	5000	230	1150000
	Total			**3850000**

4.3. Sea buckthorn and Willow Plantation

Sea buckthorn, willow and bush's roots mainly protect soil one meter deep and plays a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

4.3.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier. Picked out Seabuck plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

4.3.2. Special Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Seabuck plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height
- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

4.3.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants	20000 plants	50 Rs.	1000000
02	Transportation	20000 plants	20 Rs.	400000
03	Labor for digging pits and plantation (Men days)	400 men days	1000 Rs.	400000
	Total			**1800000**

4.4. Repair and extension of existing water channels

On both sides of the Nallah there are traditional water channels for agricultural and irrigation of fruit and forest trees. These water channels required to be repair and one is extended to plant forest trees on barren land near the Hunza-Nagar River. These channels will provide more irrigation water for vegetated riprap plantation, compact planting and long grass planted areas in Hassanabad.

4.4.1. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of water channel one	01	350000.	350000

02	Repair and extension of water channel two	01	450000	450000
	Total			**800000**

4.5. Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting and palisades on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

4.5.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

4.5.2. Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the large grasses along the trees and bushes however, we recommend at the right and left bank of Hassanabad Nallah where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation.

- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April

- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

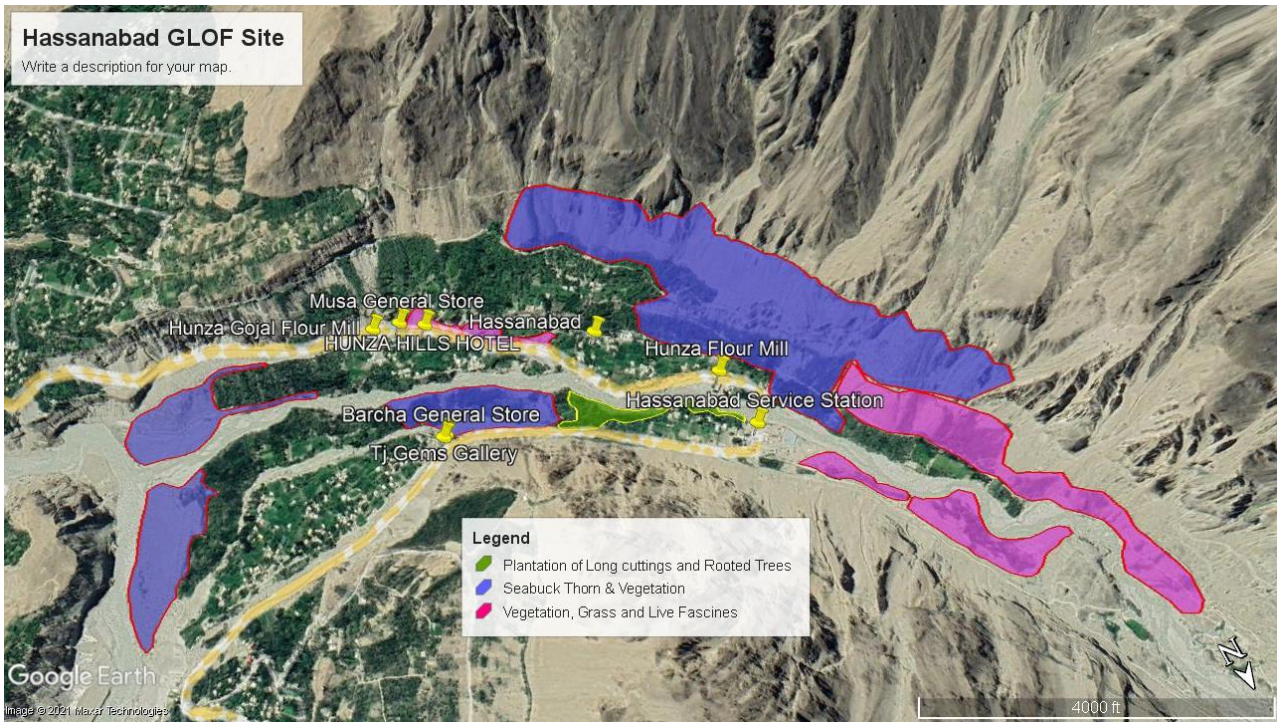
4.5.3. Budget Estimate

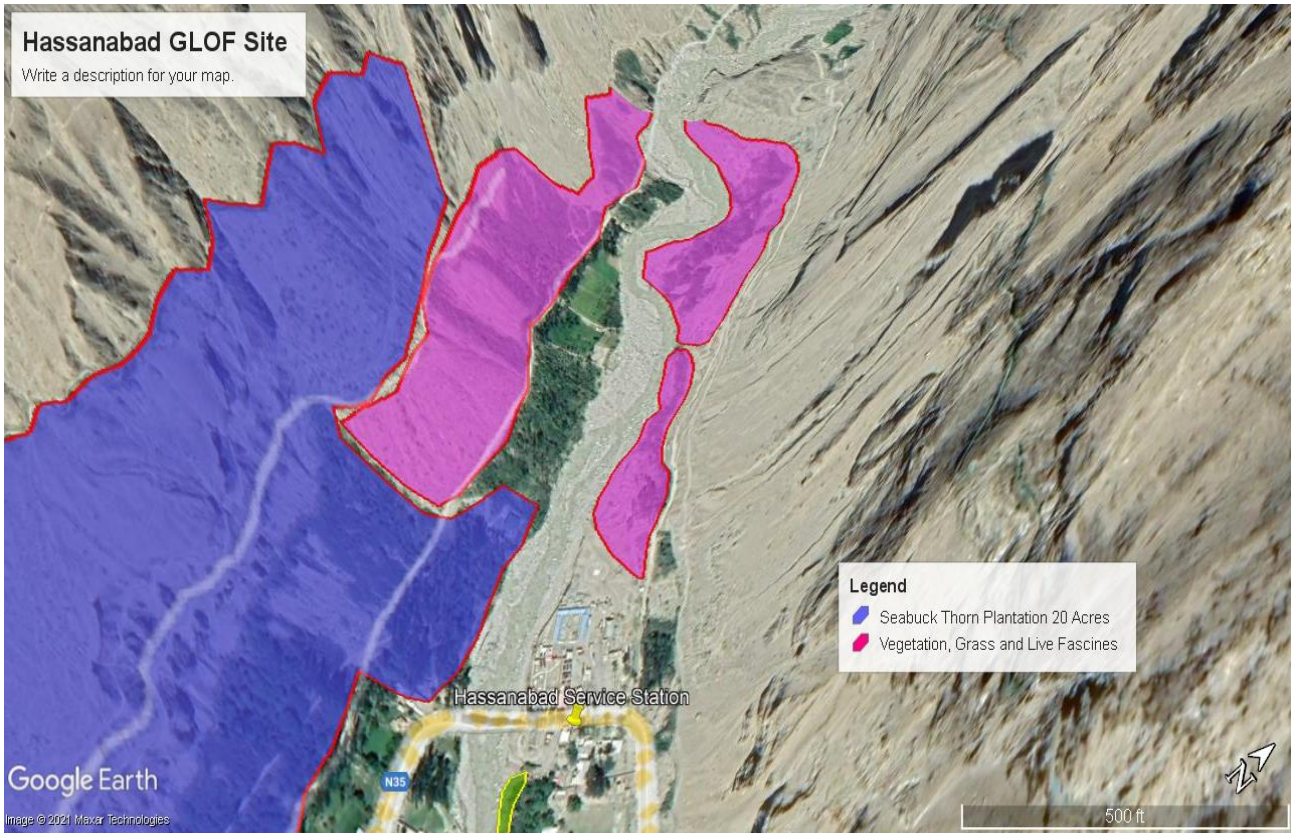
S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds	300kgs	3000	900000
03	Labor for site preparation & seeding	150 men days	1000	150000
04	Transportation to site	01	20000	20000
	Total			**1070000**

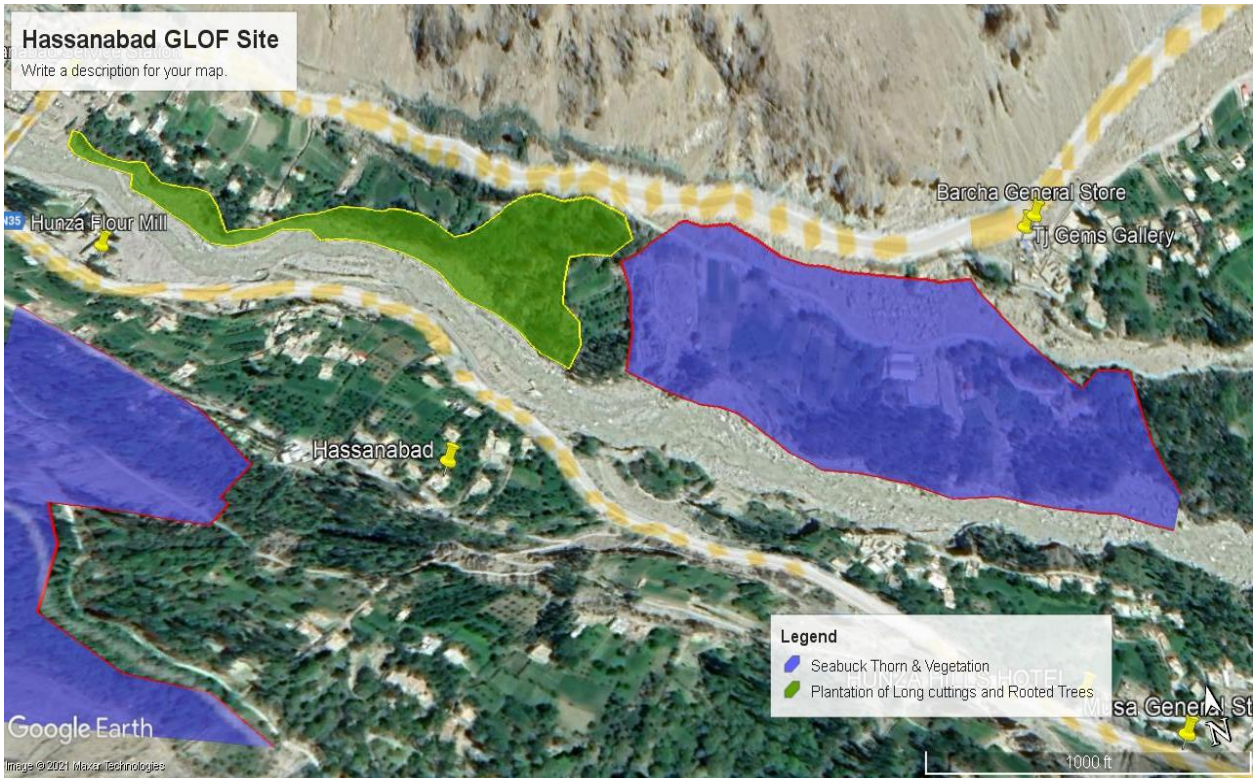
TOTAL PROPOSED BUDGET FOR GLOF-II SITE (HASSANABAD, DISTRICT HUNZA)

Activity No	Bioengineering Technique	Total
01	Palisades, Live Fascines,	2100000
02	Compact Planting and Vegetated Rip Rap	3850000
03	Sea buckthorn Plantation	1800000
04	Repair and extension of water channels	800000
05	Grass Planting	1070000
Grand Total		**9620000**

Maps of Hassanabad GLOF Site for bioengineering






Hassanabad GLOF Site
Write a description for your map.
Hunza Flour Mill
Barcha General Store
TJ Gems Gallery
Hassanabad
Legend
Seabuck Thorn & Vegetation
Plantation of Long cuttings and Rooted Trees
Google Earth
Image © 2021 Maxar Technologies
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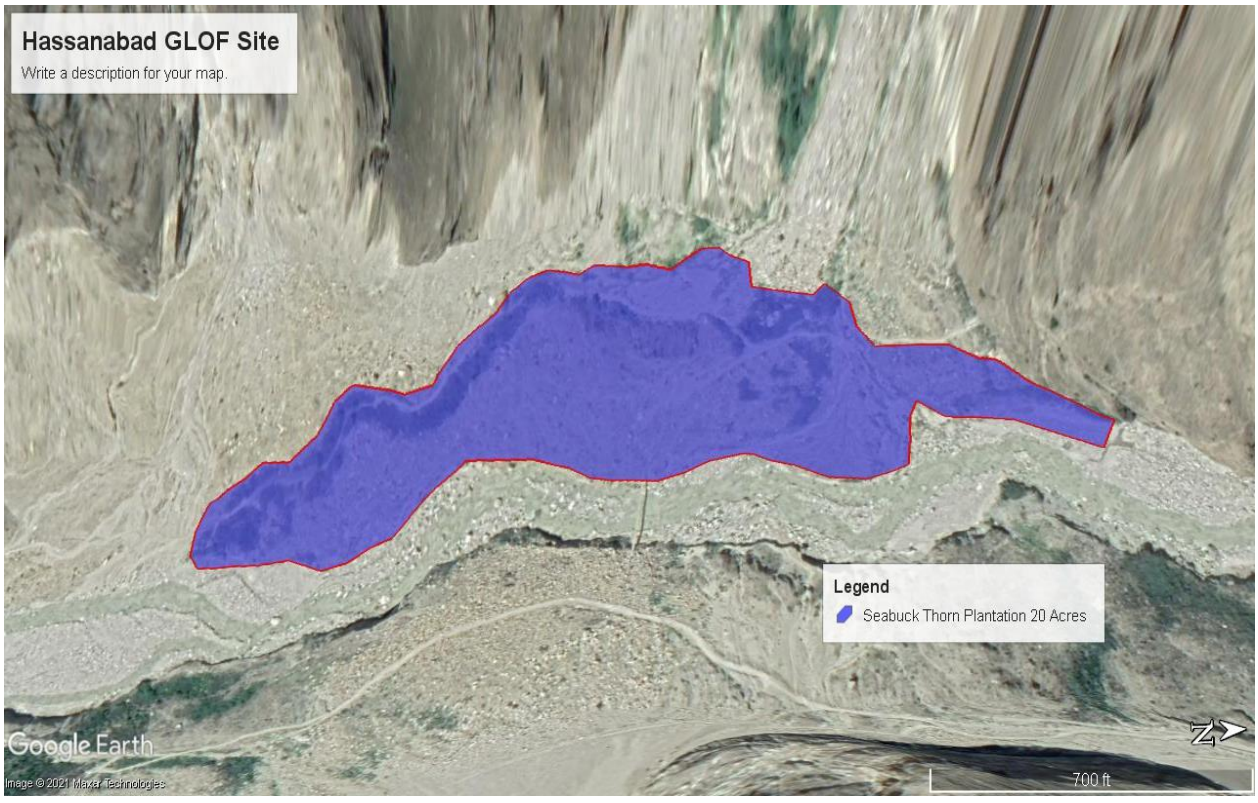

Hassanabad GLOF Site
Write a description for your map.
Legend
Seabuck Thorn Plantation 20 Acres
Google Earth
Image © 2021 Maxar Technologies
700 ft

Section IV: District Hunza,
Chapter 06: GLOF-II Site Ghulkin-Hussani, District Hunza, Giglit-Baltistan

1. Introduction

Ghulkin-Hussani Site of GLOF is consisted between two villages of Gojal subdivision in Hunza District. Gulkin is faces threats of Gulmit Glacier and Ghulkin-Hussani glacier both. Gulkin is located at an elevation of 8699ft with a central geographical coordinate of 36°24'26.47"N, 74°51'39.91"E, and Hussani village is at an elevation of 8264ft with a central geographical coordinate of 36°25'22.51"N, 74°52'36.03"E, at world geographical Globe.

The Gulkin-Hussani Glacier surges and usually floods keep the drainage changing from time to time therefore; it has devastated huge forest land and infrastructure in the area. It is almost 1337Km via Karakoram Highway from Gilgit, the capital city of Gilgit Baltistan and is situated at main KKH which connects Pakistan with China. The site is vulnerable because of the glacier surge, GLOF events and changing drainage of the glacier.

During the early summer and in rainy seasons the glacier discharges water that erodes the embankments of downstream and causes heavy floods. The Nallah has stones and debris material which erodes and damages the land, orchards, fruit and forest trees, infrastructure such as water channels, roads and even threatens KKH. Above the Nallah there are barren slopes which shear in rainy and snow melting seasons; and because of weathering.

The valley is intersected with ridges and stream banks and landscape features are prone for slope instability issues especially debris flow. Most of the slopes are stabled but barren naturaly these can be vegetated by planting gross, willow, Sea buckthorn, popular, Russian olive, and other local species those will contribute to reduce GLOF events. Stream bank's erosion problem is persistently increasing when temperature in summer increases; streams receive more floods because of glacier outburst and flood. In many instances, significant uncertainty exists about the stability of the embankment and land nearby the streams and infrastructure below the glacier especially KKH and bridges.

2. Site Assessment

2.1. Site Type

Ghulkin-Hussani Glacier is situated along the village between Gulkin and Hussani villages. Hussaini village is situated in the footings of the glacier while Gulkin is beside the village. This site is located in areas of steep, most of the area is stable and stream water erodes the embankments. Embankments of the water stream are vulnerable and

continuously eroding during floods and GLOF events that carry filth, rocks and overflowing water have huge potential to damage settlements, land and infrastructure downstream. This is almost a regular annual feature especially in summer of this GLOF site.

The site is vulnerable for debris flow in many segments. Both sides of the glacier are dry and brunt but communities have planted trees and bushes in some patches. The use of bioengineering techniques alone is mainly confined to reduce the threat of stream bank erosion and GLOF events. Where vegetation has been reduced or removed, it can be replaced by planting of appropriate species to achieve the desired effect. Structures formed from a combination of dead and living plant material can also be used to guide the river course and prevent flood entering into settlements and farmland. The plants can provide additional benefits for the local population like fodder, fruit, and firewood, but this is secondary to the protective function.

More resilient infrastructure means protection of agricultural land for farming; roads for easy communication; forest to slow down the erosion and mitigate climate change phenomenon. Stronger stream bank defenses mean that communities are protected from flood. Better and resilient infrastructure systems help to grow more crops and people are spending less time to collect and transporting water from long distances for domestic uses especially in winters.

2.2 Slope Length

Slopes on Gulkin and Hussaini both are of different length and width ranging from 100 meters to 300 meters long and 50 to 100 meters wide. Both the villages are situated on the footings of the glacier and at the edge of the water stream. There is hard rock, sandy soil, loose material slopes in patches on both sides of the water stream. Stream bank is 400 to 600 meters long in different areas Glacier to the snout of Hunza River. However, there are small segments of slopes of different sizes and lengths are situated across the main stream. The slopes have landslide issues as well as surface erosion during climatic conditions.

2.3. Slope Angle and Material Drainage

Gulkin-Hussani glacier is situated between these two villages and slopes of both villages vary from 20 to 45 degree angle. The main slop of the Gulkin identified for Sea buckthorn plantation is of 20 to 45 degree angle. The stream flows in 20 to 45 degree angle downwards towards the river. Material drainage of the main slope during the

disaster drains in the gorge. The main stream is directly drains into Hunza River after crossing KKH and Bridge. Near the Hunza River it spreads and damages a huge cultivable area which is under sand, mud and debris because of floods.

2.4. Moisture

The bare soil-covered slopes in both villages are dry and becomes wet during rainy and snow melting seasons. They have debris and huge stones on the slopes. Intense rain leads to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. Because of no vegetation cover on the slope segments, roughness of slope surface increases and rain and melting snow can easily erode through the gaps and near the village it becomes a disaster for community by destructing agricultural land, trees, forests, livestock and lives of the community. Dense cover, if forest trees and vegetation are grown at the slope, may protect the soil splash effects and can reduce runoff velocity, while roots of the vegetation may bind the soil particles, resulting to hinder surface erosion.

2.5. Stream Bank

Gulkin Nallah is flowing through the middle of the main village dividing the Gulkin and Hussani in to two villages. The floods in the stream cause heavy embankment erosion and put both villages and their infrastructure to damage. Therefore, embankment erosion issue is persistently harms the infrastructure, roads, bridges, water supply and forest cover. Both sides of the water stream of the valley are dry and muddy which are susceptible for erosion. Under the stream main KKH and bridges constructed over the stream are vulnerable as the stream keeps its direction usually changing.

3. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment exposed slope and embankment problems in the Gulkin-Hussani GLOF Site. The initial survey team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the problem and prioritized some sites as high risks and some had moderate risks. The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

3.1. Sea Buckthorn Plantation

Sea buckthorn and bush's roots mainly protect soil one meter deep and plays a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.1.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier. Picked out Seabuck plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.1.2. Special Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Sea buckthorn plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height
- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

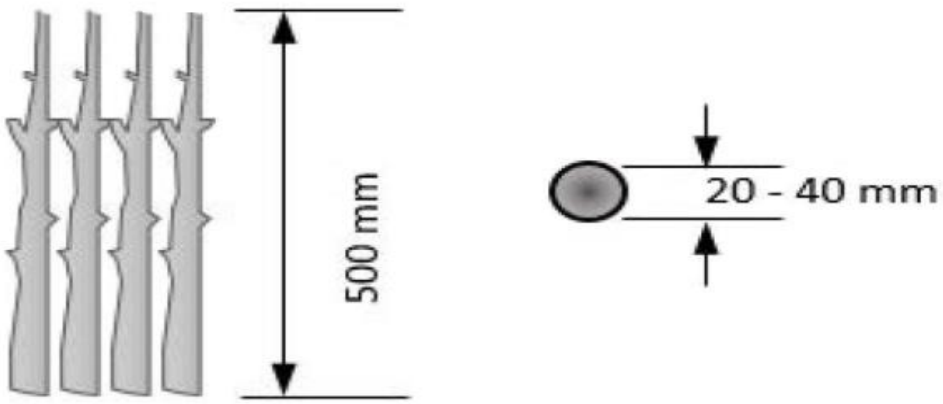
3.1.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants for Gulkin.	10000 plants	50 Rs.	**500000**
02	Laboring for digging pits and plantation	200 men days	1000	**200000**
03	Transportation	10000	20	**20000**
04	Sea buckthorn Plants for Hussani	10000 plants	85 Rs.	**850000**
05	Laboring for digging pits and plantation	200 men days	1000	**200000**
06	Transportation	10000	20	**20000**
	Total			**1790000**

3.2. Live Fascines

A palisade is a fence or wall made from wooden stakes or tree trunks. Palisades were used historically as a defensive structure. In slope and embankments' protection, palisades are barriers made from live wood cuttings installed across a slope following the contour in order to trap debris moving down the slope, to armour and reinforce the slope, and to increase the infiltration rate. Palisades are used to prevent the extension of deep, narrow gullies and the erosion of V-shaped rills by forming a strong barrier which stabilizes the gully floor and traps material moving downwards. They are also effective on steep landslide or debris slopes. Palisades can be used on a wide range of sites with slopes of up to about 60°.

Preparation of Cuttings for Palisades



This procedure applies to use live cuttings of willow, popular, other indigenous and local species of plants which are commonly available in Hassanabad valley in District Hunza of Gilgit Baltistan. It is best to use local species as they are already adapted to the growing conditions; are more like to be resistant to local diseases; are more readily available; and are likely to be on lower cost options. Live hardwood willow, popular, shrub cuttings are laid in successive shallow trenches, in lines across the slope, usually following the contour. The tips of the cuttings protrude just beyond the face of the slope, where they grow buds and leaves that intercept rainfall, slow runoff and filter sediments. In addition to the exposed stems catching surface debris, as the roots develop they reinforce the upper soil layers. This techniques are used to stabilize embankments (fill slopes) or less steep cut-slopes. The roots add tensile reinforcement to the slope and provide a measure of frictional resistance to shallow sliding. The protruding brush retards runoff and reduces surface erosion. Brush wood layers give both immediate and increasingly strong protection and reinforcement to newly constructed fill and cut slopes. They are also a good remedial measure for repairing eroded gullies. The perpendicular orientation of brush layering to the slope is effective in terms of earth reinforcement and near-surface stabilization of the slope.

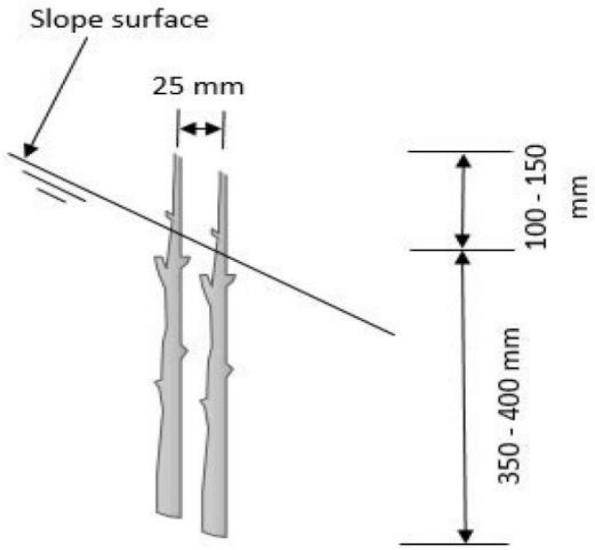
3.2.1. Site Preparation

The site along the water stream should be prepared before planting the cuttings of willow, popular, shrubs and other local species. Debris must be removed, depressions should be filled and humps should be leveled off to attain a linear profile. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 250mm above the toe of the slope, 1000mm centers up the slope and at the edge of the water stream 12 inches of distance from water level of summer season.

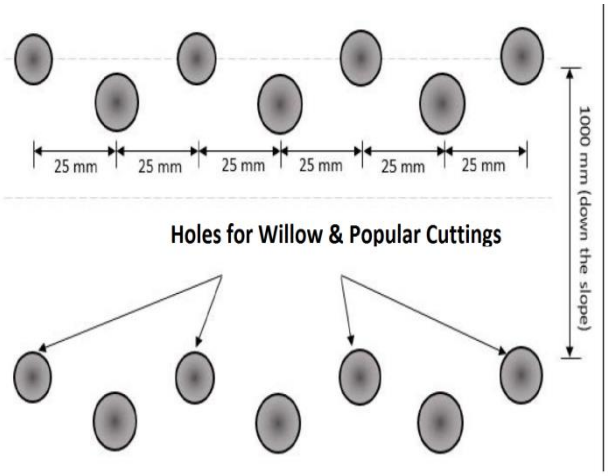
3.2.2. Planting Instructions

- Plant cuttings must be prepared from the woody material of 6 to 18 months in age.
- Cuttings should be approximately 20 mm dia., 500 mm length. They are laid in shallow trenches.
- These cuttings should be buried in moist soil for 3 to 7 days

- These cuttings may be immersed in water for two or three days
- When land is prepared plant the cuttings within 12 hours
- Cuttings from willow, popular and shrubs are more feasible for the local environment however; any other plant cutting must be suited to the site and shows the correct habit for an ability to grow from the cuttings. For example many shoots coming from the stems.



- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- Side branches shall be trimmed off carefully with a sharp tool.
- The cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- As with grass planting, the brush layers can also be angled to enhance drainage.
- Planting should be by experienced agricultural labor with technical supervision.
- Always start at the top of the slope and work downwards



- Using a pointed bar, make a hole that is bigger than the cutting
- Carefully place the cutting in the hole so that two third is buried, firm the soil around it, taking care not to damage the bark
- Make the next hole 50mm along the row

3.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Local live Plant cuttings of willow, popular, and Russian olive for Gulkin	15000 cuttings	60 Rs.	900000
02	Laboring for digging pits and plantation	250 men days	1000	250000
03	Transportation	15000	30	45000
04	Local live Plant cuttings of willow, popular, and Russian olive for Hussani	15000 cuttings	60 Rs.	900000
05	Laboring for digging pits and plantation	250 men days	1000	250000
06	Transportation	15000	30	45000
	Total			**2390000**

3.3. Vegetated Rip Rap and Compact Planting

Slopes of the Preshing valley are have loose material that have high tendency to roll down the slope because of the erosion caused by the rain, wind and weathering. This erosion of the slope can be controlled by the vegetated riprap and compact plating of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of willow, popular and other indigenous plants on the slopes, in ditches, valleys and gullies. Willow and long cuttings of popular and other local plants are easily available in Gojal sub division of Hunza District. But Juniper, Cedar, Spruce and Pine can be supplied from the forest nurseries and suppliers of the forest plants. Stems and

roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil upto 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

3.3.1. Site Preparation

The site has vast scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of the valley are 30 to 50 degree angle.

3.3.2. Special Instructions for Willow and Popular Cuttings

- Long cuttings of Willow, Russian Olive and Popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants (willow and popular) are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row

- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

3.3.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings & Rooted Plants of willow and popular for Gulkin	20000 cuttings	80 Rs.	1600000
02	Laboring for digging pits and plantation	200 men days	1000	200000
	Transportation	20000	30	60000
02	Long cuttings & Rooted Plants of willow and popular for Hussani	20000 cuttings	80 Rs.	1600000
	Laboring for digging pits and plantation	200 men days	1000	200000
	Transportation	20000	30	60000
	Total			**3720000**

3.4 Repair and extension of existing water channels

In both villages there are traditional water channels for agricultural and irrigation of fruit and forest trees. These water channels required to be repair and both can be extended to plant forest trees on barren land. These water channels are earthen channels and do not require cement and concrete work.

There are two water channels in Gulkin village for repair and extension. One is 1347 meter long. This Channel will irrigate 19.4 Acre of planted land and second one is 387 meters long including extension.

Water channel of Hussani is 1400 meter long including extension. This will irrigate 58.5 Acres of barren and planted land after repair and extension.

3.4.1. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of two water channels in Gulkin	02	350000.	700000
02	Repair and extension of water channel Hussani	01	450000	450000
	Total			**1150000**

3.5. Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting and palisades on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.5.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.5.2. Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the large grasses along the trees and bushes however, we recommend at the areas where slopes mostly are 30 to 45 degree

angle and water facility is available for irrigation. The seeds can be seeded in the areas of repair and extended water channels.

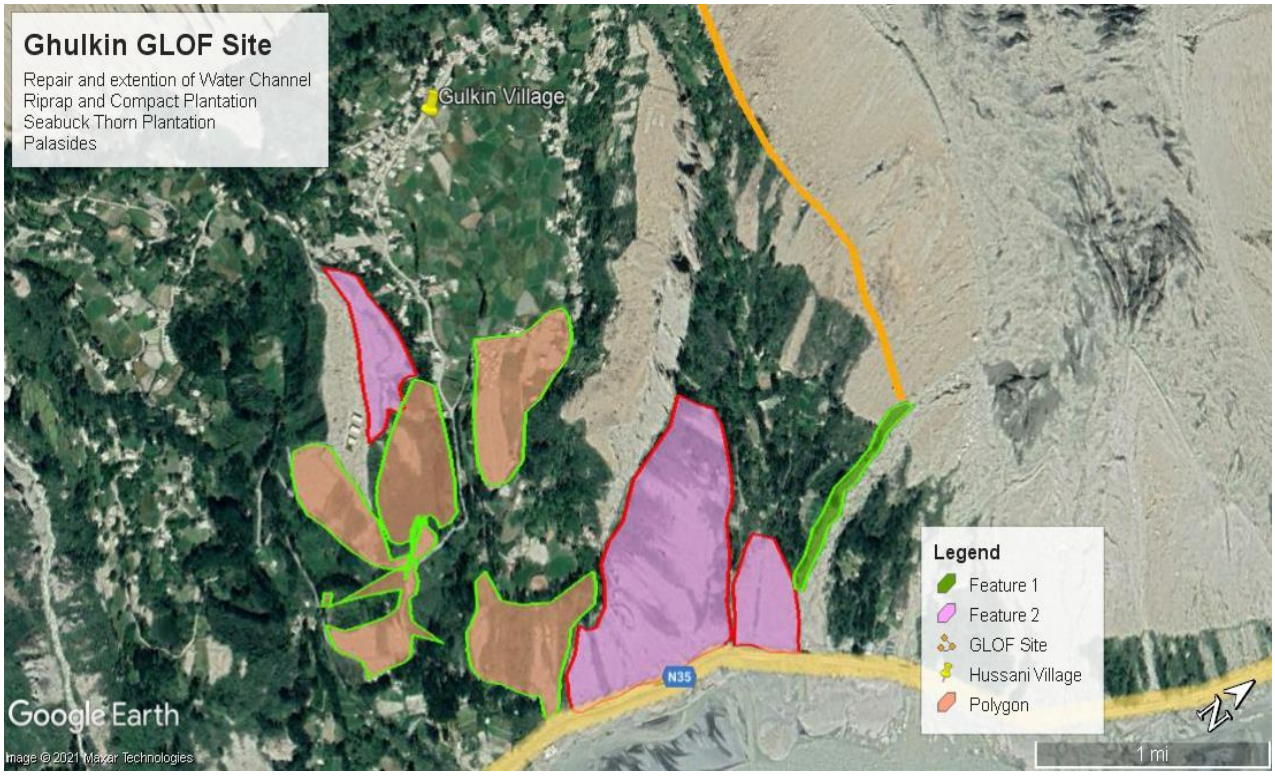
- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

3.5.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds All Inclusive for Gulkin	150kgs	3000	450000
02	Alfalfa seeds All Inclusive for Gulkin	150kgs	3000	450000
	Total			**900000**

Total Proposed Budget for GLOF-II Site (Gulkin-Hussani, District Hunza)		
Activity No	**Bioengineering Technique**	**Total**
01	Sea buckthorn Plantation	1790000
02	Palisades, Live Fascines,	2390000
03	Compact Planting and Vegetated Rip Rap	3720000
04	Repair and extension of water channels	1150000
05	Grass Planting	900000
Grand Total		**9950000**

Maps of Gulkin-Hussani GLOF Site for Bioengineering


Ghulkin GLOF Site
Repair and extention of Water Channel
Riprap and Compact Plantation
Seabuck Thorn Plantation
Palasides
Gulkin Village
N35
Legend
Feature 1
Feature 2
GLOF Site
Hussani Village
Polygon
Google Earth
Image © 2021 Maxar Technologies
1 mi


Hussani GLOF Site
Repair and extention of Water Channel
Riprap and Compact Plantation
Hussani Village
Legend
Feature 1
Feature 2
GLOF Site
Hussani Village
Polygon
Google Earth
Image © 2021 Maxar Technologies
1000 ft

Section IV: District Hunza,
Chapter 07: GLOF-II Site Shimshal, District Hunza, Gilgit-Baltistan

1. Introduction and Description of Site

Shimshal GLOF Site is situated in the last valley of Hunza District in Gilgit Baltistan. Shimshal is located at an elevation of 10677ft with a central geographical coordinate of 36°26'8.15"N, 75°19'36.72"E, with a central geographical coordinate of, at world geographical Globe. It is a valley more than a village in Hunza District and scattered in sub villages and plains. It is almost 210KM via Karakoram Highway from Gilgit, the capital city of Gilgit Baltistan and 114 KM from District Headquarter (Aliabad) of Hunza district. Shimshal valey is located on north east from the Passu Gojal and three hours' drive through high passes, glaciers and rugged mountains. towards Shimashal and through steep valley and gorges the roads leads to Shimshal Valley.

There are multiple glaciers in Shimshal valley ranging from Malangoti glacier to Yazghail, Khurdopin Glacier. There are three main water streams descending from the glaciers and fall into Shimshal River. The site is vulnerable because of the glacier surge, GLOF events and changing drainage of the glaciers in multiple areas.

During the early summer and in rainy seasons the glacier discharges water that erodes the embankments of downstream and causes heavy floods. The streams have stones and debris material which erodes and damages the land, orchards, fruit and forest trees, infrastructure such as water channels, roads and houses. Above the valley there are barren slopes which shear in rainy and snow melting seasons; and because of weathering.

The valley is intersected with ridges and stream banks and landscape features are prone for slope instability issues especially debris flow. Most of the slopes are unstable and barren naturally because of the high elevation. These can be vegetated by planting gross, willow, Sea buckthorn, popular, Russian olive, and other local species those will contribute to reduce GLOF events. Stream bank's erosion problem is persistently increasing when temperature in summer increases; streams receive more floods because of glacier outburst and flood. In many instances, significant uncertainty exists about the stability of the embankment and land nearby the streams and infrastructure below the glacier especially infrastructure and agricultural land. The environment in Shimshal is prone to frequent floods and avalanches which threaten its populations mobility and livelihoods.

2. Site Assessment

2.1. Site Type

Shimshal Valley is situated in North East in Gilgit Baltistan. it is situated in the footings of the glaciers and water stream flows in multiple areas of the valley. This site is located in areas of steep, most of the area is unstable and stream water erodes the embankments. Embankments of the water stream are vulnerable and continuously eroding during floods and GLOF events that carry filth, rocks and overflowing water have huge potential to damage settlements, land and infrastructure downstream. This is almost a regular annual feature especially in summer of this GLOF site.

The site is vulnerable for debris flow in many segments. The sides of the glacier are dry and brunt but communities have planted trees especially Sea buckthorn and bushes in many patches. The use of bioengineering techniques alone is mainly confined to reduce the threat of stream bank erosion, slope erosion and GLOF events. Where vegetation has been reduced or removed, it can be replaced by planting of appropriate species to achieve the desired effect. Structures formed from a combination of dead and living plant material can also be used to guide the river course and prevent flood entering into settlements and farmland. The plants can provide additional benefits for the local population like fodder, fruit, and firewood, but this is secondary to the protective function.

More resilient infrastructure means protection of agricultural land for farming; roads for easy communication; forest to slow down the erosion and mitigate climate change phenomenon. Stronger stream bank defenses mean that communities are protected from flood. Better and resilient infrastructure systems help to grow more crops and people are spending less time to collect and transporting water from long distances for domestic uses especially in winters.

2.2. Slope Length

Slopes in Shimshal Valley are of different length and width ranging from 100 meters to 300 meters lon and 50 to 100 meters wide. The valley is situated on the footings of the glacier and at the edge of the water stream. There is hard rock, sandy soil, loose material slopes in patches on both sides of the water stream. Stream bank is 400 to 600 meters long in different areas Glacier to the snout of Shimshal River. However, there are small segments of slopes of different sizes and lengths are situated across the main stream. The slopes have landslide issues as well as surface erosion during climatic conditions.

2.3. Slope Angle and Material Drainage

The slopes of the Shimshal valley fall from 20 to 45 degree angle. The main slops of the Shimshal valley identified for Sea buckthorn plantation is of 20 to 45 degree angle. The streams flow in 20 to 45 degree angle downwards the river. Material drainage of the main slope during the disaster drains in the gorges and the drain of the streams spreads in agricultural land and orchards by eroding stream banks and falls into Shimshal River after crossing roads, orchards, pasture and Bridge. Near the River it spreads and damages a huge cultivable area which is under sand, mud and debris because of floods.

2.4. Moisture

The bare soil-covered slopes in the valley are dry and becomes wet during rainy and snow melting seasons. They have debris, loose material and stones on the slopes. Intense rain leads to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. Because of no vegetation cover on the slope segments, roughness of slope surface increases and rain and melting snow can easily erode through the gaps and near the village it becomes a disaster for community by destructing agricultural land, trees, forests, livestock and lives of the community. Dense cover, if forest trees and vegetation are grown at the slope, may protect the soil splash effects and can reduce runoff velocity, while roots of the vegetation may bind the soil particles, resulting to hinder surface erosion.

2.5 Stream Bank

In Shimshal three Nallahs are flowing through the middle of the valley dividing the valley in sub villages. The floods in the stream cause heavy embankment erosion and put the village and infrastructure to damage. Therefore, embankment erosion issue is persistently harms the infrastructure, roads, bridges, water supply and forest cover. Both sides of the water stream of the valley are dry and muddy which are susceptible for erosion.

3 SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment exposed slope and embankment problems in the Shimshal GLOF Site and the team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the problem and prioritized some sites as high risks and some had moderate risks.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

3.1. Sea buckthorn Plantation

In Shimshal Sea buckthorn has been grown by the communities and AKRSP has supported the communities to plant Sea buckthorn on slopes and barren land. Sea buckthorn and bush's roots mainly protect soil one meter deep and plays a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.1.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buck thorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier. Picked out Sea buckthorn plants can be kept in water or saturated soil for one day and then must be

Case Study

Fifty women from Passu valley in Hunza District of Gilgit Baltistan Pakistan have been tending to a community sea buckthorn plantation along what used to be an eroded riverbank, an hour's walk from their village. The bushes were planted in April 2017 and will take another three years to fruit, but in less than a year, the barren patch of unstable land has become a stable, green oasis. By successfully managing sea buckthorn as an anti-erosion, bioengineering measure, the women have played an instrumental role in restoring a part of the valley and improving the well-being of their community.

planted in the pits prepared along the embankment of the streams.

3.1.2. Special Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Sea buckthorn plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height
- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

3.1.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants for Shimshal (Transportation, Labor)	30000 plants	60 Rs.	**1800000**
02	Transportation	30000	20	**600000**
02	Laboring for digging and planting (Men days)	300 men days	1000	**300000**
	Total			**2700000**

3.2. Vegetated Rip Rap and Compact Planting

Slopes of the Shimshal valley have loose material that have high tendency to roll down the slope because of the erosion caused by the rain, wind and weathering. This erosion of the slope can be controlled by the vegetated riprap and compact plating of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of Juniper, willow, popular and other indigenous plants on the slopes, in ditches, valleys and gullies. Willow and long cuttings of popular and other local plants are easily available in Hunza District. Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil upto 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

3.2.1. Site Preparation

The site has vast scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip

Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of the valley are 30 to 50 degree angle.

3.2.2. Plantation Instructions for Willow and Popular Cuttings

- Long cuttings of Willow, Popular and Russian Olive are recommended
- Rooted trees are also recommended for compact plantation
- Recommend to not supply rooted trees from down or other parts of GB as Shimshal is the last valley and transportation will take time.
- Cuttings of local plants (willow and popular) are strongly recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

3.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings & locally Rooted Plants of willow and popular for Shimshal	25000 cuttings	80 Rs.	2000000
02	Transportation	25000 cuttings	20 Rs.	500000
03	Laboring for plantation (Men days)	250 men days	1000 Rs. per day	250000
	Total			**2750000**

3.3. Repair and extension of existing water channels

In Shimshal valley there are traditionally earthen water channels for agricultural and irrigation of fruit/forest trees and agricultural land in different areas. These water channels required to be repair and all can be extended to plant more forest trees on barren land. These water channels are earthen channels and do not require cement and concrete work. These all channels will irrigate 210 Acres of Barren and vegetated land in Shimshal GLOF Site.

3.3.1. Budget Estimate for The Activity

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of four water channels in Shimshal GLOF Site	04	400000.	1600000
	Total			**1600000**

3.4. Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting and palisades on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface

protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.4.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.4.2. Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the large grasses along the trees and bushes however, we recommend at the areas where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation. The seeds can be seeded in the areas of repair and extended water channels.

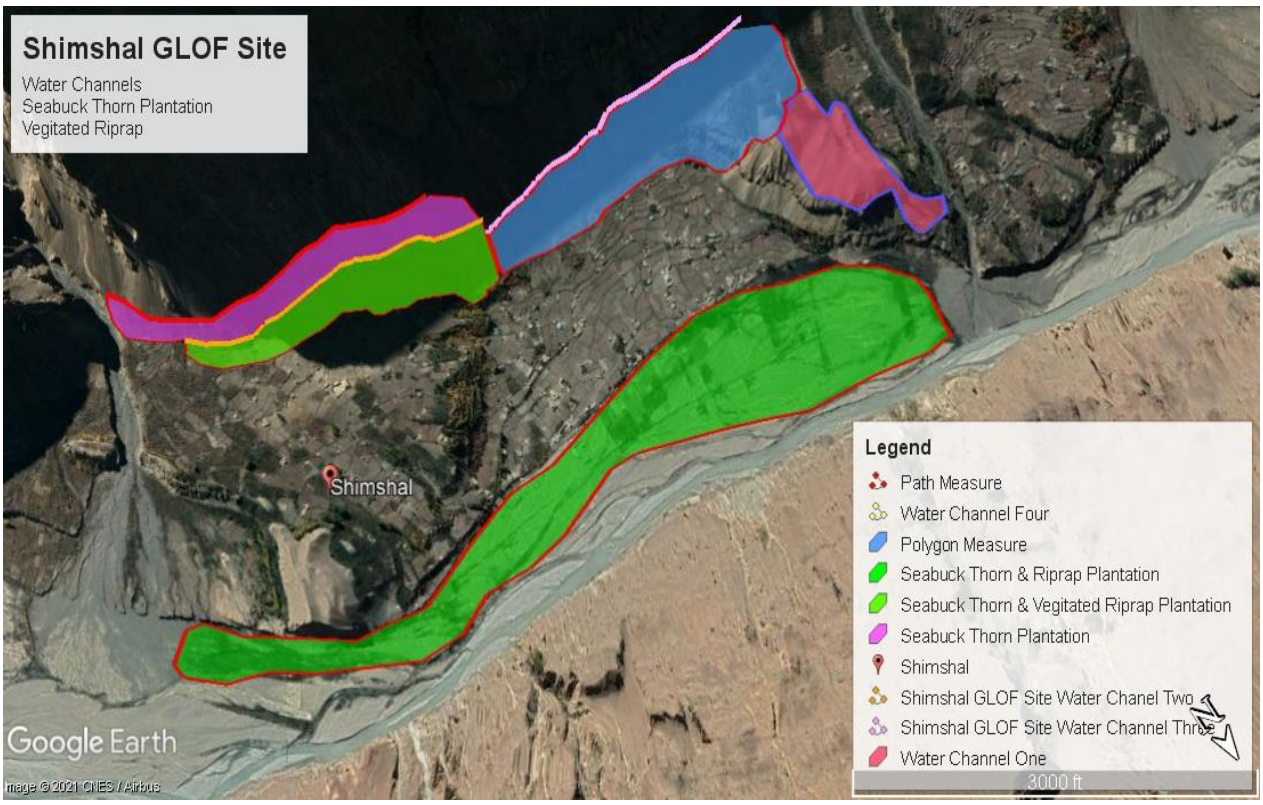
- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

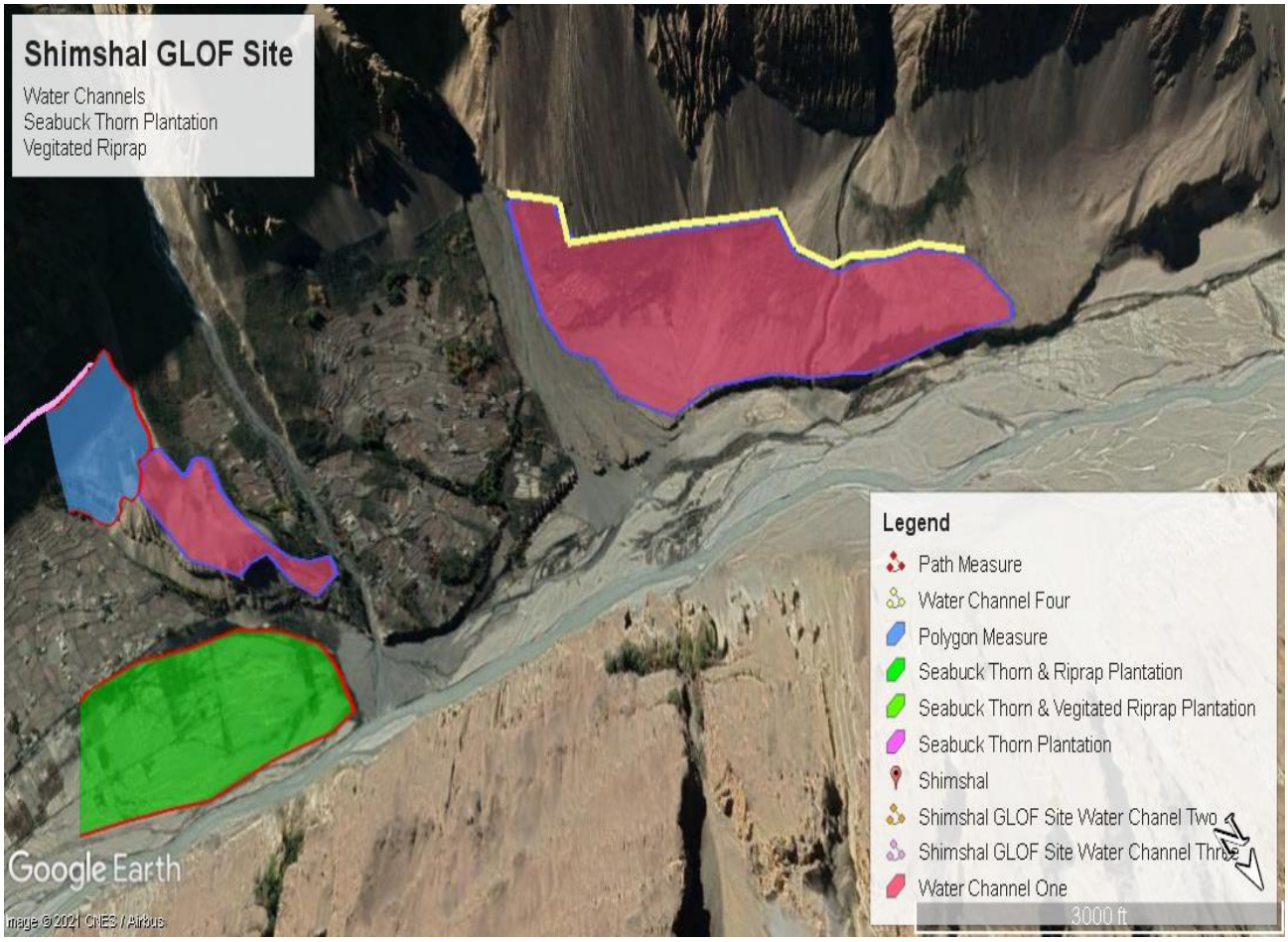
3.4.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds All Inclusive for Shimshal	300kgs	3000	900000
	Total			**900000**

Total Proposed Budget for GLOF-II Site (Shimshal, District Hunza)

Activity No	Bioengineering Technique	Total
01	Sea buckthorn Plantation	2700000
02	Compact Planting and Vegetated Rip Rap	2750000
03	Repair and extension of water channels	1600000
04	Grass Planting	900000
Grand Total		**7950000**




Shimshal GLOF Site
Water Channels
Seabuck Thorn Plantation
Vegitated Riprap
Legend
Path Measure
Water Channel Four
Polygon Measure
Seabuck Thorn & Riprap Plantation
Seabuck Thorn & Vegitated Riprap Plantation
Seabuck Thorn Plantation
Shimshal
Shimshal GLOF Site Water Chanel Two
Shimshal GLOF Site Water Channel Three
Water Channel One
3000 ft
Google Earth
Image © 2021 CNES / Airbus

Section V: District Nagar,
Chapter 08: GLOF-II Site Hisper, District Nagar, Gilgit-Baltistan

1. Introduction

Hisper GLOF Site is situated in the last valley of Nagar District in Gilgit Baltistan. Hisper is located at an elevation of 10250ft with 36°10'19.56"N, 74°59'39.65"E, with a central geographical coordinate at world geographical Globe. It is a valley more than a village in Nagar District and situated at the edge of Hisper glacier. It is almost 138.5 KM via Karakoram Highway from Gilgit, the capital city of Gilgit Baltistan and 34.5 KM from Nagar Proper of district Nagar. Hisper valley is located on north east from the Ganish Hunza and two hours' drive through high passes, glaciers and rugged mountains. Hisper Glacier is 49km long one of the longest glaciers out of the Polar Regions. Hisper glacier meets 67km long Biafo glacier at the Hisper Pass. There is a glacier (Yangutz Har glacier) above the valley on the mountain which is threat for the valley and water stream divides the valley in two villages. The site is vulnerable because of the glacier surge, GLOF events and drainage of the glaciers in multiple areas.

During summer, snow melting and rainy seasons the glacier discharges water that erodes the embankments of downstream and causes heavy floods. The streams have stones and debris material which erodes and damages the land, fruit and forest trees, infrastructure such as water channels, roads and houses. Above the valley there are barren slopes which shear in rainy and snow melting seasons because of weathering.

The valley is intersected with ridges and stream banks and landscape features are prone for slope instability issues especially debris flow. Most of the slopes are unstable and barren naturally because of the high elevation. These can be vegetated by planting gross, willow, Sea buckthorn, popular, Russian olive, and other species those will contribute to reduce GLOF events. Stream bank's erosion problem is persistently increasing when temperature in summer increases; stream receives more floods because of glacier outburst and flood. In many instances, significant uncertainty exists about the stability of the embankment and land nearby the stream and infrastructure below the glacier. The environment in Hisper along the approach road is prone to frequent floods and avalanches which threaten its population's mobility and livelihoods.

2. Site Assessment

2.1. Site Type

Hisper Valley is situated in North East in Gilgit Baltistan. It is situated in the footings of the Yanutz Har and Hisper glaciers and water stream flows in multiple areas of the valley. This site is located in areas of steep, most of the area is unstable and stream water erodes the embankments. Embankments of the water stream are vulnerable and continuously eroding during floods and GLOF events that carry filth, rocks and overflowing water have huge potential to damage settlements, land and infrastructure downstream. This is almost a regular annual feature especially in summer of this GLOF site.

The site is vulnerable for debris flow in many segments along the access road and in the village as well. The sides of the water stream and river are dry and brunt but communities have planted trees especially Sea buckthorn and bushes in some patches. The use of bioengineering techniques alone is mainly confined to reduce the threat of stream bank erosion, slope erosion and GLOF events. Where vegetation has been reduced or removed, it can be replaced by planting of appropriate species to achieve the desired effect. Structures formed from a combination of dead and living plant material can also be used to guide the river course and prevent flood entering into settlements and farmland. The plants can provide additional benefits for the local population like fodder, fruit, and firewood, but this is secondary to the protective function.

More resilient infrastructure means protection of agricultural land for farming; roads for easy communication; forest to slow down the erosion and mitigate climate change phenomenon. Stronger stream bank defenses mean that communities are protected from flood. Better and resilient infrastructure systems help to grow more crops and people are spending less time to collect and transporting water from long distances for domestic uses especially in winters.

2.2. Slope Length

In Hisper Valley slopes are of different length and width ranging from 50 meters to 100 meters long and 30 to 80 meters wide. The valley is situated on the footings of the glacier and at the edge of the water stream. There is hard rock, sandy soil, loose material slopes in patches on both sides of the water stream. Stream bank is more than 25213 meters long in different areas Glacier to the snout of Nagar River. However, there are small segments of slopes of different sizes and lengths are situated across the main stream and Nagar

River. The slopes have landslide issues as well as surface erosion during climatic conditions.

2.3. Slope Angle and Material Drainage

The slopes of the Hisper valley fall from 30 to 45 degree angle. The main slops of the Hisper valley identified for Sea buckthorn plantation is of 20 to 45 degree angle. The streams flow in 30 to 45 degree angle downwards into the Nagar River. Material drainage of the main slope during the disaster drains in the gorges. The drain of the streams spreads in agricultural land and orchards by eroding stream banks and falls into Nagar River after crossing roads, orchards, pasture and Bridge. Near the River it spreads and damages a cultivable area which is under sand, mud and debris because of floods.

2.4. Moisture

The bare soil-covered slopes in the valley are dry and becomes wet during rainy and snow melting seasons. They have debris, loose material and stones on the slopes along the Hisper road. Intense rain leads to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. Because of no vegetation cover on the slope segments, roughness of slope surface increases and rain and melting snow can easily erode through the gaps and near the village it becomes a disaster for community by destructing agricultural land, trees, forests, livestock and the only access road of the community. Dense cover, if forest trees and vegetation are grown at the slope, may protect the soil splash effects and can reduce runoff velocity, while roots of the vegetation may bind the soil particles, resulting to hinder surface erosion.

2.5. Stream Bank

In Hisper valley a water stream is flowing through the middle of the valley dividing the valley in sub villages. The floods in the stream cause heavy embankment erosion and put the village and infrastructure to damage. Therefore, embankment erosion issue is persistently harms the infrastructure, roads, bridges, water supply and forest cover. Both sides of the water stream of the valley are dry and muddy which are susceptible for erosion.

3. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment exposed slope and embankment problems in the Hisper GLOF Site and the team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the problem and prioritized some sites as high risks and some had moderate risks.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

3.1. Sea buckthorn Plantation

In Hisper Sea buckthorn is already grown in many patches of the slope and plains. Sea buckthorn and bush's roots mainly protect soil one meter deep and plays a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.1.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buck thorns from designated sites should not be picked out more than one day earlier. Picked out Sea buckthorn plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.1.2. Special Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Sea buckthorn plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height
- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

3.1.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants for Shimshal (Transportation, Labor)	20000 plants	60 Rs.	**1200000**
02	Transportation,	20000 plants	20 Rs.	**400000**
	Laboring for digging and planting	200 men days	1000 per day	**200000**
	Total			**1800000**

3.2. Vegetated Rip Rap and Compact Planting

In Hisper valley slopes have loose material that have high tendency to roll down the slope because of the erosion caused by the rain, wind and weathering. This erosion of the slope can be controlled by the vegetated riprap and compact plating of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of willow, popular and other indigenous plants on the slopes, in ditches,

valleys and gullies. Willow and long cuttings of popular and other local plants are easily available in Nagar District. Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil up to 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

3.2.1. Site Preparation

The site has vast scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of the valley are 30 to 50 degree angle.

3.2.2. Plantation Instructions for Willow and Popular Cuttings

- Long cuttings of Willow, Popular and Russian Olive are recommended
- Rooted trees are also recommended for compact plantation
- Recommend to not supply rooted trees from down or other parts of GB as Hisper is the last valley and transportation will take time.
- Cuttings of local plants (willow and popular) are strongly recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,

- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

3.2.3 Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings & locally Rooted Plants of willow and popular for Hisper	25000 cuttings	80 Rs.	2000000
02	Transportation	25000 cuttings	20 Rs.	500000
	Laboring for plantation men days	250	1000 Rs. per day	250000
	Total			**2750000**

3.3. Repair and extension of existing water channels

In Hisper valley there are traditionally earthen water channels for agricultural and irrigation of fruit/forest trees and agricultural land in different areas. These water channels required to be repair and all can be extended to plant more forest trees on barren land. These water channels are earthen channels and do not require cement and concrete work. These all channels will irrigate 128 Acres of Barren and vegetated land in Hisper GLOF Site.

3.3.1. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of four water channels in Hisper GLOF Site	03	400000.	1200000
	Total			**1200000**

3.4. Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting and palisades on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.4.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.4.2. Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the large grasses along the trees and bushes however, we recommend at the areas where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation. The seeds can be seeded in the areas of repair and extended water channels.

- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o

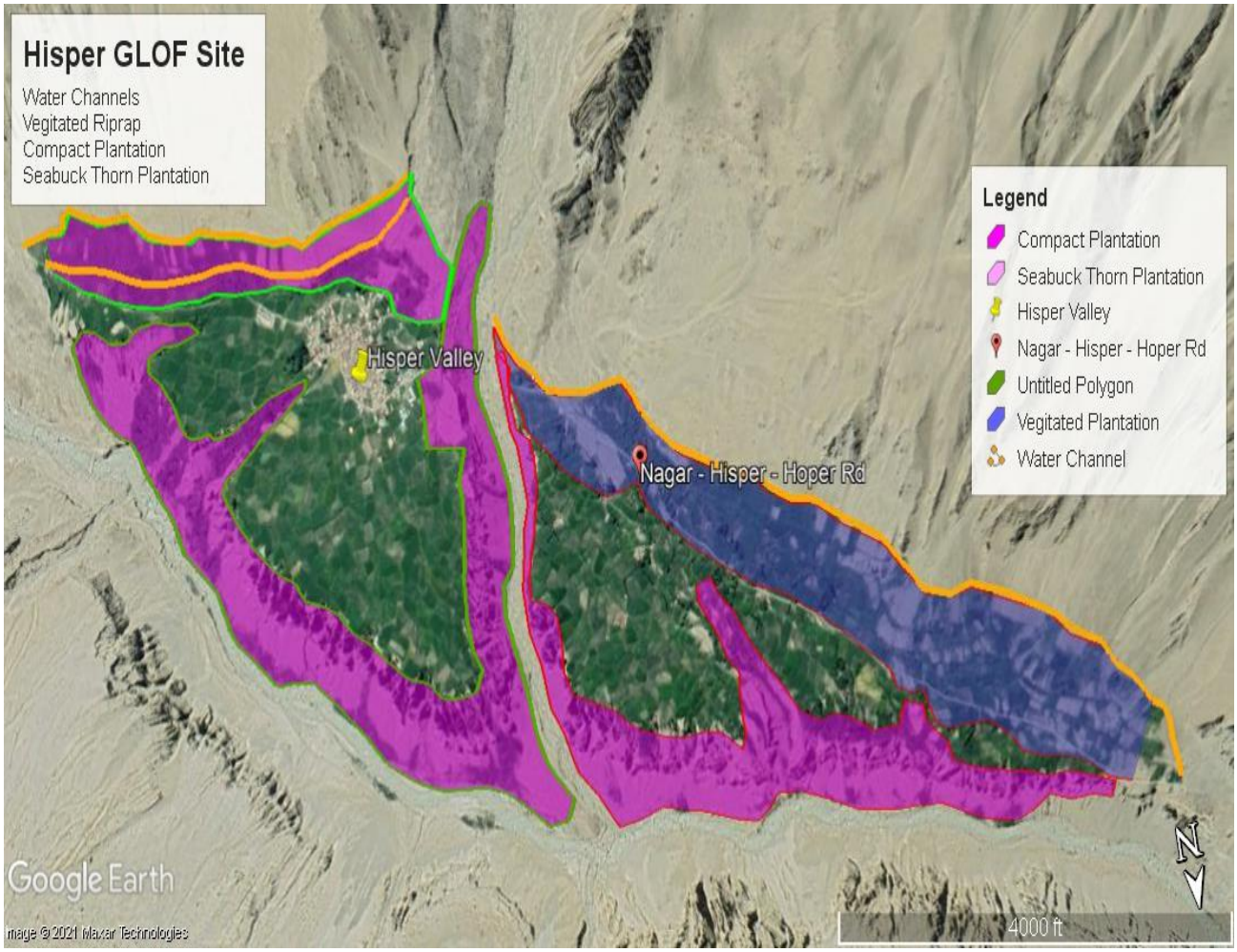
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

3.4.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds for Hisper	200kgs	3000 Rs.	600000
02	Transportation	200 kgs	40 Rs.	8000
03	Laboring (men days)	100 Men days	1000 Rs. Per day	100000
	Total			**1008000**

Total Proposed Budget for GLOF-II Site (Hisper, District Nagar)

Activity No	Bioengineering Technique	Total
01	Sea buckthorn Plantation	1800000
02	Compact Planting and Vegetated Rip Rap	2750000
03	Repair and extension of water channels	1200000
04	Grass Planting	1008000
Grand Total		**6758000**


Hisper GLOF Site
Water Channels
Vegitated Riprap
Compact Plantation
Seabuck Thorn Plantation
Legend
Compact Plantation
Seabuck Thorn Plantation
Hisper Valley
Nagar - Hisper - Hoper Rd
Untitled Polygon
Vegitated Plantation
Water Channel
Hisper Valley
Nagar - Hisper - Hoper Rd
Google Earth
Image © 2021 Maxar Technologies
4000 ft
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Section VI: District Ghizer,
Chapter 08: GLOF-II Site Badswat, District Ghizer, Gilgit-Baltistan

1. Introduction

Badswat GLOF Site is situated in the valley of Ishkoman in District Ghizer in Gilgit Baltistan. Badswat is located at an elevation of 8900ft geographically defined by longitude 36°32'45.07"N, 74° 2'39.13"E, with a central geographical coordinate at world geographical Globe. It is a valley more than a village in Ghizer District and situated at the edge of Badswat glacier. It is almost 149.6 KM via Gilgit Shandur road and from Gilgit city the capital city of Gilgit Baltistan and 66 KM from Gahkuch district headquarter of district Ghizer. The Badswat glacier is located 1.1 kilometers in northeast of the Badswat village. The main glacier trunk with south west to north east orientation has length of 6.8 kilometers and average gradient of 16.12º and is fed by four tributary glaciers. The road passes through high passes, rugged mountains. The stream from the glacier flows into Ishkoman river which eventually joins Gupis river to form Gilgit river The site is vulnerable because of the glacier surge, GLOF events and drainage of the glaciers in multiple areas. In 2018 the glacier triggered the GLOF and repeated the GLOF event in 2018 with more intensity and disaster.

In 2018, the GLOF event blocked the Ishkoman River and formed a lake which destructing agricultural land, infrastructure, roads, houses, fruit and forest trees. A large portion of its population is extremely poor and is highly vulnerable to such negative impacts of climate change. During summer, snow melting and rainy seasons the glacier discharges water that erodes the embankments of downstream and causes heavy floods. The streams have stones and debris material which erodes and damages the land, fruit and forest trees, infrastructure such as water channels, roads and houses. Above the valley there are barren slopes which shear in rainy and snow melting seasons because of weathering.

The valley is intersected with ridges and stream banks and landscape features are prone for slope instability issues especially debris flow. Most of the slopes are unstable and barren naturally because of the high elevation. These can be vegetated by planting gross, willow, Sea buckthorn, popular, Russian olive, and other species those will contribute to reduce GLOF events. Stream bank's erosion problem is persistently increasing when temperature in summer increases; stream receives more floods because of glacier outburst and flood. In many instances, significant uncertainty exists about the stability of the embankment and land nearby the stream and infrastructure below the glacier. The environment in Badswat along the approach road is prone to frequent floods and avalanches which threatened its population's mobility and livelihoods.

2. Site Assessment

2.1.Site Type

Badswat village is situated in west north in Gilgit Baltistan. It is situated in the footings of the Badswat glaciers and water stream flows in multiple areas of the valley. This site is located in areas of steep, most of the area is unstable and stream water erodes the embankments. Embankments of the water stream are vulnerable and continuously eroding during floods and GLOF events that carry filth, rocks and overflowing water have huge potential to damage settlements, land and infrastructure downstream. This is almost a regular annual feature especially in summer of this GLOF site.

The site is vulnerable for debris flow in many segments along the access road and in the village as well. The sides of the water stream and river are dry and brunt but communities have planted trees especially Sea buckthorn and bushes in some patches. The use of bioengineering techniques alone is mainly confined to reduce the threat of stream bank erosion, slope erosion and GLOF events. Where vegetation has been reduced or removed, it can be replaced by planting of appropriate species to achieve the desired effect. Structures formed from a combination of dead and living plant material can also be used to guide the river course and prevent flood entering into settlements and farmland. The plants can provide additional benefits for the local population like fodder, fruit, and firewood, but this is secondary to the protective function.

More resilient infrastructure means protection of agricultural land for farming; roads for easy communication; forest to slow down the erosion and mitigate climate change phenomenon. Stronger stream bank defenses mean that communities are protected from flood. Better and resilient infrastructure systems help to grow more crops and people are spending less time to collect and transporting water from long distances for domestic uses especially in winters.

2.2. Slope Length

In Badswat village slopes are of different length and width ranging from 50 meters to 100 meters long and 30 to 80 meters wide. The valley is situated on the footings of the glacier and at the edge of the water stream. There is hard rock, sandy soil, loose material slopes in patches on both sides of the water stream. Stream bank is more than 25213 meters long in different areas Glacier to the snout of Nagar River. However, there are small segments of slopes of different sizes and lengths are situated across the main stream and Nagar

River. The slopes have landslide issues as well as surface erosion during climatic conditions.

2.3. Topography (Slope, Angle and Material Drainage)

The slopes in Badswat fall from 35 to 55 degree angle. The main slops of the Badswat village identified for vegetation cover and Sea buckthorn plantation is of 30 to 45 degree angle. The streams flow in 25 to 45 degree angle downwards into the Ishkoman River. Material drainage of the main slope during the disaster drains in the gorges. The drain of the streams spreads in orchards by eroding stream banks and falls into the River after crossing roads, orchards, pasture and Bridge. Near the River it spreads and damages cultivable land which is under sand, mud and debris because of floods.

2.4. Moisture

The bare soil-covered slopes in the valley are dry and becomes wet during rainy and snow melting seasons. They have debris, loose material and stones on the slopes. Intense rain leads to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. Because of no vegetation cover on the slope segments, roughness of slope surface increases and rain and melting snow can easily erode through the gaps and near the village it becomes a disaster for community by destructing agricultural land, trees, forests, livestock and the only access road of the community. Dense cover, if forest trees and vegetation are grown at the slope, may protect the soil splash effects and can reduce runoff velocity, while roots of the vegetation may bind the soil particles, resulting to hinder surface erosion.

2.5. Stream Bank

In Badswat village water stream is flowing through the middle of the village dividing the valley in sub villages. The stream banks are eroded harshly during GLOF event of 2018 and damaged houses, trees, agricultural land, and infrastructure such as water supply, irrigation channels, access road and tracks. The floods in the stream cause heavy embankment erosion and put the village and infrastructure to damage. Therefore, embankment erosion issue is persistently harms the infrastructure, roads, bridges, water supply and forest cover. Both sides of the water stream of the valley are dry and muddy which are susceptible for erosion.

3. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment showed slopes and embankment problems in the Badswat GLOF Site and the team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the problem and prioritized some sites as high risks and some had moderate risks.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

3.1. Vegetated Rip Rap and Compact Planting

Slopes of the Badswat Village have loose material that have high tendency to roll down the slope because of the erosion caused by the rain, wind and weathering. This erosion of the slope can be controlled by the vegetated riprap and compact plating of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of Juniper, willow, popular and other indigenous plants on the slopes, in ditches, valleys and gullies. Willow and long cuttings of popular and other local plants are easily available in Badswat in Ishkoman valley of Ghizer District. But Juniper, Cedar, Spruce and Pine can be supplied from the forest nurseries and suppliers of the forest plants. Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil up to 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

3.1.1. Site Preparation

The site has enough scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of Badswat valley are 20 to 45 degree angle.

3.1.2. Special Instructions for Russian Olive, Willow and Popular Cuttings

- Long cuttings of willow and popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants (willow and popular) are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

3.1.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings of willow, Russian Olive and popular (all inclusive)	15000 cuttings	90 Rs.	1350000
02	Rooted Plants of Russian Olive, Popular, willow etc. (all inclusive)	25000	100	2500000
	Total			**3850000**

3.2. Sea buckthorn Plantation

In Badswat Sea buckthorn is already grown in many patches of the slope and plains. Sea buckthorn and bush's roots mainly protect soil one meter deep and plays a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.2.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier. Picked out Sea buck thorn plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.2.2. Special Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Sea buckthorn plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height
- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

3.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants for Badswat Village	15000 plants	60 Rs.	900000
02	Transportation	15000	20 Rs.	300000
02	Laboring for digging and planting	150 Men days	1000	150000
	Total			**1350000**

3.3. Repair and extension of existing water channels

Badswat village has traditionally earthen water channels for agricultural and irrigation of fruit/forest trees and agricultural land in different areas. These water channels required to be repair and all can be extended to plant more forest trees on barren land. These water channels are earthen channels and do not require cement and concrete work. Two water channels have been recommended for repair and extension. These all channels will irrigate 50.6 Acres of Barren and vegetated land in GLOF Site.

3.3.1. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of two water channels in Badswat GLOF Site	02	400000.	800000
	Total			**800000**

3.4. Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can

stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.4.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.4.2. Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the large grasses along the trees and bushes however, we recommend at the areas where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation. The seeds can be seeded in the areas of repair and extended water channels.

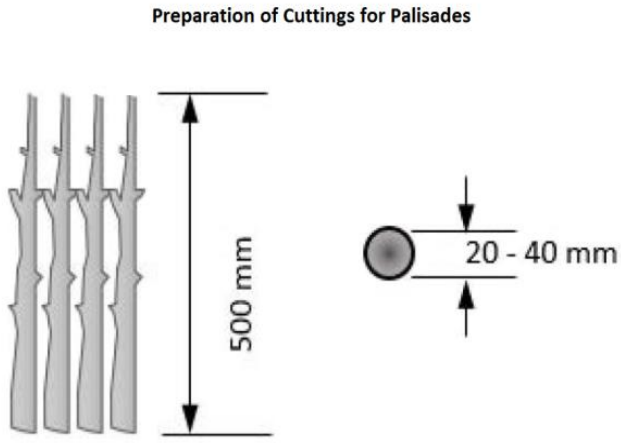
- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

3.4.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds for Badswat	200kgs	3000 Rs.	600000
02	Transportation	200	40 Rs.	8000
	Land Preparation and seeding	100 Men days	1000 Rs.	100000
	Total			**708000**

3.5. Live Fascines

A palisade is a fence or wall made from wooden stakes or tree trunks. Palisades were used historically as a defensive structure. In slope and embankments' protection, palisades are barriers made from live wood cuttings installed across a slope following the contour in order to trap debris moving down the slope, to armour and reinforce the slope, and to increase the infiltration rate. Palisades are used to prevent the extension of deep, narrow gullies and the erosion of V-shaped rills by forming a strong barrier which stabilizes the gully floor and traps material moving downwards. They are also effective on steep landslide or debris slopes. Palisades can be used on a wide range of sites with slopes of up to about 60°.



This procedure applies to use live cuttings of willow, popular, other indigenous and local species of plants which are commonly available in Badswat valley in District Ghizer of Gilgit Baltistan. It is best to use local species as they are already adapted to the growing conditions; are more like to be resistant to local diseases; are more readily available; and are likely to be on lower cost options. Live hardwood willow, popular, shrub cuttings are laid in successive shallow trenches, in lines across the slope, usually following the contour. The tips of the cuttings protrude just beyond the face of the slope, where they grow buds and leaves that intercept rainfall, slow runoff and filter sediments. In addition to the exposed stems catching surface debris, as the roots develop they reinforce the upper soil layers. This techniques

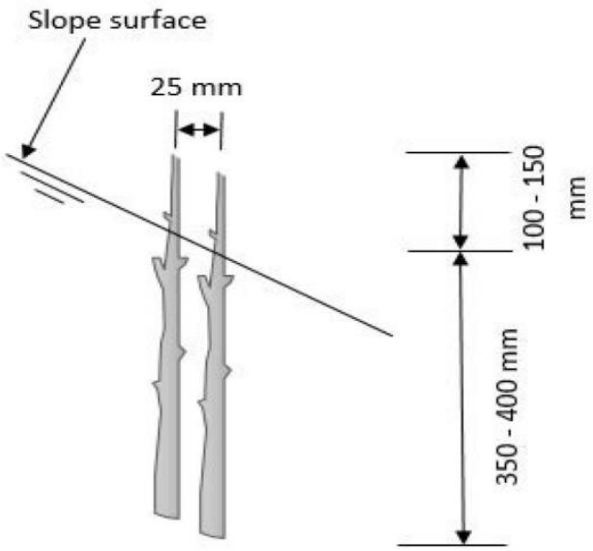
are used to stabilize embankments (fill slopes) or less steep cut-slopes. The roots add tensile reinforcement to the slope and provide a measure of frictional resistance to shallow sliding. The protruding brush retards runoff and reduces surface erosion. Brush wood layers give both immediate and increasingly strong protection and reinforcement to newly constructed fill and cut slopes. They are also a good remedial measure for repairing eroded gullies. The perpendicular orientation of brush layering to the slope is effective in terms of earth reinforcement and near-surface stabilization of the slope.

3.5.1. Site Preparation

The site along the water stream should be prepared before planting the cuttings of willow, popular, shrubs and other local species. Debris must be removed, depressions should be filled and humps should be leveled off to attain a linear profile. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 250mm above the toe of the slope, 1000mm centers up the slope and at the edge of the water stream 12 inches of distance from water level of summer season.

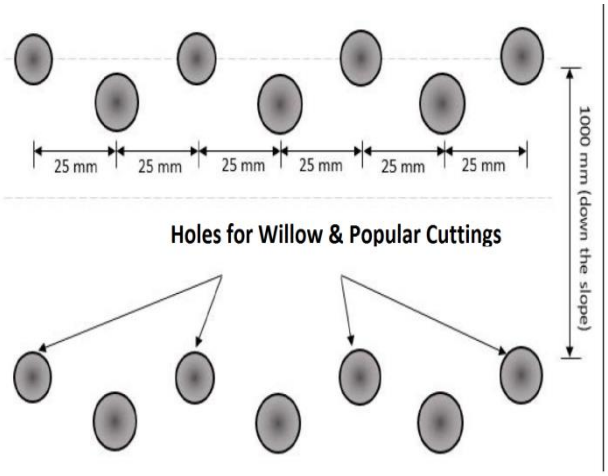
3.5.2. Planting Instructions

- Plant cuttings must be prepared from the woody material of 6 to 18 months in age.
- Cuttings should be approximately 20 mm dia., 500 mm length. They are laid in shallow trenches.
- These cuttings should be buried in moist soil for 3 to 7 days
- These cuttings may be immersed in water for two or three days
- When land is prepared plant the cuttings within 12 hours
- Cuttings from willow, popular and shrubs are more feasible for the local environment however; any other plant cutting must be suited to



the site and shows the correct habit for an ability to grow from the cuttings. For example many shoots coming from the stems.

- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- Side branches shall be trimmed off carefully with a sharp tool.
- The cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- As with grass planting, the brush layers can also be angled to enhance drainage.
- Planting should be by experienced agricultural labor with technical supervision.
- Always start at the top of the slope and work downwards

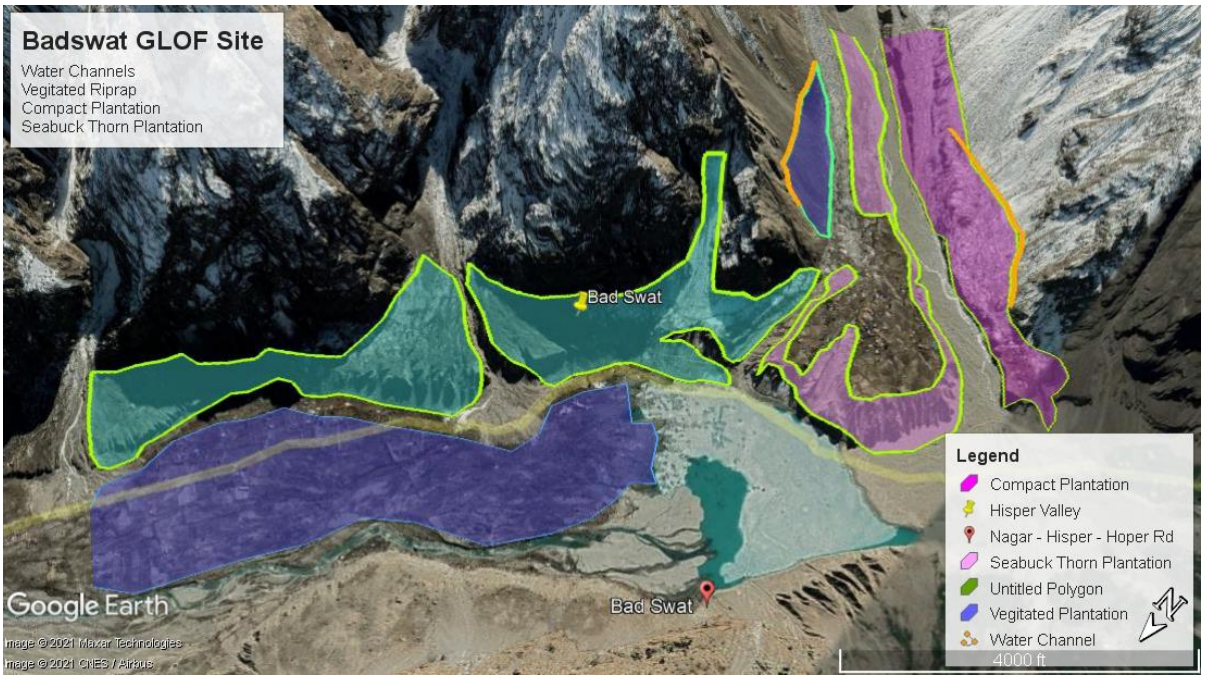


- Using a pointed bar, make a hole that is bigger than the cutting
- Carefully place the cutting in the hole so that two third is buried, firm the soil around it, taking care not to damage the bark
- Make the next hole 50mm along the row

3.5.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Local live Plant cuttings of willow, popular, and Russian olive for Badswat	15000 cuttings	60 Rs.	900000
02	Laboring for digging pits and plantation	250 men days	1000	250000
03	Transportation	15000	30	45000
	Total			**1195000**

Total Proposed Budget for GLOF-II Site (Badswat, District Ghizer)		
Activity No	**Bioengineering Technique**	**Total**
01	Compact Planting and Vegetated Rip Rap	3850000
02	Sea buckthorn Plantation	1350000
03	Repair and extension of water channels	800000
04	Grass Planting	708000
05	Palisades	1195000
Grand Total		**7903000**



Section VI: District Ghizer,
Chapter 10: GLOF-II Site Sosat, District Ghizer, Gilgit-Baltistan

1. Introduction and Description of Site:

Sosat GLOF Site is situated in District Ghizer of Gilgit Baltistan. Sosat is located at an elevation of 8255ft geographically defined by longitude 36° 9'37.34"N, 73° 7'44.04"E, with a central geographical coordinate at world geographical Globe. The Sosat village is situated below the Sosat Gol Glacier and at the edge of Gilgit Ghizer River. It is almost 120.5 KM from Gilgit city, the capital city of Gilgit Baltistan via Gilgit Shandur road and 54.3 KM from Gahkuch district headquarter of district Ghizer. The Sosat glacier is located on the top of the mountain fed by three more tributary glaciers. The road passes along Gilgit Shandur road and River through rugged mountains. The stream from the glacier flows into Gilgit Ghizer River which eventually. The site is vulnerable because of the GLOF events and drainage of the glaciers through stream.

The GLOF event blocked the Gilgit Ghizer River and formed a lake which destructing agricultural land, infrastructure, roads, houses, fruit and forest trees. A large portion of its population is vulnerable to such negative impacts of climate change. During summer, snow melting and rainy seasons the glacier discharges water that erodes the embankments of downstream and causes heavy floods. The streams have stones and debris material which erodes and damages the land, fruit and forest trees, infrastructure such as water channels, roads and houses. Above the valley there are barren slopes which shear in rainy and snow melting seasons because of weathering.

The valley is intersected with ridges and stream banks and landscape features are prone for slope instability issues especially debris flow. Most of the slopes are unstable and barren naturally because of the high elevation. These can be vegetated by planting gross, willow, Sea buckthorn, popular, Russian olive, and other species those will contribute to reduce GLOF events. Stream bank’s erosion problem is persistently increasing when temperature in summer increases; stream receives more floods because of glacier outburst and flood. In many instances, significant uncertainty exists about the stability of the embankment and land nearby the stream and infrastructure below the glacier.

2. Site Assessment

2.1. Site Type

Sosat village is situated in west of Gilgit Baltistan on the edge of Gilgit River and Gilgit Shandur Road. It is situated in the footings of the Sosat glaciers and water stream flows through the Nallah of the valley. This site is located in areas of steep, most of the area is unstable and stream water erodes the embankments. Embankments of the water stream are vulnerable and continuously eroding during floods and GLOF events that carry filth, rocks and overflowing water have huge potential to damage settlements, land and infrastructure downstream. This is almost a regular annual feature especially in summer of this GLOF site.

The site is vulnerable for debris flow in some segments along the Gilgit Shandure road and in the Nallah as well. The sides of the water stream and river are dry. Community of the Sosat have planted few trees especially Sea buckthorn and bushes in some patches. The use of bioengineering techniques is mainly confined to reduce the threat of stream bank erosion, slope erosion and GLOF events. Where vegetation has been reduced or removed, it can be replaced by planting of appropriate species to achieve the desired effect. Structures formed from a combination of dead and living plant material can also be used to guide the river course and prevent flood entering into settlements and farmland. The plants can provide additional benefits for the local population like fodder, fruit, and firewood, but this is secondary to the protective function.

More resilient infrastructure means protection of agricultural land for farming; roads for easy communication; forest to slow down the erosion and mitigate climate change phenomenon. Stronger stream bank defenses mean that communities are protected from flood. Better and resilient infrastructure systems help to grow more crops and people are spending less time to collect and transporting water from long distances for domestic uses especially in winters.

2.2. Slope Length

In Sosat village slopes are of different length and width ranging from 30 meters to 100 meters long and 20 to 80 meters wide. The valley is situated on the footings of the hills and at the edge of the water stream and Gilgit River. There is hard rock, sandy soil, loose material slopes in patches on both sides of the water stream. Stream bank is more than 1325 meters long along the village while it has long distance from the Glacier to the snout of Gilgit River. However, there are small segments of slopes of different sizes and

lengths are situated across the main stream and Gilgit River. The slopes have landslide issues as well as surface erosion during climatic conditions.

2.3. Topography (Slope, Angle and Material Drainage)

The slopes in Sosat fall from 35 to 55 degree angle. The main slops of the Sosat village identified for vegetation cover and Sea buckthorn plantation is of 40 to 55 degree angle. The streams flow in 25 to 45 degree downwards into the Gilgit River. Material drainage of the main slope during the disaster drains in the gorges. The drain of the streams spreads in orchards by eroding stream banks and falls into the River after crossing roads, orchards, pasture and Bridge. Near the River it spreads and damages cultivable land which is under sand, mud and debris because of floods.

2.3. Moisture

The bare soil-covered slopes in the valley are dry and becomes wet during rainy and snow melting seasons. They have debris and loose material on the slopes. Intense rain leads to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. Because of no vegetation cover on the slope segments, roughness of slope surface increases and rain and melting snow can easily erode through the gaps and near the village it becomes a disaster for community by destructing infrastructure especially Gilgit Shandure road, agricultural land, trees, and livestock. Dense cover, if forest trees and vegetation are grown at the slope, may protect the soil splash effects and can reduce runoff velocity, while roots of the vegetation may bind the soil particles, resulting to hinder surface erosion.

2.4. Stream Bank

In Sosat village water stream is flowing through the middle of the village dividing the valley in two sub villages. The stream banks are eroded harshly during GLOF event of in recent past and blocked the Gilgit River by forming a lake which damaged houses, trees, agricultural land, and infrastructure such as water supply, irrigation channels, road and tracks. The floods in the stream cause heavy embankment erosion and put the village and infrastructure to damage. Therefore, embankment erosion issue is persistently harms the infrastructure, roads, bridges, water supply and forest cover. Both sides of the water stream of the valley are dry and muddy which are susceptible for erosion.

3. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment showed slopes and embankment problems in the Sosat GLOF Site and the team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the problem and prioritized some sites as high risks and some had moderate risks.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

3.1. Vegetated Rip Rap and Compact Planting

Slopes of the Sosat Village have loose material that have high tendency to roll down the slope because of the erosion caused by the rain, wind and weathering. This erosion of the slope can be controlled by the vegetated riprap and compact plating of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of Juniper, willow, popular and other indigenous plants on the slopes, in ditches, valleys and gullies. Willow and long cuttings of popular, willow and other local plants are easily available in Sosat or in Gupis valley of Ghizer District.

Juniper, Cedar, Spruce and Pine can be supplied from the forest nurseries and suppliers of the forest plants. Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil up to 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

3.1.1. Site Preparation

The site has enough scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of Sosat valley are 35 to 55 degree angle.

3.1.2. Special Instructions for Willow, Russian Olive and Popular Cuttings

- Long cuttings of willow, Russian Olive and popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants (willow and popular) are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

3.1.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings of willow, Russian olive and popular (all inclusive)	10000 cuttings	90 Rs.	900000
02	Rooted Plants of willow, Russian olive and popular (all inclusive)	20000	100	2000000
	Total			**2900000**

3.2. Sea buckthorn Plantation

Sea buckthorn is already grown in some patches of the slope and plains in Sosat Village. Sea buckthorn and bush's roots mainly protect soil one meter deep and play a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plants intercept and armor the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.2.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier. Picked out Sea buckthorn plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.2.2. Special Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Sea buckthorn plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height
- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

3.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants for Sosat Village	10000 plants	60 Rs.	**600000**
02	Transportation,	10000 plants	20 Rs.	**200000**
	Laboring for digging and planting	100	1000	**100000**
	Total			**1000000**

3.3. Repair and extension of existing water channels

Sosat village has traditionally earthen water channels for agricultural and irrigation of fruit/forest trees and agricultural land in different areas. These water channels required to be repair and can be extended to plant more forest trees on barren land. These water channels are earthen channels and do not require cement and concrete work. Two water channels have been recommended for repair and extension on one each on both sides. These all channels will irrigate 74.35 Acres of Barren and vegetated land in GLOF Site.

3.3.1. Budget Estimate

S.NO	Item	Unit	Unite price	Total

01	Repair and extension of water channel one in Sosat GLOF Site	01	300000.	300000
02	Repair and extension of water channel two in Sosat GLOF Site	01	400000.	400000
	Total			**700000**

3.4. Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.4.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.4.2. Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the large grasses along the trees and bushes however, we recommend at the areas where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation. The seeds can be seeded in the areas of repair and extended water channels.

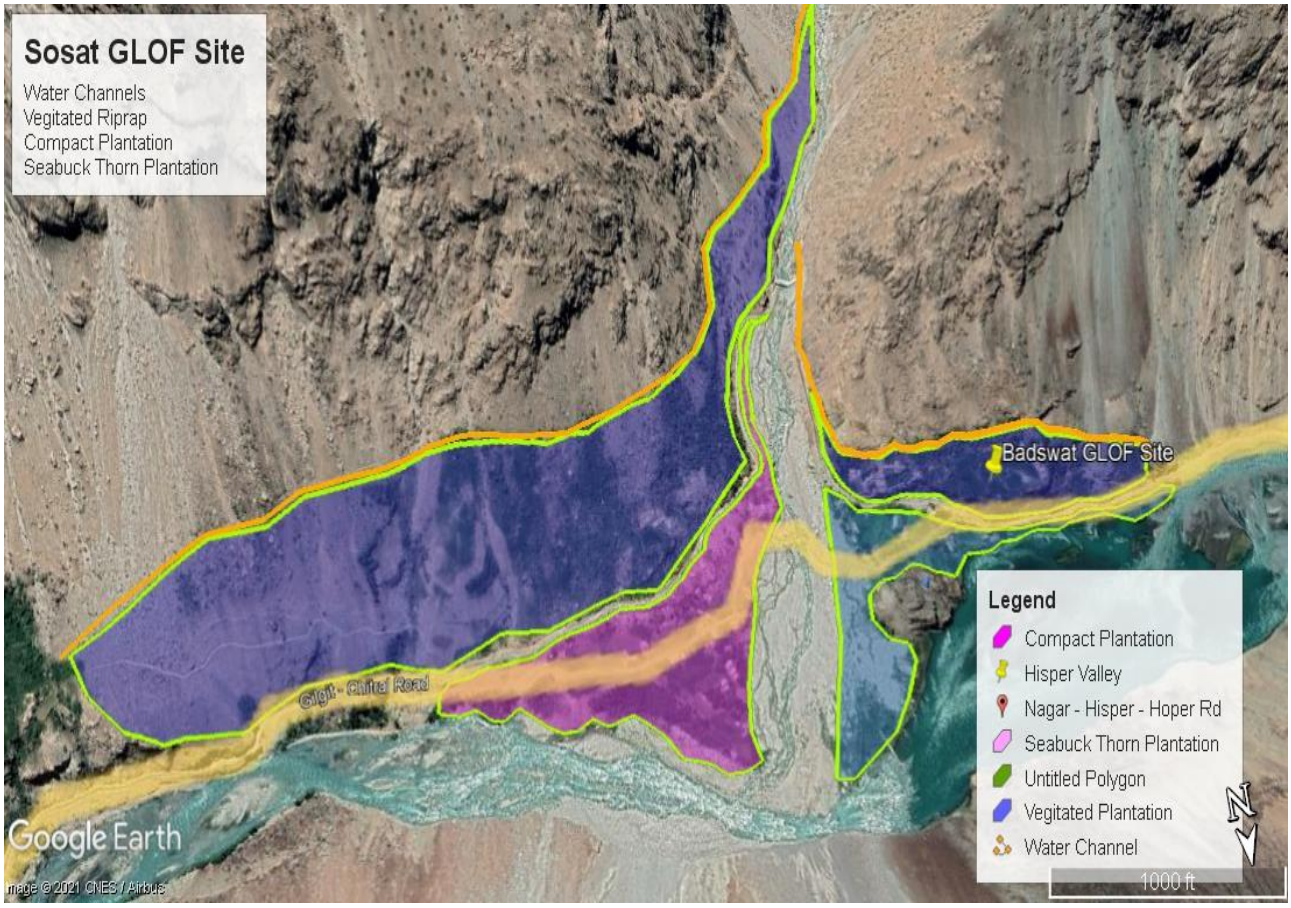
- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

3.4.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds for Sosat	200kgs	3000 Rs.	600000
02	Transportation and seeding	200 kgs	40 Rs.	8000
03	Laboring for land preparation and Seeding	100 men days	1000 Rs per day	100000
	Total			**708000**

Total Proposed Budget for GLOF-II Site (Sosat, District Ghizer)

Activity No	Bioengineering Technique	Total
01	Compact Planting and Vegetated Rip Rap	2900000
02	Sea buckthorn Plantation	1000000
03	Repair and extension of water channels	700000
04	Grass Planting	708000
Grand Total		**5308000**


Sosat GLOF Site
Water Channels
Vegitated Riprap
Compact Plantation
Seabuck Thorn Plantation
Badswat GLOF Site
Gilgit - Chitral Road
Legend
Compact Plantation
Hisper Valley
Nagar - Hisper - Hoper Rd
Seabuck Thorn Plantation
Untitled Polygon
Vegitated Plantation
Water Channel
1000 ft
Google Earth
mage © 2021 CNES / Airbus

SECTION VI: District Ghizer,
Chapter 11: GLOF-II Site Darkut, District Ghizer, Gilgit-Baltistan

1. Introduction

Darkut GLOF Site is situated in District Ghizer of Gilgit Baltistan. Darkut is located at an elevation of 8825ft geographically defined by longitude 36°38'38.60"N, 73°26'47.25"E, with a central geographical coordinate at world geographical Globe. Darkut Valley is situated in the center covered by high mountains from four sides and there are three water streams flowing from different sides along with their tributaries. It is situated below the Darkut Glaciers and at the edge of Darkut River. It is almost 180 KM from Gilgit city, the capital of Gilgit Baltistan via Gilgit Shandur road and 96 KM from Gahkuch district headquarter of district Ghizer. The Darkut glacier is located on the top of the mountain fed by three more tributary glaciers. The road passes along Gilgit Shandur road and River through rugged mountains. It turns from Gupis towards Yaseen valley. The streams flowing from the glaciers keep changes their direction because of that the valley is been devastated in many segments. The site is highly vulnerable because of the GLOF events and drainage of the glaciers through streams.

The GLOF events devastated the valley from every direction in recent past destructing agricultural land, infrastructure, roads, houses, fruit and forest trees. A large fragment of its population is vulnerable to such negative impacts of climate change. During summer, snow melting and rainy seasons the glacier discharges water that erodes the embankments of downstream and causes heavy floods and floods keep changing its way. The streams have stones and debris material which erodes and damages the land, fruit and forest trees, infrastructure such as water channels, roads and houses. Above the valley there are barren slopes which shear in rainy and snow melting seasons because of weathering.

The valley is intersected with ridges, streams and landscape features are prone for slope instability issues especially debris flow, loos material and mass movement. Most of the slopes are unstable and barren naturally because of the high elevation. These can be vegetated by planting gross, willow, Sea buckthorn, popular, Russian olive, and other species those will contribute to reduce GLOF events. Stream bank's erosion problem is persistently increasing when temperature in summer increases; stream receives more floods because of glacier outburst and rain flood. In many instances, significant uncertainty exists about the stability of the embankment and land nearby the stream and infrastructure.

2. Site Assessment

2.1. Site Type

Darkut valley is intersected with ridges, streams and landscape features are prone for slope instability issues especially debris flow, loos material and mass movement. Most of the slopes around the valley are unstable and barren because of the high elevation and deforestation. This site is located in areas of steep, most of the area is unstable and stream water erodes the embankments. Embankments of the water stream are vulnerable and continuously eroding during floods and GLOF events that carry filth, rocks and overflowing water have huge potential to damage settlements, land and infrastructure downstream. This is almost a regular annual feature especially in summer of this GLOF site.

The site is vulnerable for debris flow in some segments around the village and in the Nallahs as well. The sides of the water stream and river are dry and water streams keep changing their direction usually. Community of the valley have planted trees especially Sea buckthorn, willow, popular and bushes in many patches. The use of bioengineering techniques is mainly confined to reduce the threat of stream bank erosion, slope erosion and GLOF events. Where vegetation has been reduced or removed, it can be replaced by planting of appropriate species to achieve the desired effect. Structures formed from a combination of dead and living plant material can also be used to guide the river course and prevent flood entering into settlements and farmland. The plants can provide additional benefits for the local population like fodder, fruit, and firewood, but this is secondary to the protective function.

More resilient infrastructure means protection of agricultural land for farming; roads for easy communication; forest to slow down the erosion and mitigate climate change phenomenon. Stronger stream bank defenses mean that communities are protected from flood. Better and resilient infrastructure systems help to grow more crops and people are spending less time to collect and transporting water from long distances for domestic uses especially in winters.

2.2. Slope Length

In Darkut village slopes are of different length and width ranging from 50 meters to 300 meters long and 50 to 100 meters wide. The valley is situated on the footings of the hills and at the edge of the water stream and River. There is debris, sandy soil, loose material slopes in patches on three sides of the valley. Four streams are flowing from the valley

and divide the valley in multiple sub villages. The slopes have landslide issues as well as surface erosion during climatic conditions.

2.3. Topography (Slope, Angle and Material Drainage)

The slopes in Darkut fall from 35 to 65 degree angle. The main slops of the Darkut village identified for vegetation cover and Sea buckthorn plantation is of 40 to 55 degree angle. The streams flow in 25 to 45 degree downwards into the Darkut River. Material drainage of the main slopes during the disaster drains in the gorges and damages agricultural land, forest, infrastructure, roads, tracks, water supply and houses. The drain of the streams spreads in orchards by eroding stream banks and falls into the River after crossing roads, orchards, pasture and Bridge. Near the River it spreads and damages cultivable land which is under sand, mud and debris because of floods.

2.4. Moisture

The bare soil-covered slopes in the valley are dry and becomes wet during rainy and snow melting seasons. They have debris and loose material on the slopes. Intense rain leads to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. Because of no vegetation cover on the slope segments, roughness of slope surface increases and rain and melting snow can easily erode through the gaps and near the village it becomes a disaster for community by destructing infrastructure especially Darkut road, agricultural land, trees, and livestock. Dense cover, if forest trees and vegetation are grown at the slope, may protect the soil splash effects and can reduce runoff velocity, while roots of the vegetation may bind the soil particles, resulting to hinder surface erosion.

2.5. Stream Bank

In Darkut village water streams are flowing through the middle of the village dividing the valley in sub villages. The stream banks are eroded harshly during GLOF event of recent past and damaged houses, trees, agricultural land, and infrastructure such as water supply, irrigation channels, road and tracks. The floods in the stream cause heavy embankment erosion and put the village and infrastructure to damage. Therefore, embankment erosion issue is persistently harms the infrastructure, roads, bridges, water supply and forest cover.

3. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment showed slopes and embankment problems in the Darkut GLOF Site and the team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the problem and prioritized some sites as high risks and some had moderate risks.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

3.1. Vegetated Rip Rap and Compact Planting

Slopes of the Darkut Village have loose material that have high tendency to roll down the slope because of the erosion caused by the rain, wind and weathering. This erosion of the slope can be reduced by the vegetated riprap and compact plating of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of Juniper, willow, popular and other indigenous plants on the slopes, in ditches, valleys and gullies. Willow and long cuttings of popular, willow and other local plants are easily available in Darkut or in Yaseen valley of Ghizer District.

Juniper, Cedar, Spruce and Pine can be supplied from the forest nurseries and suppliers of the forest plants. Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil up to 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

3.1.1. Site Preparation

The site has enough scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of Darkut valley are 30 to 65 degree angle.

3.1.2. Special Instructions for Willow and Popular Cuttings

- Long cuttings of willow, Russian Olive and popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants (willow and popular) are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

3.1.3. Budget Estimate for The Activity

S.NO	Item	Unit	Unite price	Total
01	Long cuttings of willow, Russian olive and popular.	30000 cuttings	80 Rs.	2400000
02	Transportation	30000 cuttings	20	60000
03	Laboring for plantation	300 Men days	1000	300000
04	Rooted Plants of willow, Russian olive and popular	20000	100	2000000
05	Transportation	Once	32000	32000
	Total			**4792000**

3.2. Sea Buckthorn Plantation

Sea buckthorn is already grown in some patches of the slope and plains in Darkut Village. Sea buckthorn and bush's roots mainly protect soil one meter deep and play a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.2.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier. Picked out Sea buckthorn plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.2.2. Special Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Sea buckthorn plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height
- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

3.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants for Darkut Village	30000 plants	60 Rs.	**1800000**
02	Transportation,	30000 plants	30 Rs.	**900000**
03	Laboring for digging and planting	300 men days	1000Rs.	**300000**
	Total			**2700000**

3.3. Repair and extension of existing water channels

Darkut village has traditionally earthen water channels for agricultural and irrigation of fruit/forest trees and agricultural land in different areas. The GLOF event has badly damaged the water channels and forest cover. These water channels required to be repair and can be extended to plant more forest trees on barren land. These water channels are earthen channels and do not require cement and concrete work. Two water channels have been recommended for repair and extension on one each on both sides. These all channels will irrigate 301 Acres of Barren and vegetated land in GLOF Site.

3.3.1. Budget Estimate for the Activity

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of two water channel one in Darkut GLOF Site	01	500000.	500000
	Repair and extension of two water channel two in Darkut GLOF Site	01	500000.	500000
	Repair and extension of two water channel three in Darkut GLOF Site	01	500000.	500000
	Total			**1500000**

3.4. Large Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.4.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.4.2. Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the large grasses along the trees and bushes however, we recommend at the areas where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation. The seeds can be seeded in the areas of repair and extended water channels.

- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope.

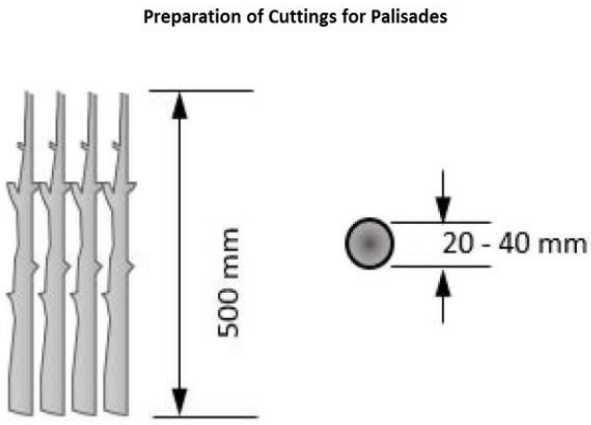
3.4.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds for Darkut	400kgs	3000 Rs.	1200000
02	Transportation	400	40 Rs.	16000
03	Land Preparation and seeding	200 men days	1000 Rs. Per day	200000
	Total			**1416000**

3.5. Live Fascines

A palisade is a fence or wall made from wooden stakes or tree trunks. Palisades were used historically as a defensive structure. In slope and embankments' protection, palisades are barriers made from live wood cuttings installed across a slope following the contour in order to trap debris moving down the slope, to armour and reinforce the slope, and to increase the infiltration rate. Palisades are used to prevent the extension of deep, narrow gullies and the erosion of V-shaped rills by forming a strong barrier which stabilizes the gully floor and traps material moving downwards. They are also effective on steep landslide or debris slopes. Palisades can be used on a wide range of sites with slopes of up to about 60°.

This procedure applies to use live cuttings of willow, popular, other indigenous and local species of plants which are commonly available in Darkut Village or in Yaseen valley in District Ghizer of Gilgit Baltistan. It is best to use local species as they are already adapted to the growing conditions; are more like to be resistant to local diseases; are more readily available; and are likely to be on lower cost options. Live hardwood willow, popular, shrub cuttings are laid in successive shallow trenches, in lines across the slope, usually following the contour. The tips of the cuttings protrude just beyond the face of the slope, where they grow buds and leaves that intercept rainfall, slow runoff and filter sediments. In addition to the exposed stems catching surface debris, as the roots develop they reinforce the upper soil layers. This techniques are used to stabilize embankments (fill slopes) or less steep cut-slopes. The roots add tensile reinforcement to the slope and provide a measure of frictional resistance to shallow sliding. The protruding brush retards runoff and reduces surface erosion. Brush wood layers give both immediate and increasingly strong protection and reinforcement to newly constructed fill and cut slopes. They are also a good remedial measure for repairing eroded gullies. The perpendicular orientation of brush layering to the slope is effective in terms of earth reinforcement and near-surface stabilization of the slope.

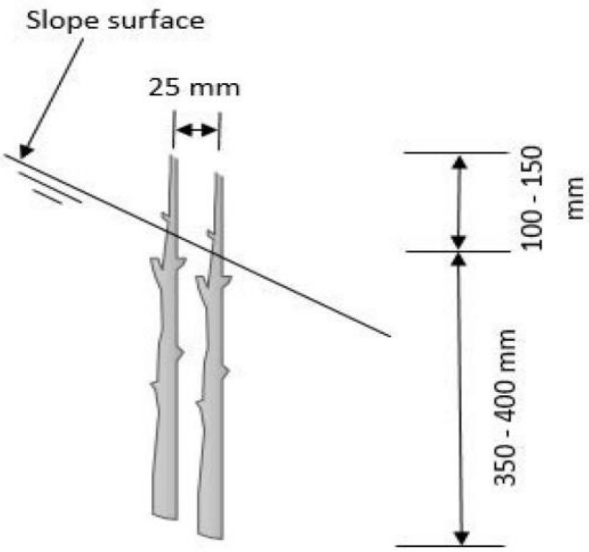


3.5.1. Site Preparation

The site along the water stream should be prepared before planting the cuttings of willow, popular, shrubs and other local species. Debris must be removed, depressions should be filled and humps should be leveled off to attain a linear profile. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 250mm above the toe of the slope, 1000mm centers up the slope and at the edge of the water stream 12 inches of distance from water level of summer season.

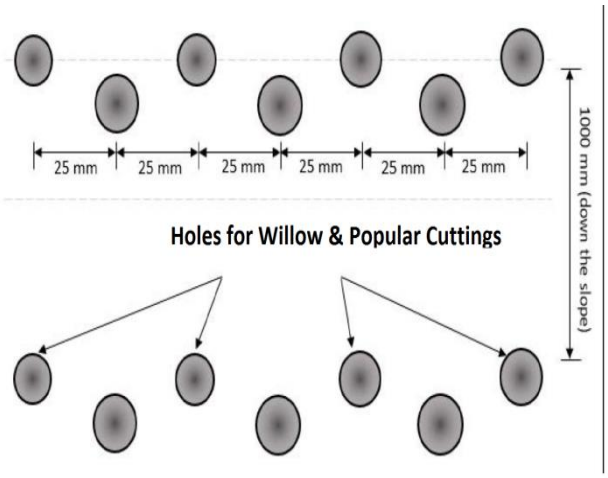
3.5.2. Planting Instructions

- Plant cuttings must be prepared from the woody material of 6 to 18 months in age.
- Cuttings should be approximately 20 mm dia., 500 mm length. They are laid in shallow trenches.
- These cuttings should be buried in moist soil for 3 to 7 days
- These cuttings may be immersed in water for two or three days
- When land is prepared plant the cuttings within 12 hours
- Cuttings from willow, popular and shrubs are more feasible for the local environment however; any other plant cutting must be suited to the site and shows the correct habit for an ability to grow from the cuttings. For example many shoots coming from the stems.



- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- Side branches shall be trimmed off carefully with a sharp tool.

- The cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- As with grass planting, the brush layers can also be angled to enhance drainage.
- Planting should be by experienced agricultural labor with technical supervision.
- Always start at the top of the slope and work downwards



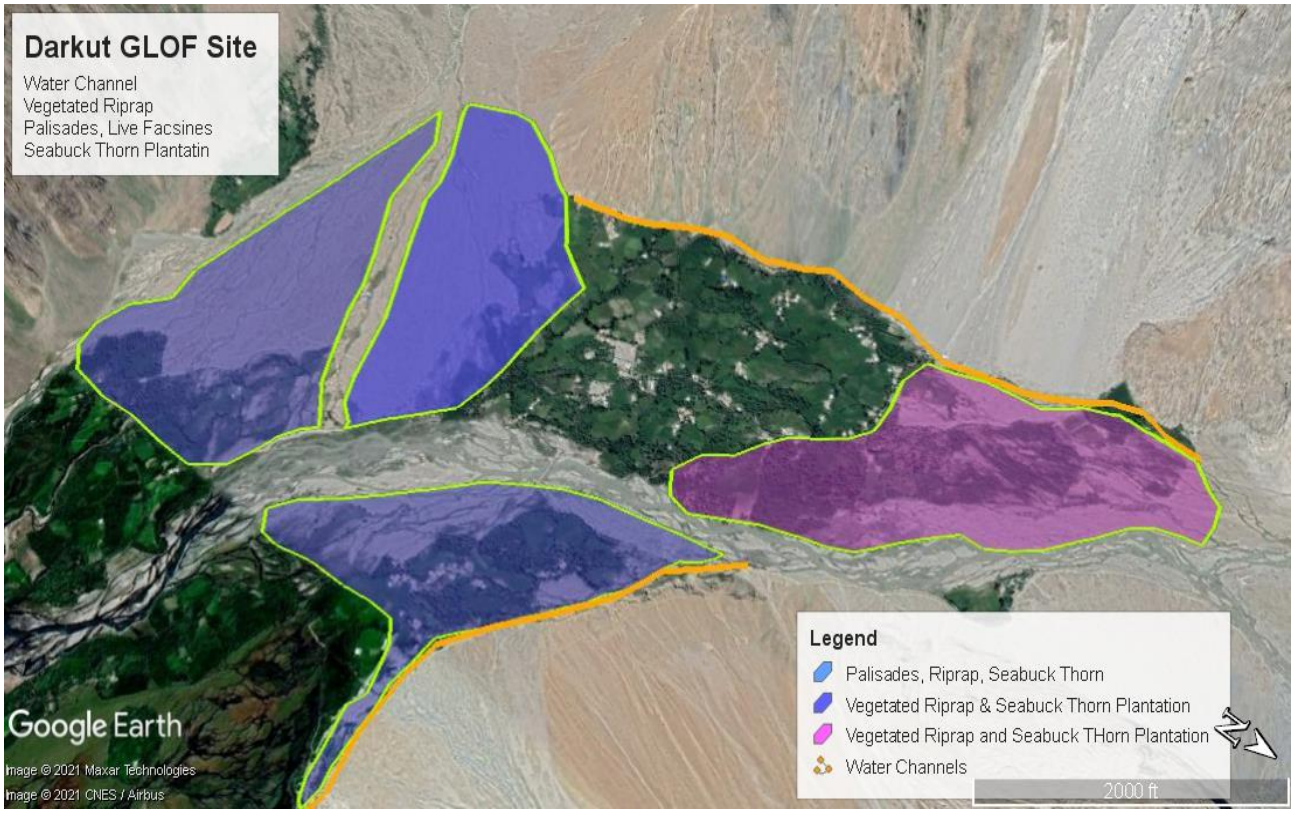
- Using a pointed bar, make a hole that is bigger than the cutting
- Carefully place the cutting in the hole so that two third is buried, firm the soil around it, taking care not to damage the bark
- Make the next hole 50mm along the row

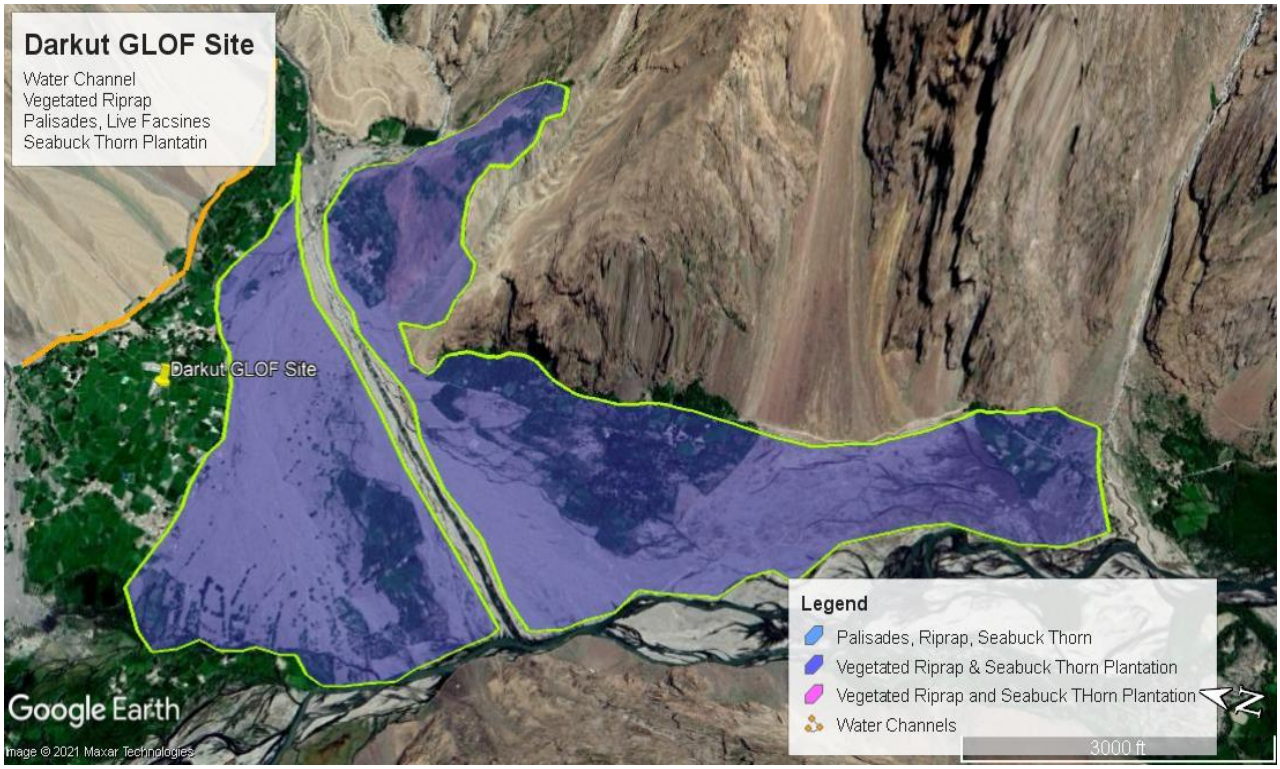
3.5.3. Budget Estimate for the Activity

S.NO	Item	Unit	Unite price	Total
01	Local live Plant cuttings of willow, popular, and Russian olive for Darkut	25000 cuttings	60 Rs.	1500000
02	Transportation	25000 Cuttings	40 Rs.	100000
03	Laboring for Plantation	250 men days	1000 Rs. Per days	250000
	Total			**1850000**

Total Proposed Budget for GLOF-II Site (Darkut, District Ghizer)

Activity No	Bioengineering Technique	Total
01	Compact Planting and Vegetated Rip Rap	4792000
02	Sea buckthorn Plantation	2700000
03	Repair and extension of water channels	1500000
04	Grass Planting	1416000
05	Palisades and Live fences	1850000
Grand Total		**12258000**




Darkut GLOF Site
Water Channel
Vegetated Riprap
Palisades, Live Facsines
Seabuck Thorn Plantatin
Darkut GLOF Site
Legend
Palisades, Riprap, Seabuck Thorn
Vegetated Riprap & Seabuck Thorn Plantation
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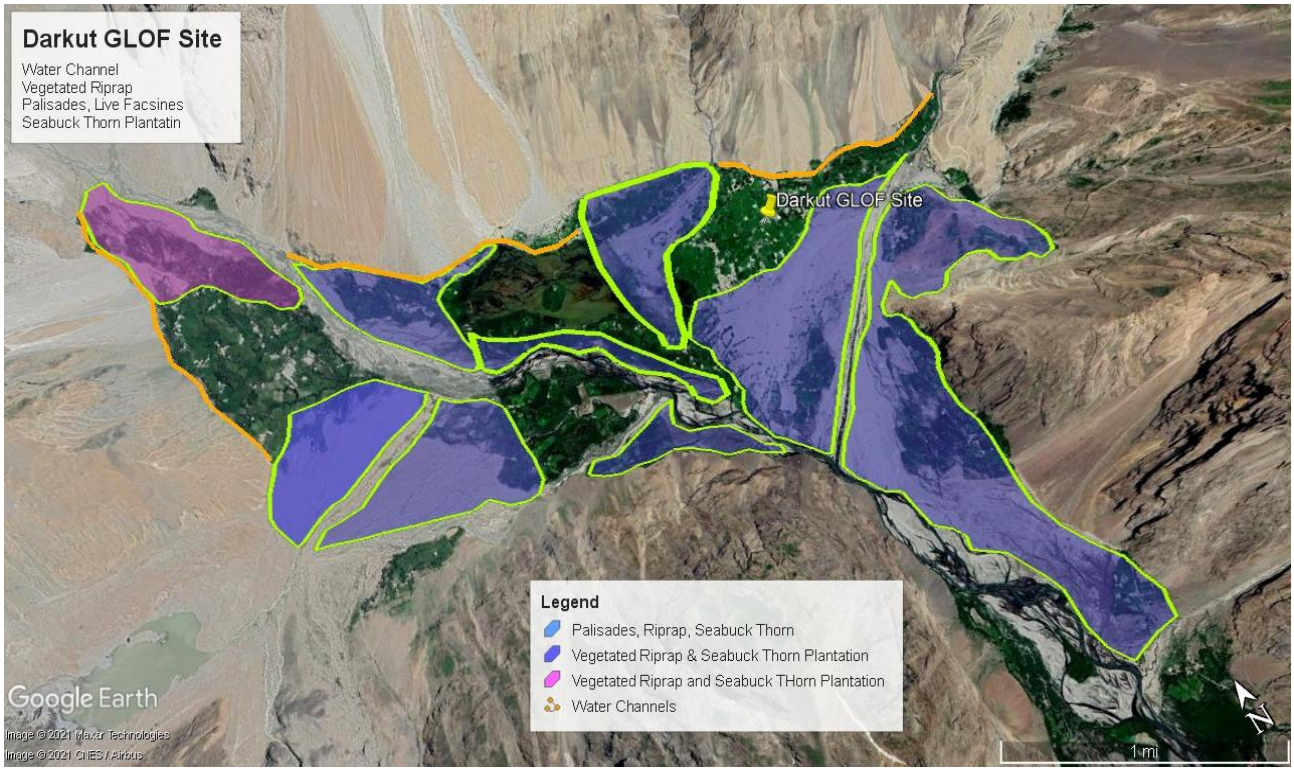
Water Channels
3000 ft
Google Earth
Image © 2021 Maxar Technologies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Vegetated Riprap and Seabuck THorn Plantation
Water Channels
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Google Earth
Image © 2021 Maxar Technologies
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SECTION VII: District Diamer,
Chapter 12: GLOF-II Site Muthat, District Diamer, Gilgit-Baltistan

1. Introduction

Muthat GLOF Site is situated in Raikot valley District Diamer of Gilgit Baltistan. Muthat is located at an elevation of 9435ft geographically defined by longitude 35°25'46.00"N, 74°39'20.06"E, with a central geographical coordinate at world geographical Globe. The Muthat village is situated below the Muthat Glacier and at the narrow valley on mountains. It is almost 123.5 KM from Gilgit city, the capital of Gilgit Baltistan via KKH. Jeep road turns left upwards mountains from Raikot Bridge and stops in the middle of the mountain as the access road do not approach the village. Our team has declared this road most dangerous approach road. After one and half hours' drive by the jeep, the only transport for Muthat; the team has to walk for more two hours to reach the GLOF site. The Muthat glacier is located on the top of the mountain fed by tributary glaciers. The road from Raikot Bridge passes hundreds of meters above along Muthat Nallah and stream through harsh rugged and rocky mountain. The Muthat stream from the glacier flows through narrow and Nasllah falls into Indus River eventually. The site is vulnerable because of the GLOF events and drainage of the glaciers through stream.

The GLOF event destructed the village and stream way by forming lake above the village. Population of the Muthat valley is vulnerable to negative impacts of climate change. During summer, snow melting and rainy seasons the glacier discharges water that erodes the embankments of downstream and causes heavy floods. The streams have stones and debris material which erodes and damages the land, fruit and forest trees, infrastructure such as water channels, roads and houses. Above the valley there are barren slopes which shear in rainy and snow melting seasons because of weathering.

The valley is intersected with ridges and stream banks and landscape features are prone for slope instability issues especially debris flow. Most of the slopes are unstable and barren naturally because of the high elevation. These can be vegetated by planting gross, Juniper, Sea buckthorn, popular, and other species those will contribute to reduce GLOF events. Stream bank's erosion problem is persistently increasing when temperature in summer increases; stream receives more floods because of glacier outburst and flood. In many instances, significant uncertainty exists about the stability of the embankment and land nearby the stream and infrastructure below the glacier.

2. Site Assessment

2.1. Site Type

Muthat village is intersected with ridges, streams and landscape features are prone for slope instability issues especially debris flow, loos material and mass movement. Some patches of the slopes above the valley are unstable and barren. Natural vegetation cover is reducing because of deforestation. This site is located in areas of steep, most of the area is unstable and stream water erodes the stream banks. Embankments of the water stream are vulnerable and continuously eroding during floods and GLOF events that carry filth, rocks and overflowing water have huge potential to damage settlements, land and infrastructure downstream. This is almost a regular annual feature especially in summer of this GLOF site.

The site is vulnerable for debris flow and soil erosion in some segments around the village and in the Nallahs as well. The sides of the water stream dry. Community plantation is very slow comparatively to deforestation in the area. The use of bioengineering techniques is mainly confined to reduce the threat of stream bank erosion, slope erosion and GLOF events. Where vegetation has been reduced or removed, it can be replaced by planting of appropriate species to achieve the desired effect. Structures formed from a combination of dead and living plant material can also be used to guide the river course and prevent flood entering into settlements and farmland. The plants can provide additional benefits for the local population like fodder, fruit, and firewood, but this is secondary to the protective function.

More resilient infrastructure means protection of agricultural land for farming; roads for easy communication; forest to slow down the erosion and mitigate climate change phenomenon. Stronger stream bank defenses mean that communities are protected from flood. Better and resilient infrastructure systems help to grow more crops and people are spending less time to collect and transporting water from long distances for domestic uses especially in winters.

2.2. Slope Length

In Muthat village slopes are of different length and width ranging from 20 meters to 80 meters long and 20 to 50 meters wide. The valley is situated on the hills and at the edge of the water stream. There is hard rock, sandy soil, loose material slopes in patches on both sides of the water stream. Stream bank is more than 2941 meters long along the village while it has long distance from the Glacier to the snout of Indus River. However,

there are small segments of slopes of different sizes and lengths are situated across the main stream. The slopes have landslide issues as well as surface erosion during climatic extremes.

2.3 Topography (Slope, Angle and Material Drainage)

The slopes in Muthat fall from 30 to 55 degree angle. The main slops of the Muthat village identified for vegetation cover and Sea buckthorn plantation is of 20 to 45 degree angle. The streams flow in 30 to 45 degree downwards into the Indust River. Material drainage of the main slope during the disaster drains in water stream. The drain of the streams after crossing long distance falls into Indus River.

2.4. Moisture

The bare soil-covered slopes in the valley are dry and becomes wet during rainy and snow melting seasons. They have debris and loose material on the slopes. Intense rain leads to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. Because of less vegetation cover on the slope segments, roughness of slope surface increases and rain and melting snow can easily erode through the gaps and becomes a disaster for community by destructing infrastructure especially their approach road, and tracks and forest trees. Dense cover, if forest trees and vegetation are grown at the slope, may protect the soil splash effects and can reduce runoff velocity, while roots of the vegetation may bind the soil particles, resulting to hinder surface erosion.

2.5. Stream Bank

In Muthat village water stream is flowing through the Nallah. The stream banks are eroded harshly during GLOF event of in recent past and blocked the Muthat water stream flow. The floods in the stream cause heavy embankment erosion and put the village and infrastructure to damage. Therefore, embankment erosion issue is persistently harms the infrastructure, roads, bridges, water supply and forest cover. Both sides of the water stream of the valley are dry and muddy which are susceptible for erosion.

3. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment showed slopes and embankment problems in the Muthat GLOF Site and the team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the problem and prioritized some sites as high risks and some had moderate risks.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

3.1. Vegetated Rip Rap And Compact Planting

Slopes of the Muthat Village have loose material that have tendency to roll down the slope because of the erosion caused by the rain, wind and weathering. This erosion of the slope can be controlled by the vegetated riprap and compact plating of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of Juniper, willow, popular and other indigenous plants on the slopes, in ditches, valleys and gullies. Willow and long cuttings of popular, willow and other local plants are easily available in Diamer District.

Juniper, Cedar, Spruce and Pine can be supplied from the forest nurseries and suppliers of the forest plants. Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil up to 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

3.1.2. Site Preparation

The site has enough scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of valley are 30 to 55 degree angle.

3.1.3. Special Instructions for Willow, Russian Olive and Popular Cuttings

- Long cuttings of willow, and popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants (willow and popular) are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

3.1.4. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings & Rooted Plants of willow, Russian olive and popular	8000 cuttings	90 Rs.	720000
02	Transportation	8000 Cuttings	50 Rs.	400000
03	Laboring for Plantation	80 men days	1000Rs.	80000
04	Plants of Juniper, spruce, Cedar and Pine	5000	250	1250000
05	Transportation	5000	50	250000
06	Laboring for Plantation	100 man days	1000	100000
	Total			**2800000**

3.2. Sea Buckthorn Plantation

Sea buckthorn is already grown in some patches of the slope and plains in Muthat Village. Sea buckthorn and bush's roots mainly protect soil one meter deep and play a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.2.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier.

Picked out Seabuck plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.2.2. Special Plantation Instructions

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Seabuck plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height
- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

3.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants for Muthat Village	10000 plants	60 Rs.	**600000**
02	Transportation,	10000 plants	40 Rs.	**400000**
	Laboring for digging and planting	100 Men days	1000	**100000**
	Total			**1100000**

3.3. Repair and extension of existing water channels

Muthat village has traditionally earthen water channels for agricultural and irrigation of fruit/forest trees and agricultural land in different areas. These water channels required to be repair and can be extended to plant more forest trees on barren land. These water channels are earthen channels and do not require cement and concrete work. Two water channels have been recommended for repair and extension. These channels will irrigate 159.3 Acres of Barren and vegetated land in this GLOF Site. Length of water irrigation channel one is 1272 Meter and channel to is 675 meter.

3.3.1. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of irrigation channels one in Muthat GLOF Site 1272 meter	01	400000.	400000
02	Repair and extension of irrigation channels Two in Muthat GLOF Site 675 meter	01	300000	300000
	Total			**700000**

3.4. Large Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.4.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.4.2. Special Instructions for planting process

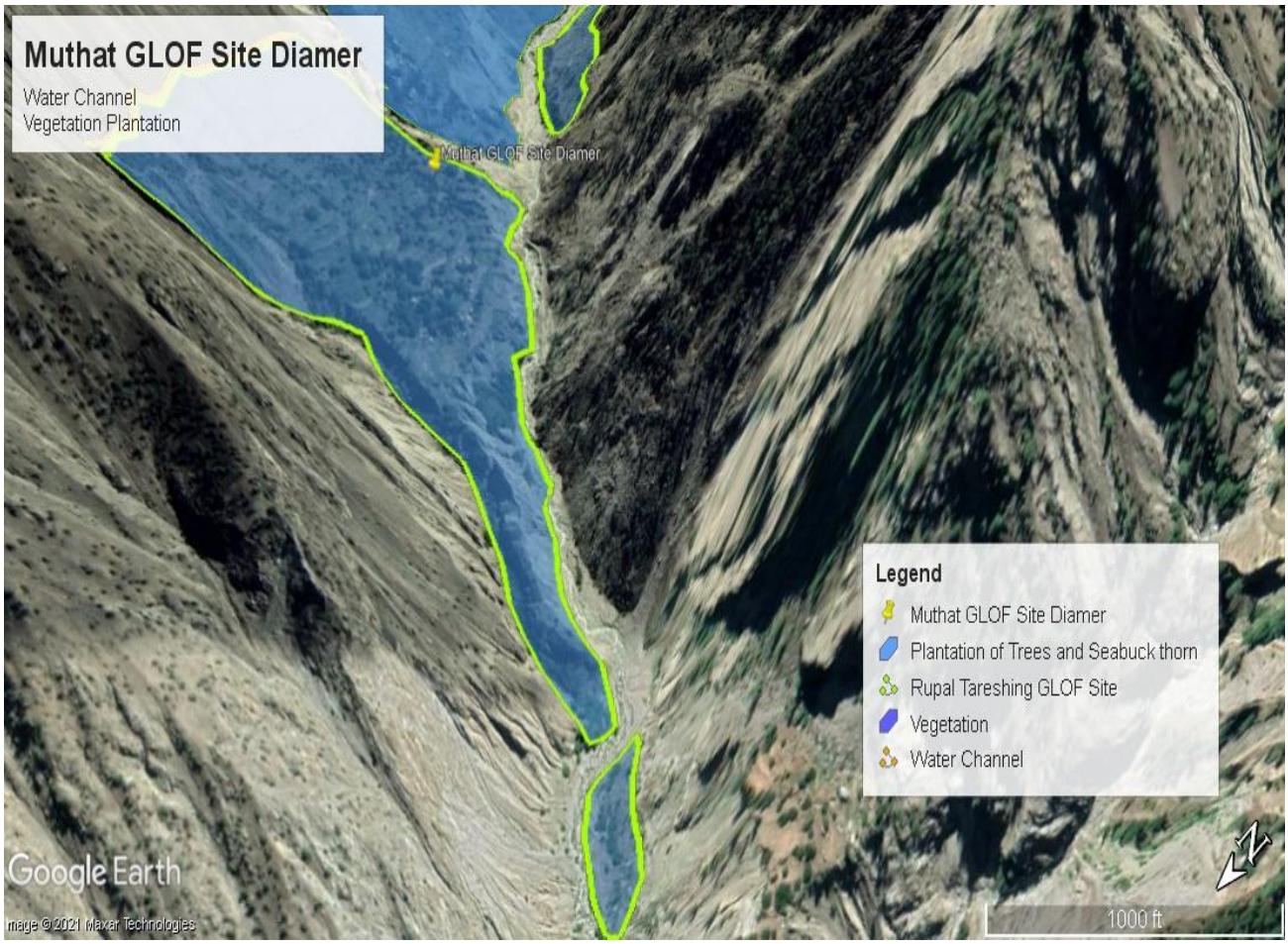
There is hundreds of Kanals of sloppy land feasible for the large grasses along the trees and bushes however, we recommend at the areas where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation. The seeds can be seeded in the areas of repair and extended water channels.

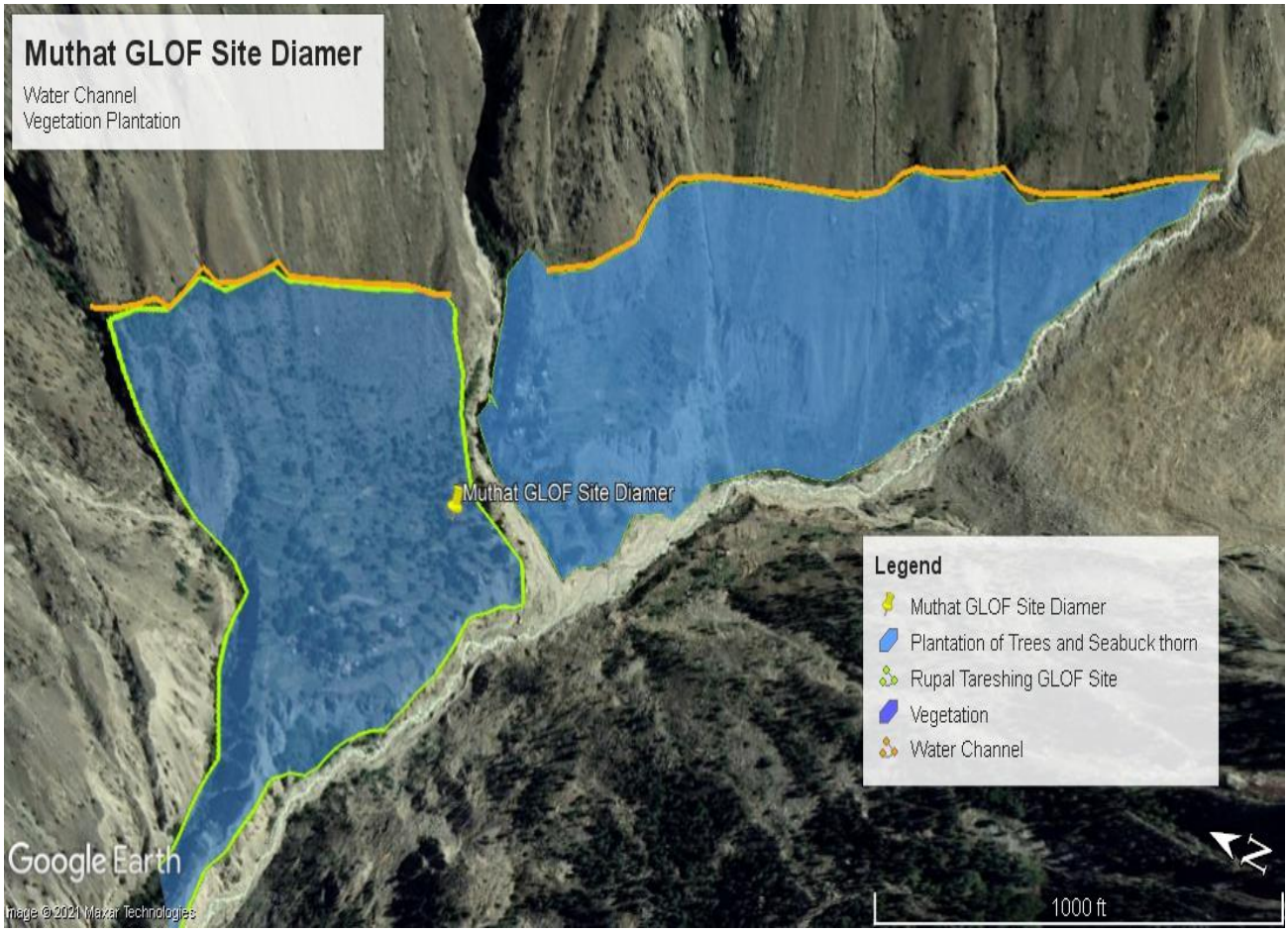
- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

3.4.3. Budget estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds for Muthat	200kgs	3000 Rs.	600000
02	Transportation	200	100 Rs.	20000
03	Laboring for land preparation and seeding	100	1000	100000
	Total			**720000**

Total Proposed Budget For GLOF-II Site (Muthat, District Diamer)		
Activity No	**Bioengineering Technique**	**Total**
01	Compact Planting and Vegetated Rip Rap	2700000
02	Sea buckthorn Plantation	1100000
03	Repair and extension of water channels	700000
04	Grass Planting	720000
Grand Total Large and local grass planting		**5220000**




Muthat GLOF Site Diamer
Water Channel
Vegetation Plantation
Muthat GLOF Site Diamer
Legend
Muthat GLOF Site Diamer
Plantation of Trees and Seabuck thorn
Rupal Tareshing GLOF Site
Vegetation
Water Channel
Google Earth
Image © 2021 Maxar Technologies
1000 ft

Section VIII: District Shigar,
Chapter 13: GLOF-II Site Arindu, District Shigar, Gilgit-Baltistan

1. Introduction

Arindu GLOF Site is situated in District Shigar of Gilgit Baltistan. Arindu is located at an elevation of 9120ft, geographically defined by longitude 35°51'51.64"N, 75°20'4.55"E, with a central geographical coordinate at world geographical Globe. Arindu Valley is situated in the area covered by high mountains from every side and there are two water streams flowing from different sides fed by different tributaries in multiple areas. It is situated below the Arindu Glaciers and at the edge of Arindu River. It is almost 123 KM from Skardu city, via Shigar Arindu road. The Arindu glacier is located on the top of the Arindu Nallah fed by three more tributary glaciers. The road passes through rugged mountains. The stream flowing from the glaciers keep changes their direction because that the valley is been devastated in many segments. The site is highly vulnerable because of the GLOF events and drainage of the glaciers through streams.

The GLOF events devastated the valley from every direction in recent past destructing agricultural land, infrastructure, roads, houses, fruit and forest trees. A large fragment of its population is vulnerable to such negative impacts of climate change. During summer, snow melting and rainy seasons the glacier releases water that erodes the embankments of downstream and causes heavy floods and floods keep changing its way in the valley. The streams have stones and debris material which erodes and damages the land, fruit and forest trees, infrastructure such as water channels, roads and houses. Above the valley there are barren slopes which shear in rainy and snow melting seasons because of weathering.

The valley is intersected with ridges, streams and landscape features are prone for slope instability issues especially debris flow, loos material and mass movement. Most of the slopes are unstable and barren naturally because of the high elevation. These can be vegetated by planting gross, willow, Sea buckthorn, popular, Russian olive, and other species those will contribute to reduce GLOF events. Stream bank's erosion problem is persistently increasing when temperature in summer increases; stream receives more floods because of glacier outburst and rain flood. In many instances, significant uncertainty exists about the stability of the stream banks and land nearby the stream and infrastructure.

2. Site Assessment

2.1.Site Type

Arindu valley is intersected with ridges, streams and landscape features are prone for slope instability issues especially debris flow, loos material and mass movement. Most of the slopes around the valley are unstable and barren because of the high elevation and less vegetation. This site is located in areas of steep Nallah, most of the area is unstable and stream water erodes the Banks of stream. Verges of the water stream are vulnerable and continuously eroding during floods and GLOF events that carry filth, rocks and overflowing water have huge potential to damage settlements, land and infrastructure downstream. This is almost a regular annual feature especially in summer of this GLOF site.

The site is vulnerable for debris flow in some segments around the village and in the Nallahs as well. The sides of the water stream and river are dry and water streams keep changing their direction usually. Community of the valley have planted trees especially Sea buckthorn, willow, and bushes in many patches. The use of bioengineering techniques is mainly confined to reduce the threat of stream bank erosion, slope erosion and GLOF events. Where vegetation has been reduced or removed, it can be replaced by planting of appropriate species to achieve the desired effect. Structures formed from a combination of dead and living plant material can also be used to guide the river course and prevent flood entering into settlements and farmland. The plants can provide additional benefits for the local population like fodder, fruit, and firewood, but this is secondary to the protective function.

More resilient infrastructure means protection of agricultural land for farming; roads for easy communication; forest to slow down the erosion and mitigate climate change phenomenon. Stronger stream bank defenses mean that communities are protected from flood. Better and resilient infrastructure systems help to grow more crops and people are spending less time to collect and transporting water from long distances for domestic uses especially in winters.

2.2. Slope Length

In Arindu village slopes are of different length and width ranging from 60 meters to 600 meters long and 50 to 120 meters wide. The valley is situated on the footings of the hills and at the edge of the water stream and River. There is debris, sandy soil, loose material slopes in patches on three sides of the valley. Four streams are flowing from the valley

and divide the valley in multiple sub villages. The slopes have landslide issues as well as surface erosion during climatic conditions.

2.3. Topography (Slope, Angle and Material Drainage)

The slopes in Arindu fall from 30 to 65 degree angle. The main slops of the Arindu village identified for vegetation cover and Sea buckthorn plantation is of 20 to 45 degree angle. The streams flow in 10 to 25 degree downwards. Material drainage of the main slopes during the disaster drains in the gorges and damages agricultural land, forest, infrastructure, roads, tracks, water supply and houses. The drain of the streams spreads in orchards by eroding stream banks and deposits in orchards, agricultural land pasture. Near the village it spreads and damages cultivable land which is under sand, mud and debris because of floods in many patches.

2.4. Moisture

The bare soil-covered slopes in the valley are dry and becomes wet during rainy and snow melting seasons. The valley has debris and loose material on the slopes. Intense rain leads to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. Because of no vegetation cover on the slope segments, roughness of slope surface increases and rain and melting snow can easily erode through the gaps and near the village it becomes a disaster for community by destructing infrastructure especially Arindu road, agricultural land, trees, and livestock. Dense cover, if forest trees and vegetation are grown at the slope, may protect the soil splash effects and can reduce runoff velocity, while roots of the vegetation may bind the soil particles, resulting to hinder surface erosion.

2.5. Stream Bank

In Arindu village water streams are flowing through the middle of the village dividing the valley in sub villages. The stream banks are eroded harshly during GLOF event of recent past and damaged houses, trees, agricultural land, and infrastructure such as water supply, irrigation channels, road and tracks. The floods in the stream cause heavy embankment erosion and put the village and infrastructure to damage. Therefore, embankment erosion issue is persistently harms the infrastructure, roads, bridges, water supply and forest cover.

3. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment showed slopes and embankment problems in the Arindu GLOF Site and the team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the problem and prioritized some sites as high risks and some had moderate risks.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

3.1. Vegetated Rip Rap and Compact Planting

Slopes of the Arindu village have loose material that have high tendency to roll down the slope because of the erosion caused by the rain, wind and weathering. This erosion of the slope can be reduced by the vegetated riprap and compact plating of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of Juniper, willow, popular and other indigenous plants on the slopes, in ditches, valleys and gullies. Willow and long cuttings of popular, willow and other local plants are easily available in Arindu valley of Shigar District. Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil up to 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

3.1.1. Site Preparation

The site has enough scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of Darkut valley are 30 to 65 degree angle.

3.1.2. Special Instructions for Willow and Popular Cuttings

- Long cuttings of willow, Russian Olive and popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants (willow and popular) are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

3.1.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings & Rooted Plants of willow, Russian olive and popular	30000 cuttings	100 Rs.	3000000
02	Transportation and laboring for digging & Plantation	30000	30	900000
	Total			**3900000**

3.2. Sea buckthorn Plantation

Sea buckthorn is already grown in some patches of the slope and plains in Arindu Village. Sea buckthorn and bush's roots mainly protect soil one meter deep and play a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.2.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier. Picked out Seabuck plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.2.2. Special Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Sea buckthorn plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height
- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

3.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants for Arindu Village	30000 plants	60 Rs.	**1800000**
02	Transportation, and laboring for digging and planting	30000 plants	30 Rs.	**900000**
	Total			**2700000**

3.3. Repair and extension of existing water channels

Arindu village has traditionally earthen water channels for agricultural and irrigation of fruit/forest trees and agricultural land in different areas. The GLOF event has badly damaged the water channels and forest cover. Although new water channels also required for afforestation and existing water channels required to be repair and can be extended to plant more forest trees on barren land. These water channels are earthen channels and do not require cement and concrete work. Six water channels have been recommended for repair and extension in the valley. These all channels will irrigate 481 Acres of Barren and vegetated land in GLOF Site.

3.2.1. Budget Estimate for The Activity

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of two water channels in Arindu GLOF Site	06	300000.	1800000
	Total			**1800000**

3.3. Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.3.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.3.2. Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the large grasses along the trees and bushes however, we recommend at the areas where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation. The seeds can be seeded in the areas of repair and extended water channels.

- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o

- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

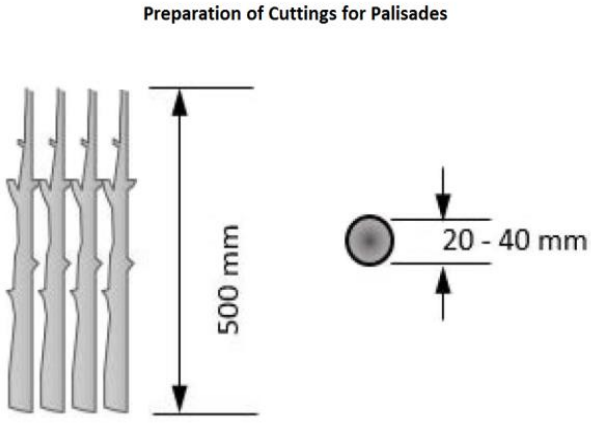
3.3.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds for Arindu	300kgs	3000 Rs.	900000
02	Transportation and seeding	300	40 Rs.	12000
	Total			**912000**

3.4. Live Fascines

A palisade is a fence or wall made from wooden stakes or tree trunks. Palisades were used historically as a defensive structure. In slope and embankments' protection, palisades are barriers made from live wood cuttings installed across a slope following the contour in order to trap debris moving down the slope, to armour and reinforce the slope, and to increase the infiltration rate. Palisades are used to prevent the extension of deep, narrow gullies and the erosion of V-shaped rills by forming a strong barrier which stabilizes the gully floor and traps material moving downwards. They are also effective on steep landslide or debris slopes. Palisades can be used on a wide range of sites with slopes of up to about 60°.

This procedure applies to use live cuttings of willow, popular, other indigenous and local species of plants which are commonly available in



Arindu Village or in Shigar District of Gilgit Baltistan. It is best to use local species as they are already adapted to the growing conditions; are more like to be resistant to local diseases; are more readily available; and are likely to be on lower cost options. Live hardwood willow, popular, shrub cuttings are laid in successive shallow trenches, in lines across the slope, usually following the contour. The tips of the cuttings protrude just beyond the face of the slope, where they grow buds and leaves that intercept rainfall, slow runoff and filter sediments. In addition to the exposed stems catching surface debris, as the roots develop they reinforce the upper soil layers. This techniques are used to stabilize embankments (fill slopes) or less steep cut-slopes. The roots add tensile reinforcement to the slope and provide a measure of frictional resistance to shallow sliding. The protruding brush retards runoff and reduces surface erosion. Brush wood layers give both immediate and increasingly strong protection and reinforcement to newly constructed fill and cut slopes. They are also a good remedial measure for repairing eroded gullies. The perpendicular orientation of brush layering to the slope is effective in terms of earth reinforcement and near-surface stabilization of the slope.

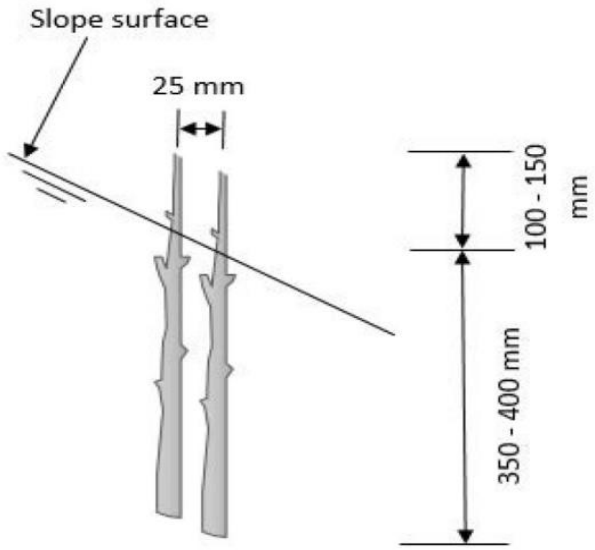
3.4.1. Site Preparation

The site along the water stream should be prepared before planting the cuttings of willow, popular, shrubs and other local species. Debris must be removed, depressions should be filled and humps should be leveled off to attain a linear profile. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 250mm above the toe of the slope, 1000mm centers up the slope and at the edge of the water stream 12 inches of distance from water level of summer season.

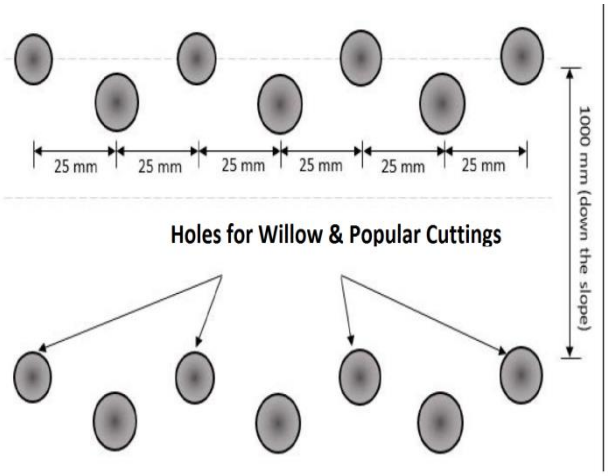
3.4.2. Planting Instructions

- Plant cuttings must be prepared from the woody material of 6 to 18 months in age.
- Cuttings should be approximately 20 mm dia., 500 mm length. They are laid in shallow trenches.
- These cuttings should be buried in moist soil for 3 to 7 days

- These cuttings may be immersed in water for two or three days
- When land is prepared plant the cuttings within 12 hours
- Cuttings from willow, popular and shrubs are more feasible for the local environment however; any other plant cutting must be suited to the site and shows the correct habit for an ability to grow from the cuttings. For example many shoots coming from the stems.



- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- Side branches shall be trimmed off carefully with a sharp tool.
- The cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- As with grass planting, the brush layers can also be angled to enhance drainage.
- Planting should be by experienced agricultural labor with technical supervision.
- Always start at the top of the slope and work downwards



- Using a pointed bar, make a hole that is bigger than the cutting
- Carefully place the cutting in the hole so that two third is buried, firm the soil around it, taking care not to damage the bark
- Make the next hole 50mm along the row

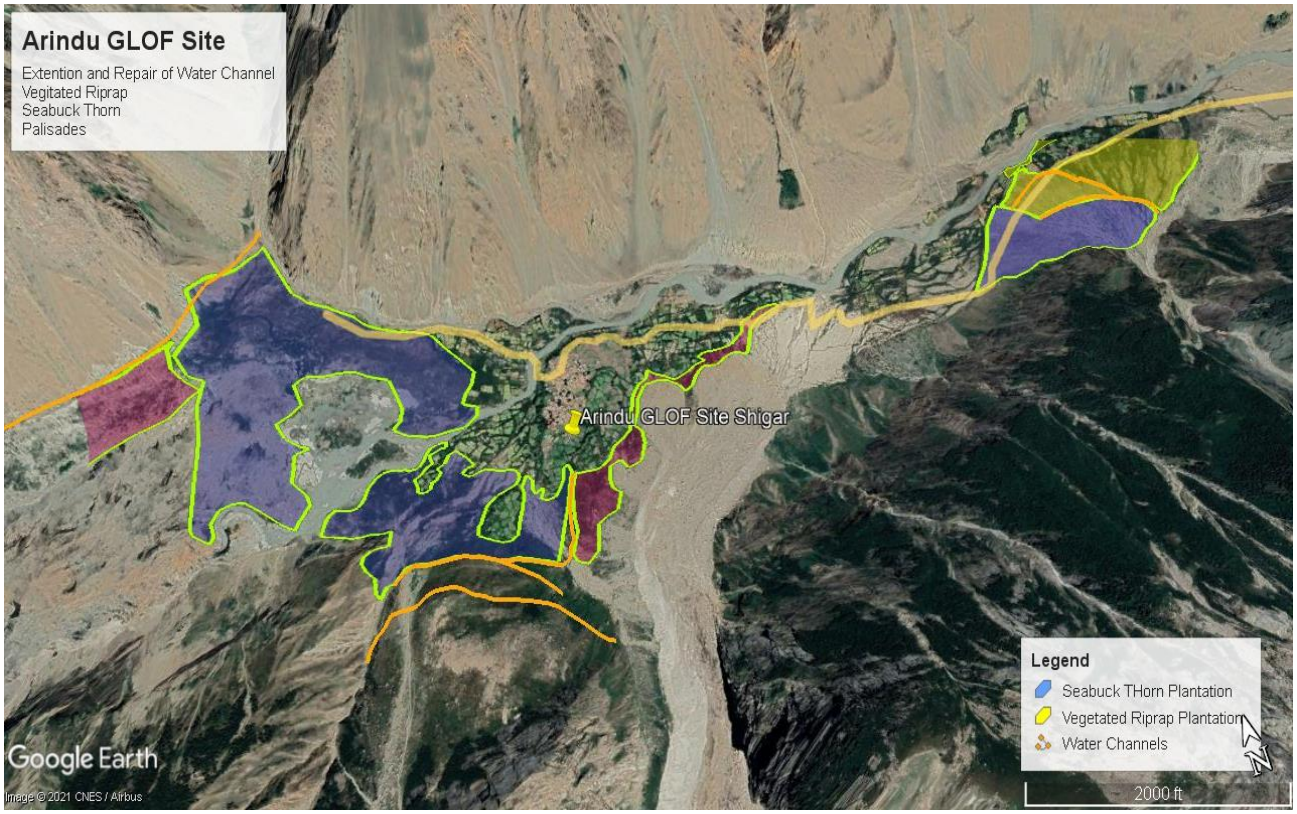
3.4.3. Budget Estimate

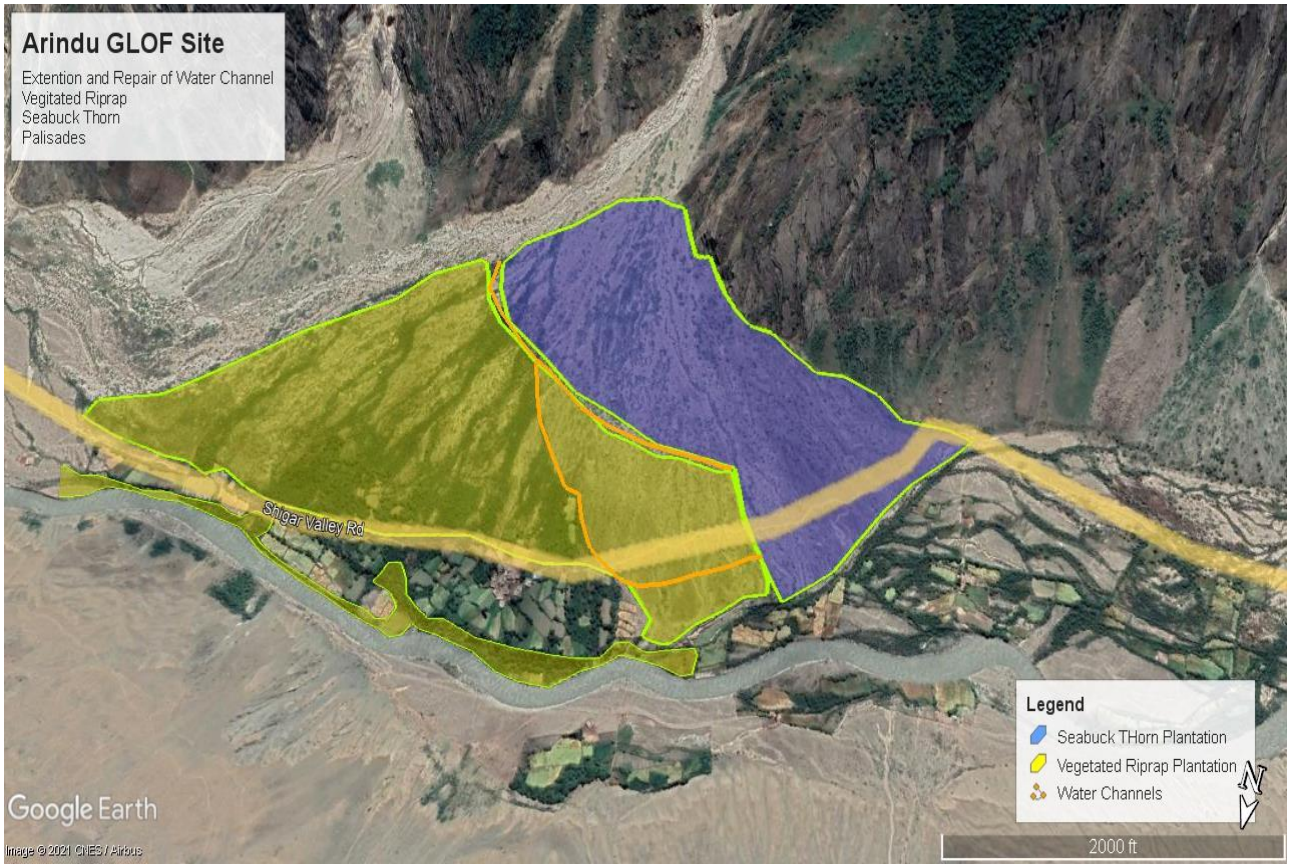
S.NO	Item	Unit	Unite price	Total
01	Local dry & live Plant cuttings of willow, popular, and Russian olive (all inclusive) for Arindu	25000 cuttings	60 Rs.	1500000
	Total			**1500000**

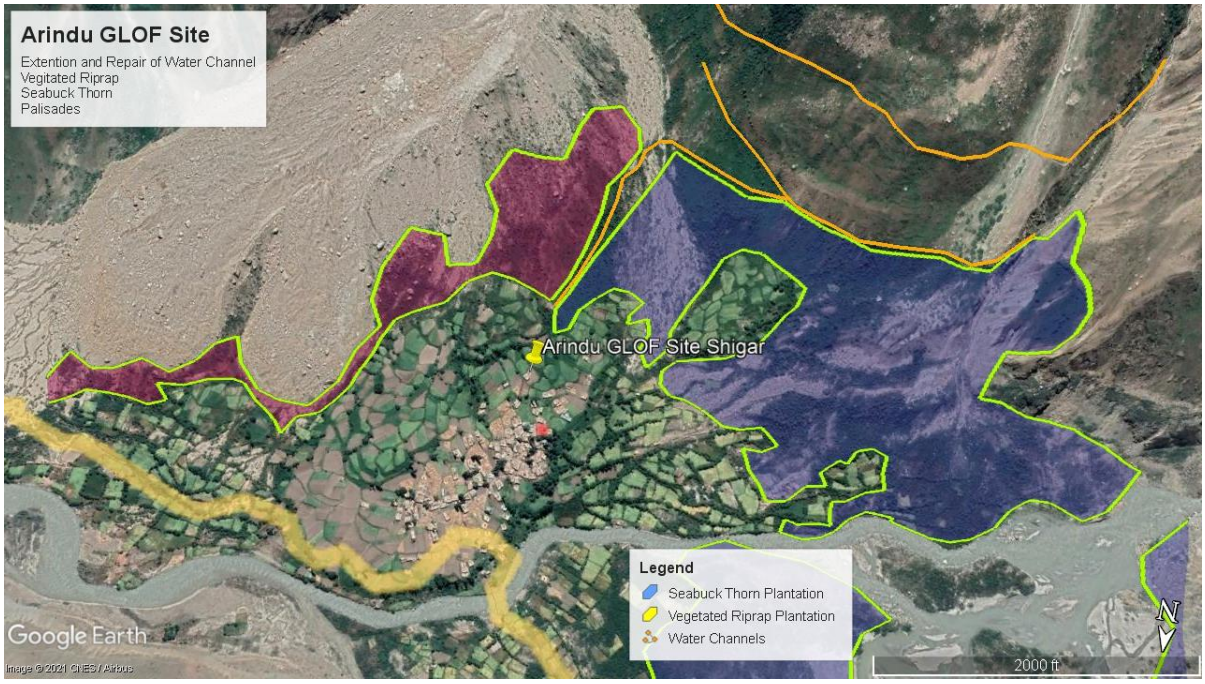
Total Proposed Budget for GLOF-II Site (Arindu, District Shigar)

Activity No	Bioengineering Technique	Total
01	Compact Planting and Vegetated Rip Rap	3900000
02	Sea buckthorn Plantation	2700000
03	Repair and extension of water channels	1800000
04	Grass Planting	912000
05	Live fences	1500000
Grand Total		**10812000**

Map of GLOF Site Arindu for bioengineering






Arindu GLOF Site
Extention and Repair of Water Channel
Vegitated Riprap
Seabuck Thorn
Palisades
Arindu GLOF Site Shigar
Legend
Seabuck Thorn Plantation
Vegetated Riprap Plantation
Water Channels
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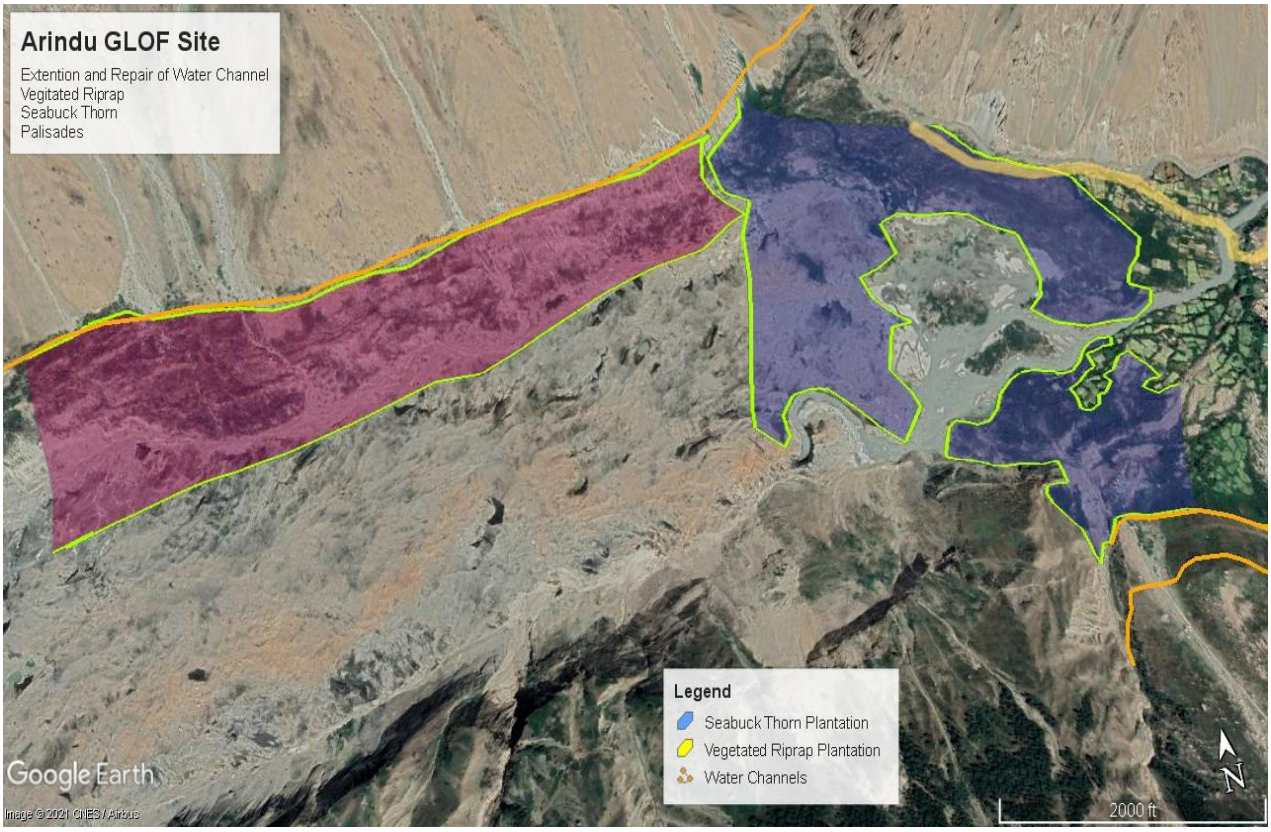
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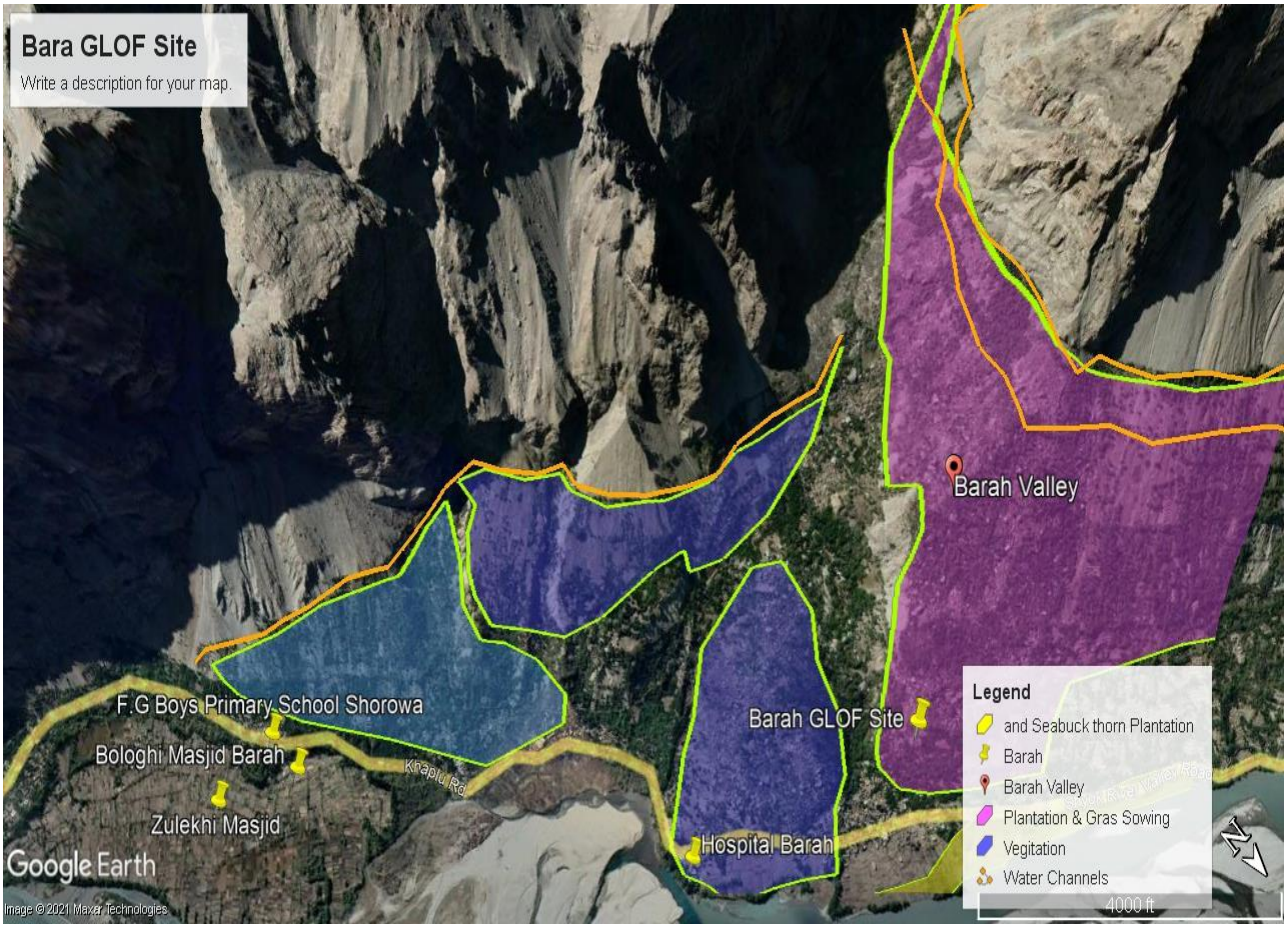
Section IX: District Ghanche,
Chapter 14: GLOF-II Site Barah Village, District Ghanche, Gilgit-Baltistan



1. Introduction

Barah GLOF Site is situated in District Ghanche of Gilgit Baltistan. Barah is located at an elevation of 8335ft geographically defined by longitude 35°12'16.83"N, 76°15'51.59"E, with a central geographical coordinate at world geographical Globe. Barah village is situated under high mountains and Barah Glacier and water stream flowing from the center of the village and fall into Ghanche River. It is almost 110 KM from Skardu city and 20 KM before district headquarter Khapulo. The road passes along Ghanche River through rugged mountains. The streams flowing from the glaciers pass through village comparatively stable water way. The site is vulnerable because of the GLOF events and drainage of the glaciers through streams for future.

In the history the GLOF events wrecked the valley along the water stream as mentioned by the people in FGD conducted in Barah. It had damaged agricultural land, infrastructure, roads, houses, fruit and forest trees. During summer, snow melting and rainy seasons the glacier releases water that erodes the embankments of downstream and causes floods. The streams have stones and compacted material and above the village on hills there is loose material and debris which erodes and damages the land, fruit and forest trees, infrastructure such as water channels, roads and houses. Above the valley there are less vegetated slopes which shear in rainy and snow melting seasons because of weathering.

Some of the slopes are unstable and barren naturally and some are less vegetated. These can be vegetated by planting gross, willow, Sea buckthorn, popular, Russian olive, and other species those will contribute to reduce GLOF events. Stream bank's erosion problem is in this site is comparatively compacted but can be eroded in future because of floods and GLOF events. In some instances, significant uncertainty exists about the stability of the embankment and land nearby the stream and infrastructure.

2. Site Assessment

2.1. Type

Barah valley is comparatively compacted and and landscape features are prone for slope instability issues especially debris flow, loos material and mass movement. Some of the slopes above the valley are unstable and less vegetated because of unavailability of funds and vegetation. This site is located in areas of steep, some of the area is unstable above the village.

The site is vulnerable for debris flow in some segments around the village and in the Nallahs as well. The sides of the water stream and river are dry and Shyok River erodes the village in many areas. Community of the valley has planted trees, Sea buckthorn, willow, popular and bushes in many patches. The use of bioengineering techniques is mainly confined to reduce the threat of river bank erosion, slope erosion and GLOF events. Where vegetation has been reduced or removed, it can be replaced by planting of appropriate species to achieve the desired effect. Structures formed from a combination of dead and living plant material can also be used to guide the river course and prevent flood entering into settlements and farmland. The plants can provide additional benefits for the local population like fodder, fruit, and firewood, but this is secondary to the protective function.

Stronger stream bank defenses mean that communities are protected from flood. Better and resilient infrastructure systems help to grow more crops and people are spending less time to produce agricultural products.

2.3. Slope Length

In Barah village slopes are of different length and width ranging from 30 meters to 200 meters long and 50 to 100 meters wide. The valley is situated on the footings of the hills and at the edge of the water stream and River. There is debris, sandy soil, loose material slopes in patches above the valley. The slopes have landslide issues as well as surface erosion during climatic conditions.

2.4. Topography (Slope, Angle and Material Drainage)

The slopes in Barah fall from 25 to 65 degree angle. The main slops of the Barah village identified for vegetation cover and Sea buckthorn plantation is of 40 to 65 degree angle. The streams flow in 25 to 45 degree downwards into the Shyok River. Material drainage of the main slopes during the disaster can drain in the gorges and can damage agricultural land, forest, infrastructure, roads, tracks, water supply and houses. The drain of the

streams may spreads in orchards by eroding stream banks. Near the River it spreads and damages cultivable land which is under sand, mud and debris because of floods.

2.5. Moisture

The bare soil-covered slopes in the valley are dry and becomes wet during rainy and snow melting seasons. They have debris and loose material on the slopes. Intense rain can lead to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. Because of less vegetation cover on the slope segments, roughness of slope surface increases and rain and melting snow can easily erode through the gaps and near the village it can become a disaster for community Dense cover, if forest trees and vegetation are grown at the slopes, may protect the soil splash effects and can reduce runoff velocity, while roots of the vegetation may bind the soil particles, resulting to hinder surface erosion.

2.6. Stream Bank

In Barah village water stream is flowing through the middle of the village dividing the village in two sub villages. The stream banks are compressed and vegetated in the village. The community has constructed walls along stream but if occurs the GLOFF event can erode stream banks harshly and damage houses, trees, agricultural land, and infrastructure such as water supply, irrigation channels, road and tracks. Therefore, embankment erosion issue is persistently harmful for infrastructure, roads, bridges, water supply and forest cover.

3. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment showed slopes erosion problems in the Barah GLOF Site and the team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the future problems and prioritized some sites as high risk and some had moderate risk.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

3.1. Vegetated Rip Rap and Compact Planting

Slopes of the Barah Village have loose material that have high tendency to roll down the slope because of the erosion caused by the rain, wind and weathering. This erosion of the slope can be reduced by the vegetated riprap and compact planting of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of willow, popular, Russian Olive and other indigenous plants on the slopes, in ditches, valleys and gullies. Long cuttings of popular, willow, Russian Olive and other local plants are easily available in Barah or in Ghanche District.

Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil up to 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

3.1.1. Site Preparation

The site has enough scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of Darkut valley are 30 to 65 degree angle.

3.1.2. Special Instructions for Willow and Popular Cuttings

- Long cuttings of willow, Russian Olive and popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants (willow and popular) are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days

- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

3.1.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings & Rooted Plants of willow, Russian olive and popular (all inclusive)	30000 cuttings	90 Rs.	2700000
	Total			**2700000**

3.2. Sea buckthorn Plantation

Sea buckthorn is already grown in some patches of the slope and plains in Barah Village. Sea buckthorn and bush's roots mainly protect soil one meter deep and play a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots

physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.2.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier. Picked out Sea buckthorn plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.2.2. Special Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Sea buckthorn plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height
- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

3.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants for Barah Village (all Inclusive)	30000 plants	60 Rs.	**1800000**
	Total			**1800000**

3.3. Repair and extension of existing water channels

Barah village has traditionally earthen water channels for agricultural and irrigation of fruit/forest trees and agricultural land in different areas. These channels are constructed long ago and vegetated land increases. The channels cannot supply more water for more plantations. These water channels required to be repair and can be extended to plant more forest trees on barren land. These water channels are earthen channels and do not require cement and concrete work. Three water channels have been recommended for repair and extension on one each on both sides. These all channels are of different lengths in size. Channel No one is 3280 meter long, channel two is 5011 and third channel is 2383 meters in length.

3.3.1. Budget Estimate for the activity

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of two water channels in Barah GLOF Site	03	500000.	1500000
	Total			**1500000**

3.4. Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.4.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.4.2. Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the large grasses along the trees and bushes however, we recommend at the areas where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation. The seeds can be seeded in the areas of repair and extended water channels.

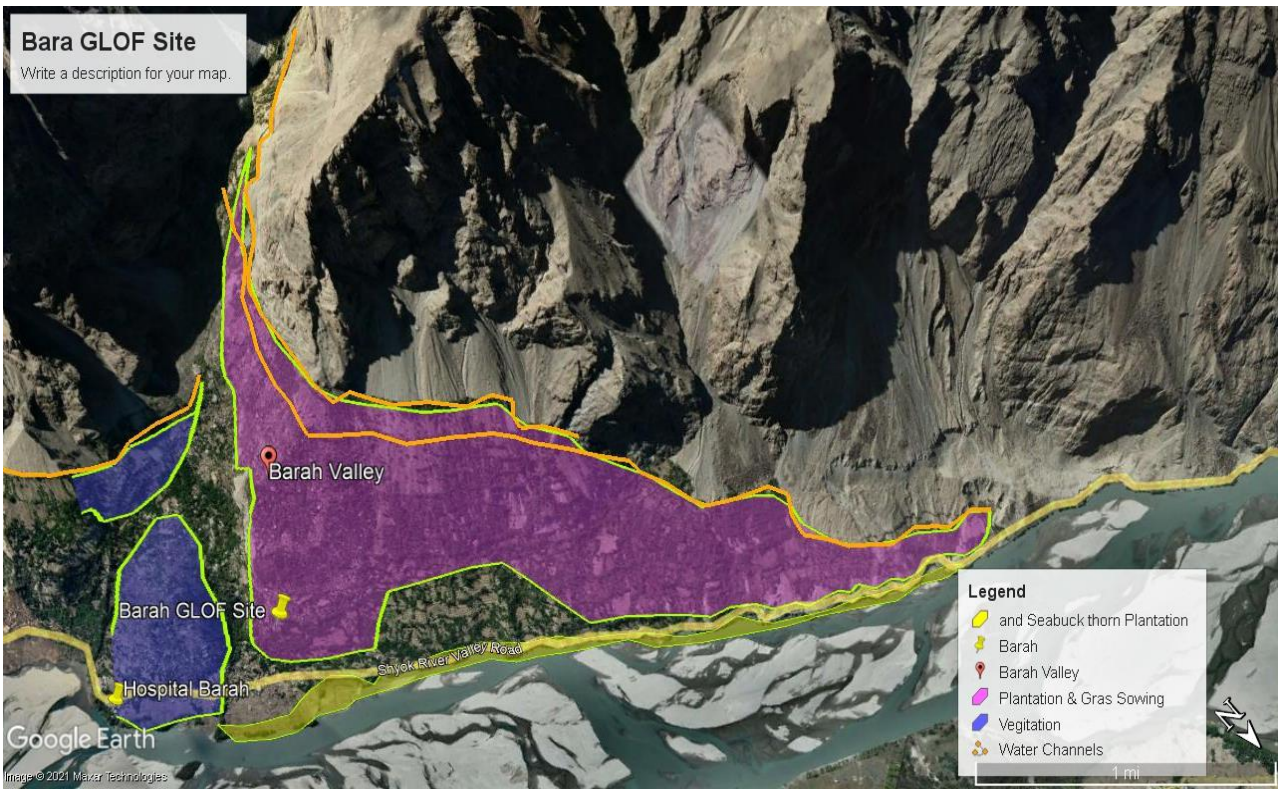
- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

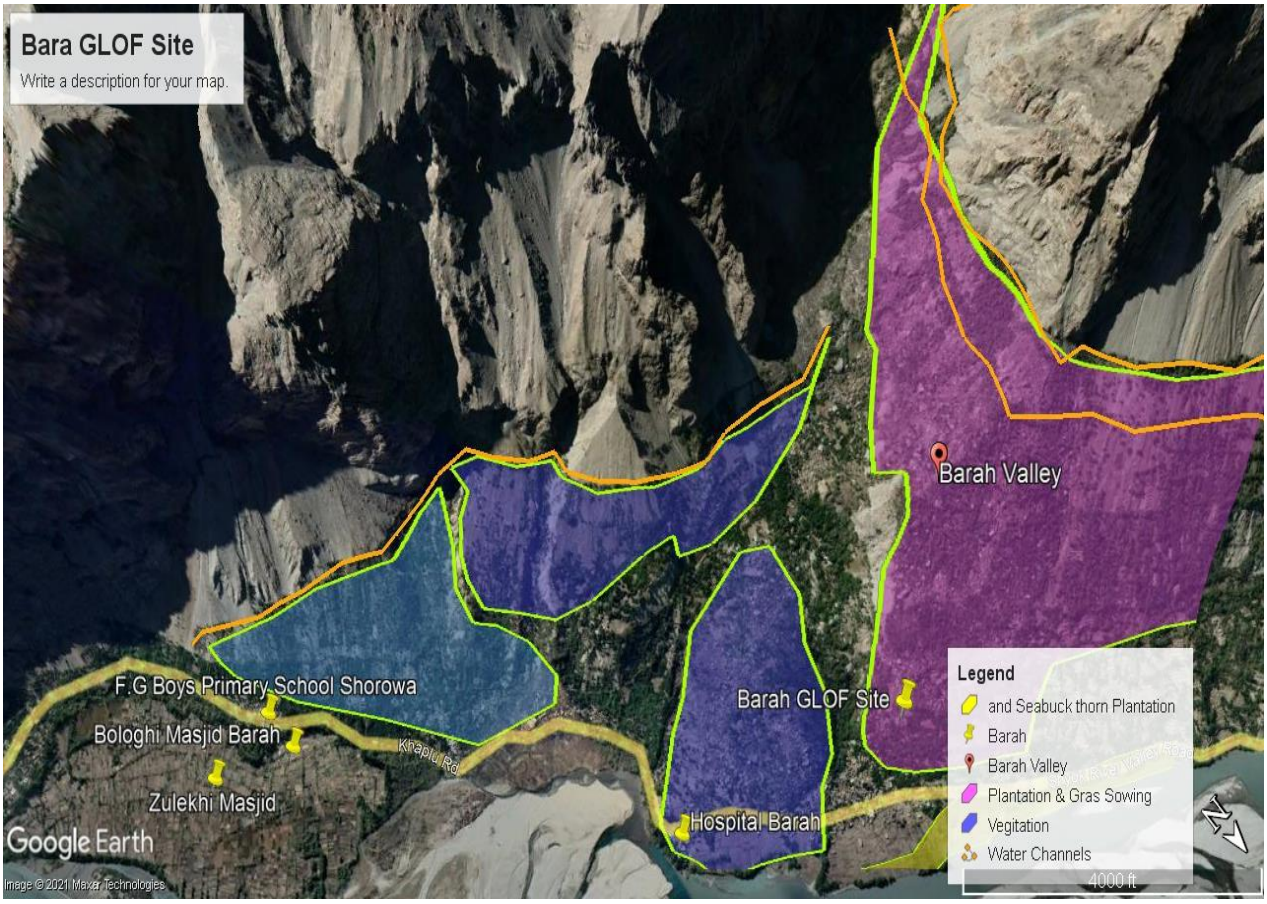
3.4.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds for Barah	200kgs	3000 Rs.	600000
02	Transportation and seeding	200	40 Rs.	8000
	Total			**608000**

Total Proposed Budget for GLOF-II Site (Barah, District Ghanche)		
Activity No	**Bioengineering Technique**	**Total**
01	Compact Planting and Vegetated Rip Rap	2700000
02	Sea buckthorn Plantation	1800000
03	Repair and extension of water channels	1500000
04	Grass Planting	608000
Grand Total		**6608000**

Maps of Barrah GLOF Site for bioengineering




Bara GLOF Site
Write a description for your map.
Barah Valley
F.G Boys Primary School Shorowa
Bologhi Masjid Barah
Zulekhi Masjid
Khaplu Rd
Barah GLOF Site
Hospital Barah
Legend
and Seabuck thorn Plantation
Barah
Barah Valley
Plantation & Gras Sowing
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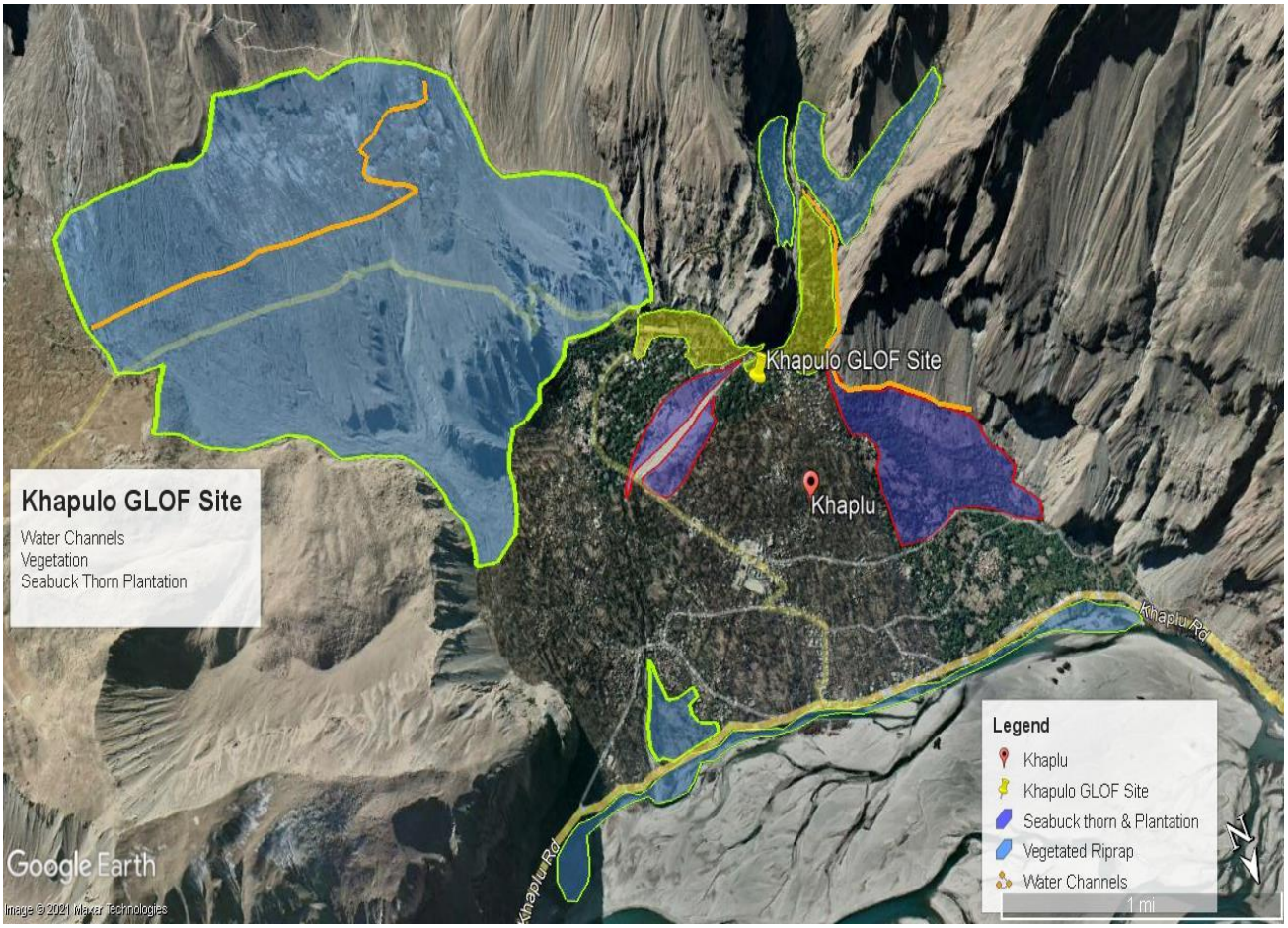
Water Channels
4000 ft
Google Earth
Image © 2021 Maxar Technologies

Section IX: District Ghanche,
Chapter 15: GLOF-II Site Khapulo Nallah, Ghanche



1. Introduction

Khapulo is a city that serves as administrative capital of district Ghanche in Gilgit Baltistan. Khapulo Nallah is located at an elevation of 8866ft geographically defined by longitude 35°9'19.81"N, 76°19'58.47"E, with a central geographical coordinate at world geographical Globe. Khapulo Nallah passes through center of Khapulo city. The town is situated under high mountains and Khapulo Glacier and water stream is flowing from the center of the city and fall into Shyok River. It is laying 112.7 KM east of the Skardu city. The road passes along Shyok River through rugged mountains. The stream in the Khapulo Nallah is flowing from the glaciers pass through city comparatively stable water way. The site is vulnerable because of the GLOF events and drainage of the glaciers through streams for future.

In the history the GLOF events wrecked the valley along the water stream as mentioned by the people in FGD conducted in Khapulo. It had damaged agricultural land, infrastructure, roads, houses, fruit and forest trees. During summer, snow melting and rainy seasons the glacier releases water that erodes the embankments of downstream and causes floods. The streams have stones and compacted material and above the village on hills there is loose material and debris which erodes and damages the land, fruit and forest trees, infrastructure such as water channels, roads and houses. Above the valley there are less vegetated slopes which shear in rainy and snow melting seasons because of weathering.

Some of the slopes are unstable and barren naturally and some are less vegetated. These can be vegetated by planting gross, willow, Sea buckthorn, popular, Russian olive, and other species those will contribute to reduce GLOF events. Stream bank's erosion problem is in this site is comparatively compacted but can be eroded in future because of floods and GLOF events. In some instances, significant uncertainty exists about the stability of the embankment and land nearby the stream and infrastructure.

2. Site Assessment

2.1. Site Type

Khapulo valley is comparatively compacted and landscape features are prone for slope instability issues especially debris flow, loos material and mass movement. Some of the slopes above the valley are unstable and less vegetated because of unavailability of funds and vegetation. This site is located in steep areas, some of the area is unstable above the city.

The site is vulnerable for debris flow in some segments around the village and in the Nallahs as well. The sides of the water stream and river are dry and Shyok River erodes the city in many areas. Community of the valley has planted trees, Sea buckthorn, willow, popular and bushes in many patches. The use of bioengineering techniques is mainly confined to reduce the threat of river bank erosion, slope erosion and GLOF events. Where vegetation has been reduced or removed, it can be replaced by planting of appropriate species to achieve the desired effect. Structures formed from a combination of dead and living plant material can also be used to guide the river course and prevent flood entering into settlements and farmland. The plants can provide additional benefits for the local population like fodder, fruit, and firewood, but this is secondary to the protective function.

Stronger stream bank defenses mean that communities are protected from flood. Better and resilient infrastructure systems help to grow more crops and people are spending less time to produce agricultural products.

2.3. Slope Length

In Khapulo, slopes are of different length and width ranging from 50 meters to 200 meters long and 50 to 100 meters wide. The valley is situated on the footings of the hills and at the edge of the water stream and River. There is debris, sandy soil, loose material slopes in patches above the valley. The slopes have landslide issues as well as surface erosion during climatic conditions.

2.4. Topography (Slope, Angle and Material Drainage)

The slopes in Khapulo fall from 35 to 65 degree angle right above the city. The main slops of the Khapulo identified for vegetation cover and Sea buckthorn plantation is of 40 to 65 degree angle. The streams flow in 25 to 45 degree downwards into the Shyok River. Material drainage of the main slopes during the disaster can drain in the gorges and can damage agricultural land, forest, infrastructure, roads, tracks, water supply and

houses. The drain of the streams may spreads in orchards by eroding stream banks. Near the River it spreads and damages cultivable land which is under sand, mud and debris because of floods.

On the right side of the valley loose material creates floods during heavy rains. Bare soil of the slopes do not bear splash of rain and usually erodes that destruct infrastructure, agricultural land and communication system in the city.

2.5. Moisture

The bare soil-covered slopes in the valley are dry and becomes wet during rainy and snow melting seasons. They have debris and loose material on the slopes. Intense rain can lead to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. Because of less vegetation cover on the slope segments, roughness of slope surface increases and rain and melting snow can easily erode through the gaps and near the village it can become a disaster for community Dense cover, if forest trees and vegetation are grown at the slopes, may protect the soil splash effects and can reduce runoff velocity, while roots of the vegetation may bind the soil particles, resulting to hinder surface erosion.

2.6. Stream Bank

In Khapulo water stream is flowing through the middle of the Khapulo city dividing the city in two parts. The stream banks are compressed and vegetated in some areas of the city. The community has constructed walls along stream but if GLOFF event occurs can erode stream banks harshly and damage houses, trees, agricultural land, and infrastructure such as water supply, irrigation channels, road and tracks. Therefore, embankment erosion issue is persistently harmful for infrastructure, roads, bridges, water supply, forest cover and to whole city as well.

3. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment showed slopes erosion problems in the Khapulo GLOF Site and the team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the future problems and prioritized some sites as high risk and some had moderate risk.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

3.1. Vegetated Rip Rap and Compact Planting

Slopes of the Khapulo GLOF Site have loose material that have high tendency to roll down the slope because of the erosion triggered by the heavy rain, wind and weathering. This erosion of the slope can be reduced by the vegetated riprap and compact planting of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of willow, popular, Russian Olive and other indigenous plants on the slopes, in ditches, valleys and gullies. Long cuttings of popular, willow, Russian Olive and other local plants are easily available in Ghanche District.

Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil up to 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

3.1.1. Site Preparation

The site has enough scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of Darkut valley are 30 to 65 degree angle.

3.1.2. Special Instructions for Willow, Russian Olive and Popular Cuttings

- Long cuttings of willow, Russian Olive and popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants (willow and popular) are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

3.1.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings & Rooted Plants of willow, Russian olive and popular (all inclusive)	30000 cuttings	90 Rs.	2700000
	Total			**2700000**

3.2. Sea buckthorn Plantation

Sea buckthorn is already grown in some patches of the slope and plains in Khapulo GLOF Site. Sea buckthorn and bush's roots mainly protect soil one meter deep and play a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.2.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier. Picked out Sea buckthorn plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.2.2. Special Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Sea buckthorn plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height

- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

3.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants for Khapulo GLOF Site (all Inclusive)	30000 plants	60 Rs.	**1800000**
	Total			**1800000**

3.3. Repair and extension of existing water channels

Khapulo has traditionally earthen water channels for agricultural and irrigation of fruit/forest trees and agricultural land in different areas. These channels are constructed long ago and vegetated land increases from time to time. The channels cannot supply more water for more plantation and forest cover. These water channels required to be repair and can be extended to plant more forest trees on barren land. These water channels are earthen channels and do not require cement and concrete work. Three water channels have been recommended for repair and extension both sides. These all channels are of different lengths in size. Channel No one is 2320 meter long, channel two is 3209 and third channel is 706 meters in length.

3.3.1. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of water channels No 01 in Khapulo GLOF Site	01	500000.	500000
02	Repair and extension of water channels No 02 in Khapulo GLOF Site	01	400000.	400000
03	Repair and extension of water channels No 03 in Khapulo GLOF Site	01	250000.	250000
	Total			**1150000**

3.4. Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.4.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.4.2. Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the grasses along the trees and bushes however, we recommend at the areas where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation. The seeds can be seeded in the areas of repair and extended water channels.

- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds

- Don’t provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

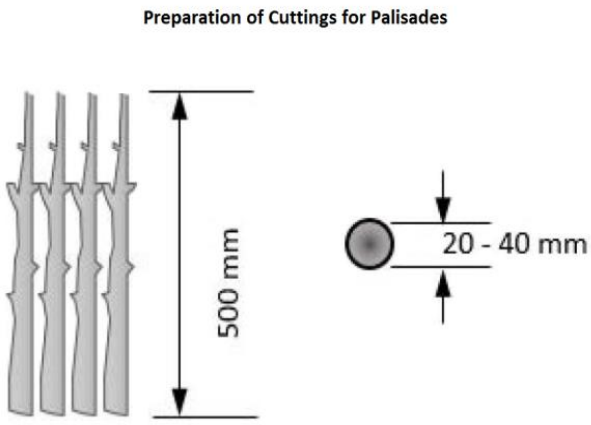
3.4.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds for Khapulo	300kgs	3000 Rs.	900000
02	Transportation and seeding	300	40 Rs.	12000
	Total			**912000**

3.5. Live Fascines

A palisade is a fence or wall made from wooden stakes or tree trunks. Palisades were used historically as a defensive structure. In slope and embankments’ protection, palisades are barriers made from live wood cuttings installed across a slope following the contour in order to trap debris moving down the slope, to armour and reinforce the slope, and to increase the infiltration rate. Palisades are used to prevent the extension of deep, narrow gullies and the erosion of V-shaped rills by forming a strong barrier which stabilizes the gully floor and traps material moving downwards. They are also effective on steep landslide or debris slopes. Palisades can be used on a wide range of sites with slopes of up to about 60°.

This procedure applies to use live cuttings of willow, popular, other indigenous and local species of plants which are commonly available in Khapulo Town or in surrounding valleys in District Ghanche of Gilgit Baltistan. It is best to use local species as they are already adapted to the growing conditions; are more like to be resistant to local diseases; are more



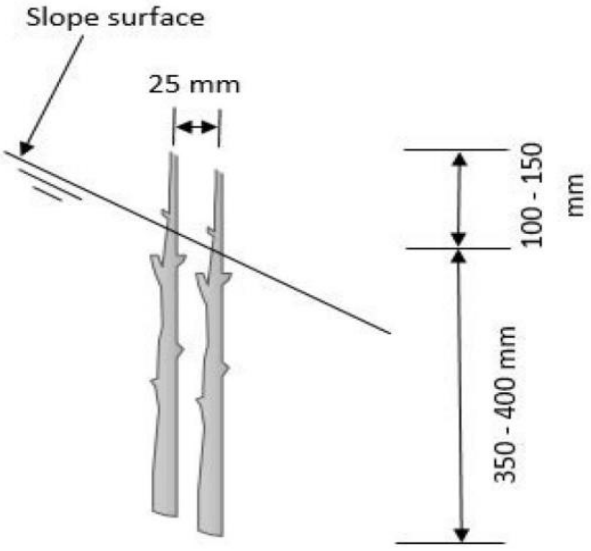
readily available; and are likely to be on lower cost options. Live hardwood willow, popular, shrub cuttings are laid in successive shallow trenches, in lines across the slope, usually following the contour. The tips of the cuttings protrude just beyond the face of the slope, where they grow buds and leaves that intercept rainfall, slow runoff and filter sediments. In addition to the exposed stems catching surface debris, as the roots develop they reinforce the upper soil layers. This techniques are used to stabilize embankments (fill slopes) or less steep cut-slopes. The roots add tensile reinforcement to the slope and provide a measure of frictional resistance to shallow sliding. The protruding brush retards runoff and reduces surface erosion. Brush wood layers give both immediate and increasingly strong protection and reinforcement to newly constructed fill and cut slopes. They are also a good remedial measure for repairing eroded gullies. The perpendicular orientation of brush layering to the slope is effective in terms of earth reinforcement and near-surface stabilization of the slope.

3.5.1. Site Preparation

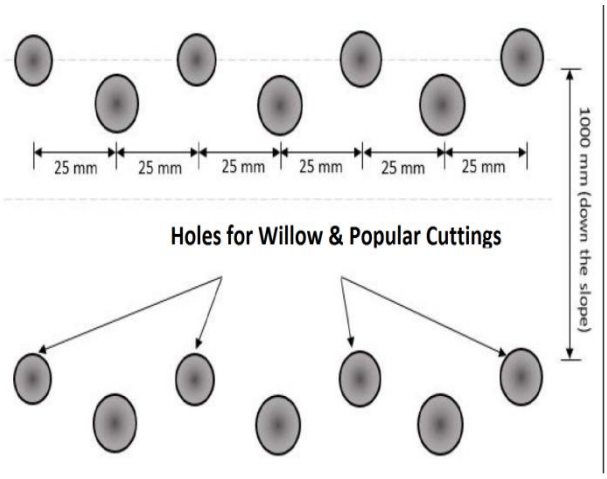
The site along the water stream should be prepared before planting the cuttings of willow, popular, shrubs and other local species. Debris must be removed, depressions should be filled and humps should be leveled off to attain a linear profile. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 250mm above the toe of the slope, 1000mm centers up the slope and at the edge of the water stream 12 inches of distance from water level of summer season.

3.5.2. Planting Instructions

- Plant cuttings must be prepared from the woody material of 6 to 18 months in age.
- Cuttings should be approximately 20 mm dia., 500 mm length. They are laid in shallow trenches.
- These cuttings should be buried in moist soil for 3 to 7 days
- These cuttings may be immersed in water for two or three days



- When land is prepared plant the cuttings within 12 hours
- Cuttings from willow, popular and shrubs are more feasible for the local environment however; any other plant cutting must be suited to the site and shows the correct habit for an ability to grow from the cuttings. For example many shoots coming from the stems.
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- Side branches shall be trimmed off carefully with a sharp tool.
- The cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- As with grass planting, the brush layers can also be angled to enhance drainage.
- Planting should be by experienced agricultural labor with technical supervision.
- Always start at the top of the slope and work downwards

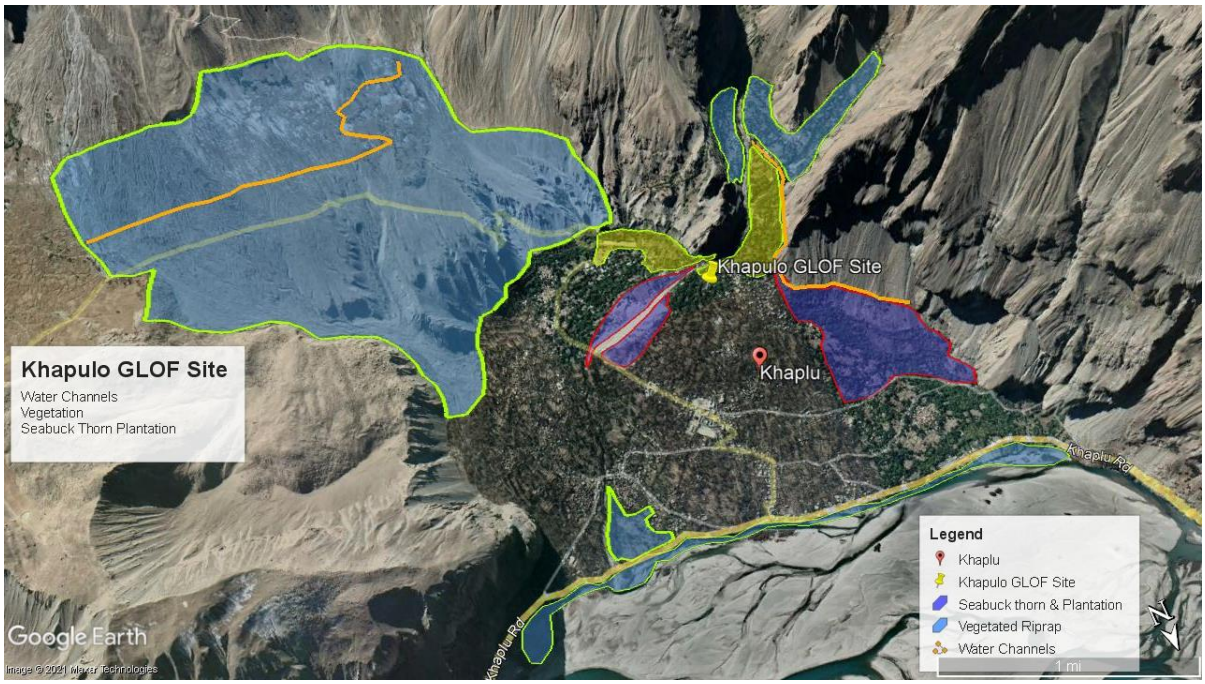


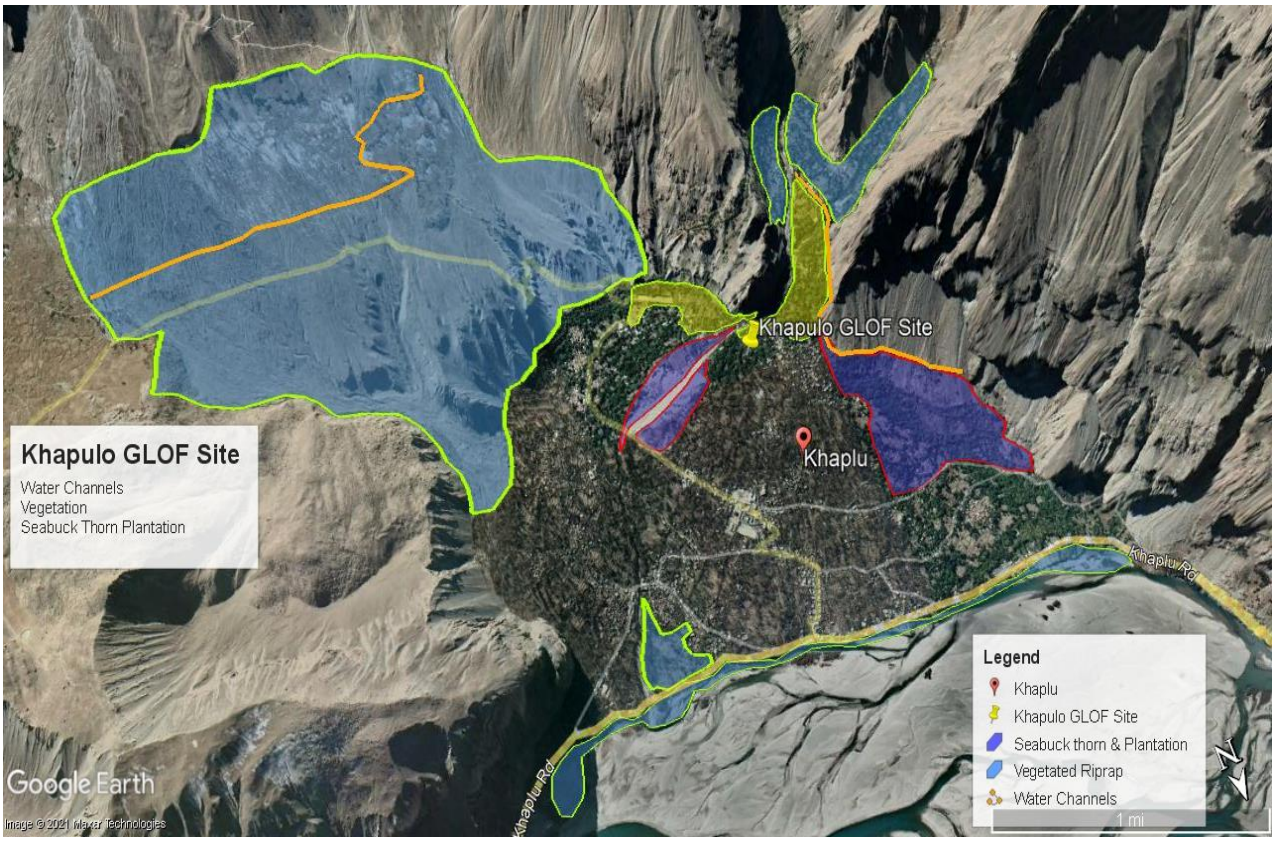
- Using a pointed bar, make a hole that is bigger than the cutting
- Carefully place the cutting in the hole so that two third is buried, firm the soil around it, taking care not to damage the bark
- Make the next hole 50mm along the row

3.5.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Local live Plant cuttings of willow, popular, and Russian olive (all inclusive) for Satrungbat	25000 cuttings	60 Rs.	1500000
	Total			**1500000**

Total Proposed Budget For GLOF-II Site (Khapulo, District Ghanche)		
Activity No	**Bioengineering Technique**	**Total**
01	Compact Planting and Vegetated Rip Rap	2700000
02	Sea buckthorn Plantation	1800000
03	Repair and extension of water channels	1150000
04	Grass Planting	912000
05	Palisades	1500000
Grand Total Large and local grass planting		**6562000**




Khapulo GLOF Site
Water Channels
Vegetation
Seabuck Thorn Plantation
Khapulo GLOF Site
Khaplu
Khaplu Rd
Legend
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Khapulo GLOF Site
Seabuck thorn & Plantation
Vegetated Riprap
Water Channels
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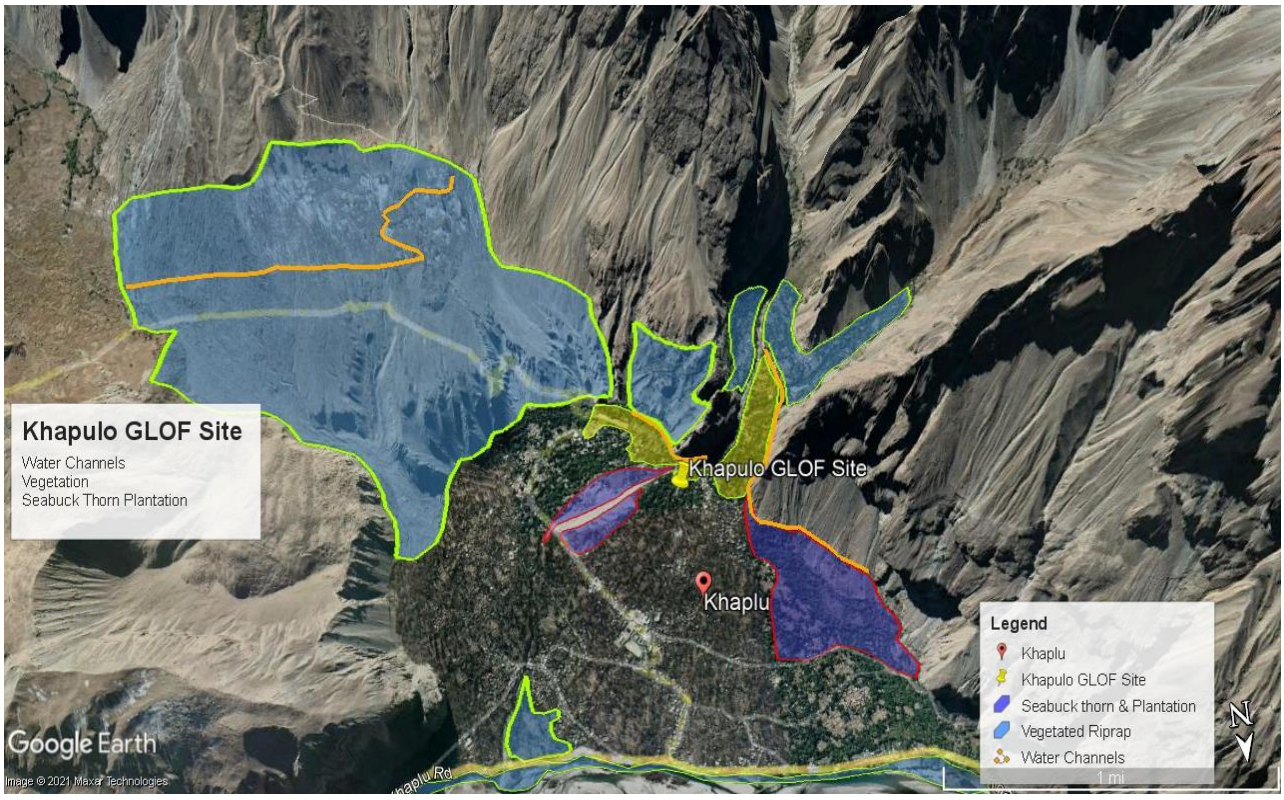
Khapulo GLOF Site
Water Channels
Vegetation
Seabuck Thorn Plantation
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Khapulo GLOF Site
Seabuck thorn & Plantation
Vegetated Riprap
Water Channels
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Google Earth
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Section X : District Kharmung,
Chapter 16: GLOF-II Site Ghundus District Kharmung, Gilgit-Baltistan

1. Introduction

Ghundus Village is situated near kharmang Khas in District Kharmang under the loose slope mountains. Ghundus Village is located at an elevation of 8296ft geographically defined by longitude 34°57'46.67"N, 76°12'41.02"E, with a central geographical coordinate at world geographical Globe. Ghundus Village Nallah passes through center of village dividing the village in two sub villages. The village is situated under high mountains and Ghundus Glacier and water stream is flowing from the center of the village and fall into Indus River. It is laying almost 120 KM east of the Skardu city. The road passes along Indust River through rugged mountains. The stream in the Ghundus Nallah is flowing from the glaciers pass through village comparatively stable water way. The site is vulnerable because of the GLOF events, loose material slopes above the village and drainage of the glaciers through streams for future.

In the history the GLOF events destroyed the valley along the water stream as mentioned by the people in FGD conducted in Ghundus. It had damaged agricultural land, infrastructure, roads, houses, fruit and forest trees. During summer, snow melting and rainy seasons the glacier releases water that erodes the embankments of downstream and causes floods. The streams have stones and compacted material and above the village on hills there is loose material and debris which erodes and damages the land, fruit and forest trees, infrastructure such as water channels, roads and houses. Above the valley there are less vegetated slopes which shear in rainy and snow melting seasons because of weathering.

Some of the slopes are unstable and barren naturally and some are less vegetated. These can be vegetated by planting gross, willow, Sea buckthorn, popular, Russian olive, and other species those will contribute to reduce GLOF events. Stream bank's erosion problem is in this site is comparatively compacted but can be eroded in future because of floods and GLOF events. In some instances, significant uncertainty exists about the stability of the embankment and land nearby the stream and infrastructure.

2. Site Assessment

2.1.Site Type

Ghundus valley is comparatively compacted and landscape features are prone for slope instability issues especially debris flow, loos material and mass movement. Some of the slopes above the valley are unstable and less vegetated because of unavailability of funds and vegetation as mentioned by the community members

The site is vulnerable for debris flow in some segments above the village and in the Nallahs as well. The sides of the water stream and river are dry and Indus River erodes the village in many areas. Community of the valley has planted trees, Sea buckthorn, willow, popular and bushes in many patches. The use of bioengineering techniques is mainly confined to reduce the threat of river bank erosion, slope erosion and GLOF events. Where vegetation has been reduced or removed, it can be replaced by planting of appropriate species to achieve the desired effect. Structures formed from a combination of dead and living plant material can also be used to guide the river course and prevent flood entering into settlements and farmland. The plants can provide additional benefits for the local population like fodder, fruit, and firewood, but this is secondary to the protective function.

Stronger stream bank defenses mean that communities are protected from flood. Better and resilient infrastructure systems help to grow more crops and people are spending less time to produce agricultural products.

2.2. Slope Length

In Ghundus, slopes are of different length and width ranging from 35 meters to 100 meters long and 30 to 80 meters wide. The valley is situated on the footings of the hills and at the edge of the water stream and River. There is debris, sandy soil, loose material slopes in patches above the valley. The slopes have landslide issues as well as surface erosion during climatic conditions.

2.3. Topography (Slope, Angle and Material Drainage)

The slopes in Ghundus fall from 30 to 55 degree angle right above the village. The main slops of the Ghundus identified for vegetation cover and Sea buckthorn plantation is of 40 to 60 degree angle. The streams flow in 25 to 45 degree downwards into the Indus River. Material drainage of the main slopes during the disaster can drain in the gorges and can damage agricultural land, forest, infrastructure, roads, tracks, water supply and

houses. The drain of the streams may spreads in orchards by eroding stream banks. Near the River it spreads and damages cultivable land which is under sand, mud and debris because of floods.

Above the valley loose material creates floods during heavy rains. Bare soil of the slopes do not bear splash of rain and usually erodes that destruct infrastructure, agricultural land and communication system in the village.

2.4. Moisture

The bare soil-covered slopes in the valley are dry and becomes wet during rainy and snow melting seasons. They have debris and loose material on the slopes. Intense rain can lead to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. Because of less vegetation cover on the slope segments, roughness of slope surface increases and rain and melting snow can easily erode through the gaps and near the village it can become a disaster for community Dense cover, if forest trees and vegetation are grown at the slopes, may protect the soil splash effects and can reduce runoff velocity, while roots of the vegetation may bind the soil particles, resulting to hinder surface erosion.

2.5. Stream Bank

In Ghundus water stream is flowing through the middle of the Ghundus village dividing the village in two parts. The stream banks are compressed and vegetated in some areas of the village. The community has constructed walls along stream but if GLOF event occurs can erode stream banks harshly and damage houses, trees, agricultural land, and infrastructure such as water supply, irrigation channels, road and tracks. Therefore, embankment erosion issue is persistently harmful for infrastructure, roads, bridges, water supply, forest cover and to whole city as well.

3. Site Specific Recommended Bioengineering Techniques

Initial site assessment showed slopes erosion problems in the Ghundus GLOF Site and the team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites, causes and reasons of the threats and issues. They understood the future problems and prioritized some sites as high risk and some had moderate risk.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

3.1. Vegetated Rip Rap and Compact Planting

Slopes of the Ghundus GLOF Site have loose material that have high tendency to roll down the slope because of the erosion triggered by the heavy rain, wind and weathering. This erosion of the slope can be reduced by the vegetated riprap and compact planting of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of willow, popular, Russian Olive and other indigenous plants on the slopes, in ditches, valleys and gullies. Long cuttings of popular, willow, Russian Olive and other local plants are easily available in Kharmang District.

Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil up to 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

3.1.1. Site Preparation

The site has enough scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of Darkut valley are 30 to 65 degree angle.

3.1.2. Special Instructions for Willow and Popular Cuttings

- Long cuttings of willow, Russian Olive and popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants (willow and popular) are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

3.1.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings & Rooted Plants of willow and popular (all inclusive)	30000 cuttings	90 Rs.	2700000
02	Plants of Juniper, spruce, Cedar and Pine (all inclusive)	20000	250	3750000
	Total			**6450000**

3.2. Sea Buckthorn Plantation

Sea buckthorn is already grown in some patches of the slope and plains in Satrungbat GLOF Site. Sea buckthorn and bush's roots mainly protect soil one meter deep and play a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.2.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buckthorns from designated sites should not be picked out more than one day earlier. Picked out Seabuck plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.2.2. Special Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Sea buckthorn plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn thorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height

- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

3.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants for Ghundus GLOF Site (all Inclusive)	20000 plants	60 Rs.	**1200000**
	Total			**1200000**

3.3. Repair and extension of existing water channels

Ghundus has traditionally earthen water channels for agricultural and irrigation of fruit/forest trees and agricultural land in different areas. These channels are constructed long ago and vegetated land increases from time to time. The channels cannot supply more water for more plantation and forest cover. These water channels required to be repair and can be extended to plant more forest trees on barren land. These water channels are earthen channels and do not require cement and concrete work. Three water channels have been recommended for repair and extension both sides. These all channels are of different lengths in size. Channel No one is 945 meter long, channel two is 1283 and third channel is 950 meters in length.

3.3.1. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of water channels No 01 in Ghundus GLOF Site	01	300000.	500000
02	Repair and extension of water channels No 02 in Ghundus GLOF Site	01	400000.	400000
03	Repair and extension of water channels No 03 in Ghundus GLOF Site	01	300000.	300000
	Total			**1000000**

3.4. Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.4.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.4.2 Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the large grasses along the trees and bushes however, we recommend at the areas where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation. The seeds can be seeded in the areas of repair and extended water channels.

- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds

- Don’t provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.
- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

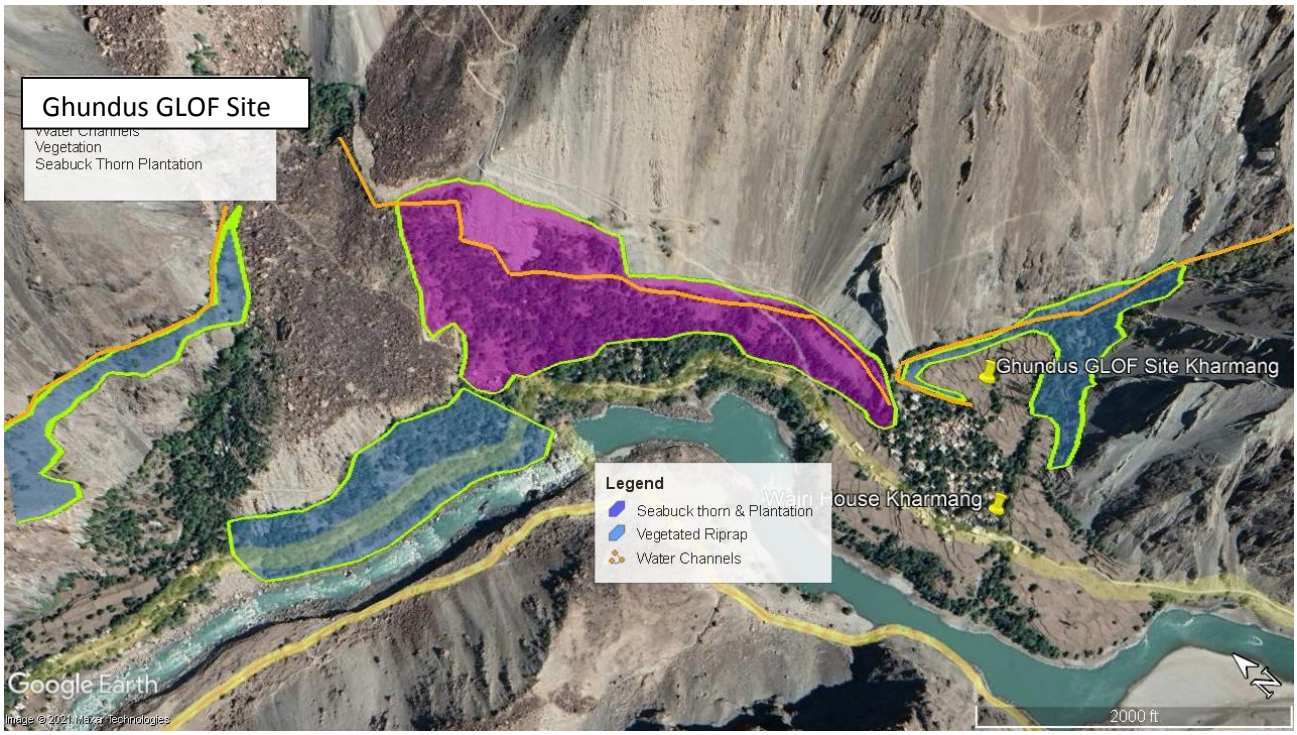
3.4.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds for Ghundus	300kgs	3000 Rs.	900000
02	Transportation and seeding	300	40 Rs.	12000
	Total			**912000**

Total Proposed Budget for GLOF-II Site (Ghundus, District Kharmang)

Activity No	Bioengineering Technique	Total
01	Compact Planting and Vegetated Rip Rap	1800000
02	Sea buckthorn Plantation	1200000
03	Repair and extension of water channels	1000000
04	Grass Planting	608000
Grand Total		**4608000**

Ghundus GLOF site for Bioengineering



Section 11: District Skardu,
Chapter 17: GLOF-II Site Satrungbat Basho, District Skardu, Gilgit-Baltistan

1. Introduction

Satrungbat Village is situated in Basho valley in District Skardu under the loose slope hills and Hard Rock Mountains. Satrungbat Village is located at an elevation of 10048ft geographically defined by longitude 35°27'11.08"N, 75°18'37.50"E, with a central geographical coordinate at world geographical Globe. Satrungbat Nallah passes through the Basho valley dividing the valley in sub villages. Water stream commencements from Satrungbat glacier, feed by many tributary glaciers. The valley is situated on Gilgit Skardu road almost 32 KM west of the Skardu city. Crossing a bridge from Indus River the road passes along Basho Valley through rugged mountains. The stream in the Nallah is flowing from the glaciers pass through Basho valley falls into Indus River below the valley. The site is vulnerable because of the GLOF events, loose material slopes above the village and drainage of the floods through streams as it keeps changing the its way in Sultababad village and embankment erosion is persistently an issue.

In the history the GLOF events destroyed the valley along the water stream as mentioned by the people in FGD conducted in Satrungbat. It had damaged agricultural land, infrastructure, roads, houses, fruit and forest trees. During summer, snow melting and rainy seasons the glacier releases water that erodes the embankments of downstream and causes floods. The streams have stones and compacted material and above the village on hills there is loose material and debris which erodes and damages the land, fruit and forest trees, infrastructure such as water channels, roads and houses. Above the valley there are High Mountain of hard rock and less vegetated slopes which shear in rainy and snow melting seasons because of weathering.

Some of the slopes are unstable and barren naturally and some are less vegetated. These can be vegetated by planting gross, willow, Sea buckthorn, popular, juniper, cedar, and other species those will contribute to reduce GLOF events. Stream bank's erosion problem persistently exists in Satrungbat and Sultanabad Area of this GLOF site. In some instances, significant uncertainty exists about the stability of the embankment and agricultural land, forest cover nearby the stream and infrastructure.

2. Site Assessment

2.1. Site Type

Satrungbat site in Basho valley is comparatively compacted with forest cover in Baltistan region and landscape features are prone for slope instability issues especially debris flow, loos material and mass movement. Some of the slopes above the valley are unstable and less vegetated because of unavailability of funds and vegetation as mentioned by the community members.

The site is vulnerable for debris flow in some segments above the village and some segments are highly vulnerable because of the rock falling and during heavy rains. The sides of the water stream in Satrungbat and Sultanabad village of Basho valley are vulnerable because of the changing behavior of the water flow and floods. Community of the valley has planted trees, Sea buckthorn, willow, popular and bushes in many patches. The use of bioengineering techniques is mainly confined to reduce the threat of river bank erosion, slope erosion and GLOF events. Where vegetation has been reduced or removed, it can be replaced by planting of appropriate species to achieve the desired effect. Structures formed from a combination of dead and living plant material can also be used to guide the river course and prevent flood entering into settlements and farmland. The plants can provide additional benefits for the local population like fodder, fruit, and firewood, but this is secondary to the protective function.

Stronger stream bank defenses mean that communities are protected from flood. Better and resilient infrastructure systems help to grow more crops and people are spending less time to produce agricultural products.

2.2.Slope Length

In Satrungbat, slopes are of different length and width ranging from 30 meters to 100 meters long and 30 to 80 meters wide. The valley is situated on the footings of the hills and at the edge of the Satrungbat water stream. There is debris, sandy soil, loose material slopes in patches above and sides of the valley. The slopes have landslide issues as well as surface erosion during climatic conditions.

2.3. Topography (Slope, Angle and Material Drainage)

The slopes in Satrungbat fall from 30 to 55 degree angle right above the village. The main slops of the Satrungbat identified for vegetation cover and Sea buckthorn plantation is of 20 to 25 degree angle. The streams flow in 10 degree in Sultanabad while 25 to 45 degree downwards into the Indus River throughout the Basho Valley. Material drainage

of the main slopes during the disaster can drain in the gorges and can damage agricultural land, forest, infrastructure, roads, tracks, water supply and houses. The drain of the streams spreads in orchards by eroding stream banks. It spreads and damages cultivable land which is under sand, mud and debris because of floods.

Above the valley loose material creates floods during heavy rains. Bare soil of the slopes and Rocky Mountains do not bear splash of rain and usually erodes that destruct infrastructure, agricultural land and communication system in the valley.

2.4. Moisture

The bare soil-covered slopes in the valley are dry and becomes wet during rainy and snow melting seasons. They have debris and loose material on the slopes. Intense rain leads to heavy erosion of bare soil-covered slope; easily effected by the splash and melting of snow in spring and early summer seasons. Because of less vegetation cover on the slope segments, roughness of slope surface increases and rain and melting snow can easily erode through the gaps and near the village it can become a disaster for community Dense cover, if forest trees and vegetation are grown at the slopes, may protect the soil splash effects and can reduce runoff velocity, while roots of the vegetation may bind the soil particles, resulting to hinder surface erosion.

2.5. Stream Bank

In Satrungbat water stream is flowing through the middle of the Satrungbat village and Basho valley dividing the valley in multiple villages. The stream banks are compressed and vegetated in some areas of the valley. The community has constructed gabions and protective walls in some portions of the stream. If GLOF event occurs can erode stream banks harshly and damage houses, trees, agricultural land, and infrastructure such as water supply, irrigation channels, road and tracks. Therefore, embankment erosion issue is persistently harmful for infrastructure, roads, bridges, water supply, and forest cover and to whole valley as well.

3. SITE SPECIFIC RECOMMENDED BIOENGINEERING TECHNIQUES

Initial site assessment showed slopes erosion problems in the Satrungbat GLOF Site and the team has recommended the site for detail site inspection for bioengineering techniques. During detail site inspection the team has studied the existing site attributes and potential climate related threats and issues. The team assessed the vulnerable sites,

causes and reasons of the threats and issues. They understood the future problems and prioritized some sites as high risk and some had moderate risk.

The team has completed site assessment activity through designed tools and suggested the following bioengineering techniques for resilient and sustainable solutions and infrastructure development in the project area to mitigate the slope and embankment erosion.

3.1. Vegetated Rip Rap and Compact Planting

Slopes of the Satrungbat GLOF Site have loose material that have high tendency to roll down the slope because of the erosion triggered by the heavy rain, wind and weathering. This erosion of the slope can be reduced by the vegetated riprap and compact planting of the trees. The stem and roots of the plants will catch and hold the loose material and will moderate erosion. The slopes of the valley have loose material and water sensitive. They start moving downwards in rainy and snow melting seasons. Vegetation can protect the surface from water infiltration and erosion by rain splash.

The procedure of compact plantation and vegetated Rip Rap applies to use long cuttings or rooted trees of willow, popular, Russian Olive and other indigenous plants on the slopes, in ditches, valleys and gullies. Long cuttings of popular, willow, Russian Olive and other local plants are easily available in Satrungbat and Basho valley in Skardu District.

Stems and roots can reduce the velocity of the surface runoff by increasing surface roughness. It can also stabilize the slope and reduce the risk of landslides occurring. Plants will intercept a portion of rainwater and flow along the branches and stems to the ground at a low velocity as well as will allow it to evaporate into the air at the plant surface and leafs. Therefore, compact planting and vegetated Rip Rap along with grass is recommended by the consultants. Because trees can stabilize the whole soil layer in the slope terrain, whereas bush and shrub roots mainly protect soil up to 1m deep, and grasses can conserve top soil to a depth of around 25cm (jha etal. 2000).

3.1.1. Site Preparation

The site has enough scope for compact planting and Rip Rap vegetation on the mountain slopes, ditches, and gullies above the valley. For compact planting and vegetated Rip Rap, plants require trenches on slopes and pits on leveled ground. It requires no any special preparation of land. Trenches should be inserted vertically but can be at an angle

on steep slopes. Trenches can be constructed on the slopes up to 70 degree but the slopes of Basho valley are 30 to 65 degree angle.

3.1.2. Special Instructions for Willow and Popular Cuttings

- Long cuttings of willow, Russian Olive and popular are recommended
- Rooted trees are also recommended for compact plantation
- Cuttings of local plants (willow and popular) are recommended
- Cuttings must be minimum of 4 feet long
- These cuttings should be immersed in water for five to ten days
- Cuttings of willow, and popular are more feasible for the local environment
- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- The lower end of cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- Side branches shall be trimmed off carefully with a sharp tool
- Using a pointed bar, make a hole that is bigger in size than the cutting
- Carefully place the cutting in the hole so that minimum of 12 inches of the cutting is buried, firm the soil around it,
- Taking good care of to not damage the barks
- Make the next hole 5 feet along the row
- Plant rooted trees as well 5 feet along the row
- Rooted plants must be provided in planting season February and March
- If rooted plants could not be provided in February and March than local long cuttings should be preferred
- Fresh cuttings must be kept moist between harvesting and planting
- Planting should be by agricultural labor with experienced supervision.

3.1.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Long cuttings & Rooted Plants of willow, Russian olive and popular (all inclusive)	20000 cuttings	90 Rs.	1800000
	Total			**1800000**

3.2. Sea Buckthorn Plantation

Sea buckthorn is already grown in some patches of the s lope and plains in Satrungbat GLOF Site. Sea buckthorn and bush's roots mainly protect soil one meter deep and play a significant role to increase resilience of embankments of water streams and stabilization of cut slopes. The plant intercepts and armour the surface against erosion and also to have live poles inserted, from which will come strong woody roots that reinforce the soil and increase its resistance to shear. Dense network of the Sea buckthorn and deep roots physically binds and restrains soil particles in the ground. Sea buckthorn is a small size plant which is not harmful if it falls into the stream water as water can easily wash it out downwards in the stream. While large plants can obstruct the spillway which can be more disastrous during heavy rains and floods. Large plants can cause diversion of floods if they fell into running stream water by hampering the flow of floods.

3.2.1. Site Preparation

Sea buckthorn is recommended at the embankments of the water stream which erodes the embankment on left side under the village. Sea buckthorn will help to control the erosion and to increase the resilience of the embankments of water streams. Embankments should be prepared by digging the holes at the distances of 3 feet between two plants. Sea buck thorns from designated sites should not be picked out more than one day earlier. Picked out Sea buckthorn plants can be kept in water or saturated soil for one day and then must be planted in the pits prepared along the embankment of the streams.

3.2.2. Special Instructions for Plantation

- Pits should be prepared at the embankments and nearby slopes before the day on which planting of the Sea buck plant will take place.
- Using the measuring tape and string, lines to be planted shall be marked by pegs starting from two feet above the water flowing level (at peak season) and at the distances of two to three feet.
- Plant must be prepared and planted within 24 hours
- Sea buckthorn shall be used or another shrub or local small tree that is suited to the site and shows the correct habit for ability to grow from roots or shoots.
- Plants should be picked with sharp tools, with no damage to the roots and barks.
- Plants shall be 6 to 18 months of age and 2 to 5 feet in height

- Roots of the plants should be wrapped in wet jute or any other cotton cloth while they are transported to the site.

3.2.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Sea buckthorn Plants for Satrungbat GLOF Site (all Inclusive)	20000 plants	60 Rs.	**1200000**
	Total			**1200000**

3.3. Repair and extension of existing water channels

Satrungbat has traditionally earthen water channels for agricultural and irrigation of fruit/forest trees and agricultural land in different areas. These channels are constructed long ago and vegetated land increases from time to time. The channels cannot supply more water for more plantation and forest cover. These water channels required to be repair and can be extended to plant more forest trees on barren land. These water channels are earthen channels and do not require cement and concrete work. Three water channels have been recommended for repair and extension both sides. These all channels are of different lengths in size. Channel No one is 945 meter long, channel two is 1283 and third channel is 950 meters in length.

3.3.1. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Repair and extension of water channels No 01 in Satrungbat GLOF Site	01	300000.	500000
02	Repair and extension of water channels No 02 in Satrungbat GLOF Site	01	400000.	400000
03	Repair and extension of water channels No 03 in Satrungbat GLOF Site	01	300000.	300000
	Total			**1000000**

3.4. Grass Planting

This technique is recommended to use along with the trees and bushes used as compact planting on the slopes and along with the stream banks. Alfalfa grass is recommended as the specie is widely used for slopes and surface stabilization in many parts of the area. Alfalfa grass has a large and finely structured root system that can extend down to several meters of depth and provide soil reinforcement as well as surface protection. This grass will increase resilience to extreme climatic conditions, GLOF events and provide fodder for the animals of the farmers. The grass has stabilization and economic impact for the vulnerable slopes and community both. Contour lines of alfalfa grass can stabilize the natural slopes and surfaces. Their deep, rigorous root system will help to stabilize the slopes and surfaces structurally, reduce erosion, and trap sediment to facilitate the growth of other species and plants such as bushes and sea buck thorn. These large grasses have additional uses as thatching material and fodder for cattle.

3.4.1. Site Preparation

The site must be prepared before the day on which seeding of the local grasses or alfalfa will take place. Debris should be removed and hollows should be filled as much as possible. Humps must be leveled off to attain a linear profile. Seeding of the alfalfa and local grasses can be by local farmers and semi-skilled labors.

3.4.2. Special Instructions for planting process

There is hundreds of Kanals of sloppy land feasible for the large grasses along the trees and bushes however, we recommend at the areas where slopes mostly are 30 to 45 degree angle and water facility is available for irrigation. The seeds can be seeded in the areas of repair and extended water channels.

- Effectiveness not proven on slopes > 55o don't seed on slopes which are more than > 55o
- Will not grow effectively on rock slopes therefore don't waste time, resources and energies on rock slopes
- Seeding should be in moths of October, November and March, April
- If the site is likely to be flooded frequently, do not waste resource on those sites.
- Wet the slope minimum of one hour prior to seeding the alfalfa seeds
- Don't provide running water in huge quantity, instead very minimal amount of water should be provided at initial stages. However, it will take more time than usual.

- If possible or available, a handful of manure should be used during site preparation
- If rain is not expected in three days, pour water carefully or seep very small amount of water to the seeded slope

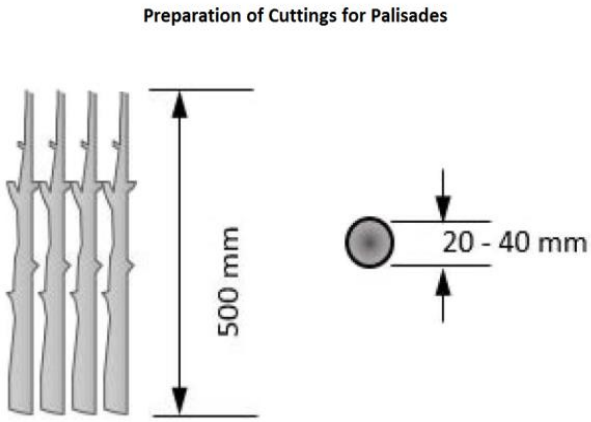
3.4.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Alfalfa seeds for Satrungbat	300kgs	3000 Rs.	900000
02	Transportation and seeding	300	40 Rs.	12000
	Total			**912000**

3.5. Live Fascines

A palisade is a fence or wall made from wooden stakes or tree trunks. Palisades were used historically as a defensive structure. In slope and embankments' protection, palisades are barriers made from live wood cuttings installed across a slope following the contour in order to trap debris moving down the slope, to armour and reinforce the slope, and to increase the infiltration rate. Palisades are used to prevent the extension of deep, narrow gullies and the erosion of V-shaped rills by forming a strong barrier which stabilizes the gully floor and traps material moving downwards. They are also effective on steep landslide or debris slopes. Palisades can be used on a wide range of sites with slopes of up to about 60°.

This procedure applies to use live cuttings of willow, popular, other indigenous and local species of plants which are commonly available in Satrungbat Village or in Basho valley in District Skardu of Gilgit Baltistan. It is best to use local species as they are already adapted to the growing conditions; are more like to be resistant to local diseases; are more readily available; and are likely to be on lower cost options. Live hardwood willow, popular, shrub cuttings are laid in successive shallow trenches, in lines across the slope, usually following the contour. The tips of the cuttings protrude just beyond the face of the slope, where they grow buds and leaves that intercept



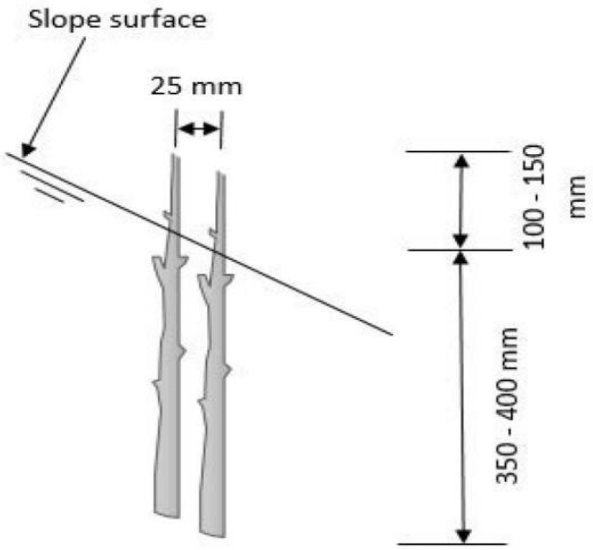
rainfall, slow runoff and filter sediments. In addition to the exposed stems catching surface debris, as the roots develop they reinforce the upper soil layers. This techniques are used to stabilize embankments (fill slopes) or less steep cut-slopes. The roots add tensile reinforcement to the slope and provide a measure of frictional resistance to shallow sliding. The protruding brush retards runoff and reduces surface erosion. Brush wood layers give both immediate and increasingly strong protection and reinforcement to newly constructed fill and cut slopes. They are also a good remedial measure for repairing eroded gullies. The perpendicular orientation of brush layering to the slope is effective in terms of earth reinforcement and near-surface stabilization of the slope.

3.5.1. Site Preparation

The site along the water stream should be prepared before planting the cuttings of willow, popular, shrubs and other local species. Debris must be removed, depressions should be filled and humps should be leveled off to attain a linear profile. Using a measuring tape and string, the lines to be planted shall be marked by pegs starting from 250mm above the toe of the slope, 1000mm centers up the slope and at the edge of the water stream 12 inches of distance from water level of summer season.

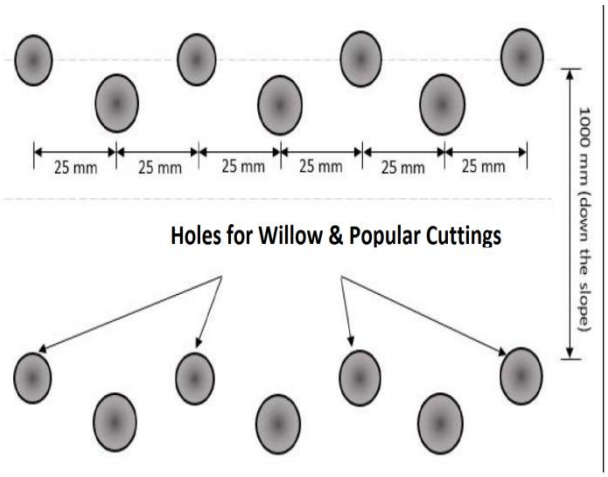
3.5.2. Planting Instructions

- Plant cuttings must be prepared from the woody material of 6 to 18 months in age.
- Cuttings should be approximately 20 mm dia., 500 mm length. They are laid in shallow trenches.
- These cuttings should be buried in moist soil for 3 to 7 days
- These cuttings may be immersed in water for two or three days
- When land is prepared plant the cuttings within 12 hours
- Cuttings from willow, popular and shrubs are more feasible for the local environment



however; any other plant cutting must be suited to the site and shows the correct habit for an ability to grow from the cuttings. For example many shoots coming from the stems.

- The lower end of each cutting shall be cut at 45 degrees and top cuts perpendicular to the stem.
- Side branches shall be trimmed off carefully with a sharp tool.
- The cutting must be wrapped in a jute or cotton bag when they are transported to the site.
- As with grass planting, the brush layers can also be angled to enhance drainage.
- Planting should be by experienced agricultural labor with technical supervision.
- Always start at the top of the slope and work downwards

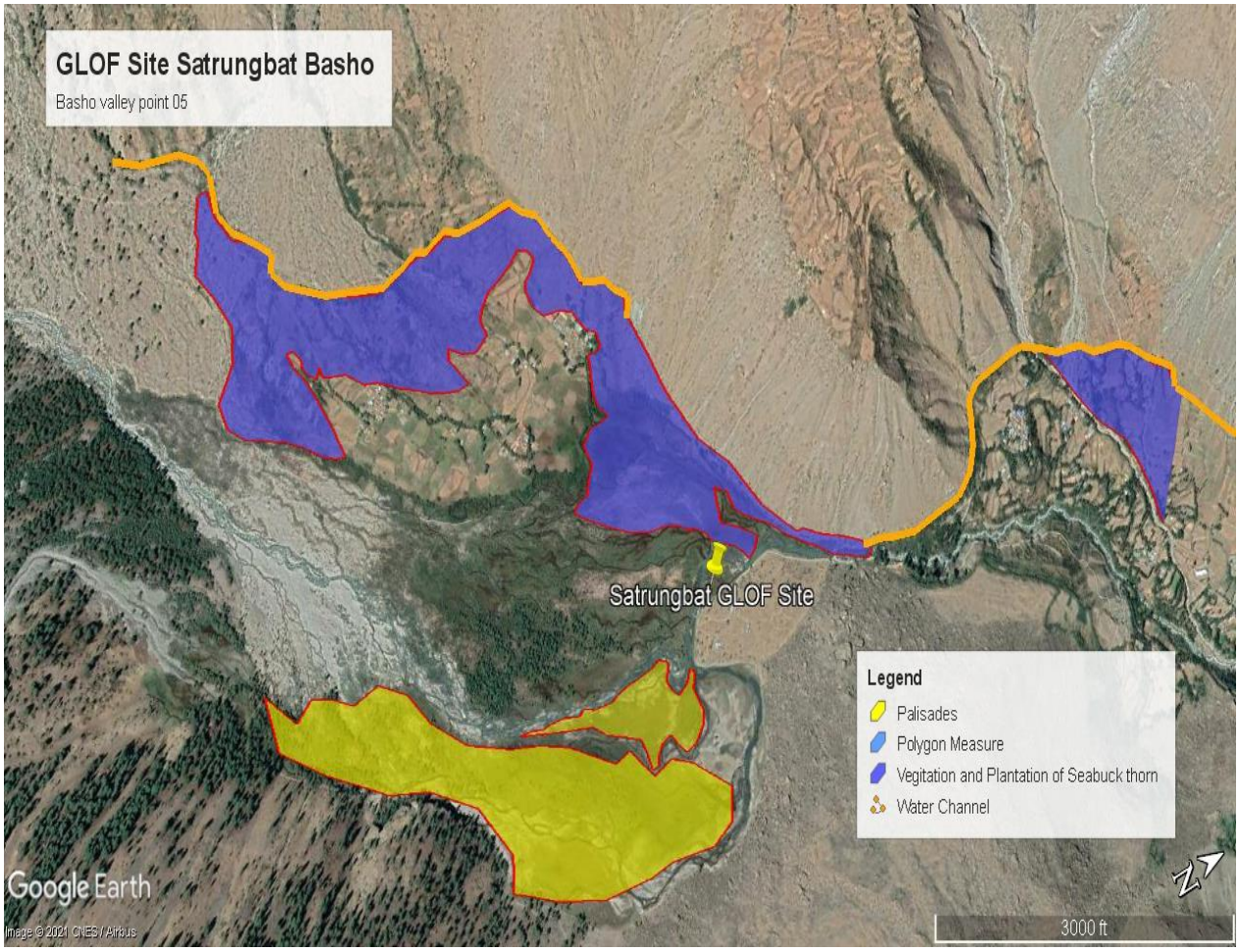


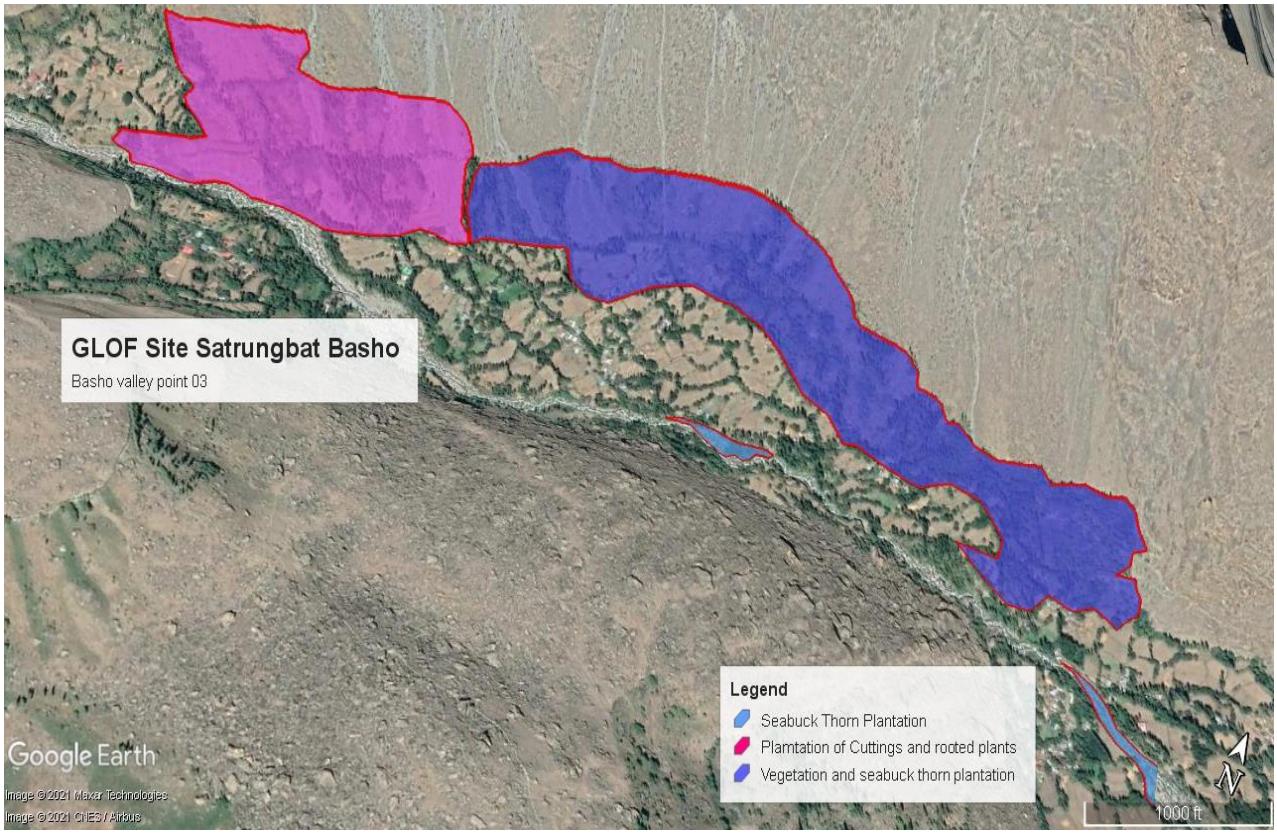
- Using a pointed bar, make a hole that is bigger than the cutting
- Carefully place the cutting in the hole so that two third is buried, firm the soil around it, taking care not to damage the bark
- Make the next hole 50mm along the row

3.5.3. Budget Estimate

S.NO	Item	Unit	Unite price	Total
01	Local dry & live Plant cuttings of willow, popular, and Russian olive (all inclusive) for Satrungbat Skardu	25000 cuttings	60 Rs.	1500000
	Total			**1500000**

Total Proposed Budget for GLOF-II Site (Satrungbat Basho Valley, District Skardu)		
Activity No	**Bioengineering Technique**	**Total**
01	Compact Planting and Vegetated Rip Rap	1800000
02	Sea buckthorn Plantation	1200000
03	Repair and extension of water channels	1000000
04	Grass Planting	912000
05	Palisades, Live fences	1500000
Grand Total Large and local grass planting		**6412000**


GLOF Site Satrungbat Basho
Basho valley point 05
Satrungbat GLOF Site
Legend
Palisades
Polygon Measure
Vegitation and Plantation of Seabuck thorn
Water Channel
Google Earth
Image © 2021 CNES / Airbus
3000 ft


GLOF Site Satrungbat Basho
Basho valley point 03
Legend
Seabuck Thorn Plantation
Plamtation of Cuttings and rooted plants
Vegetation and seabuck thorn plantation
Google Earth
Image © 2021 Maxar Technologies
Image © 2021 CNES / Airbus
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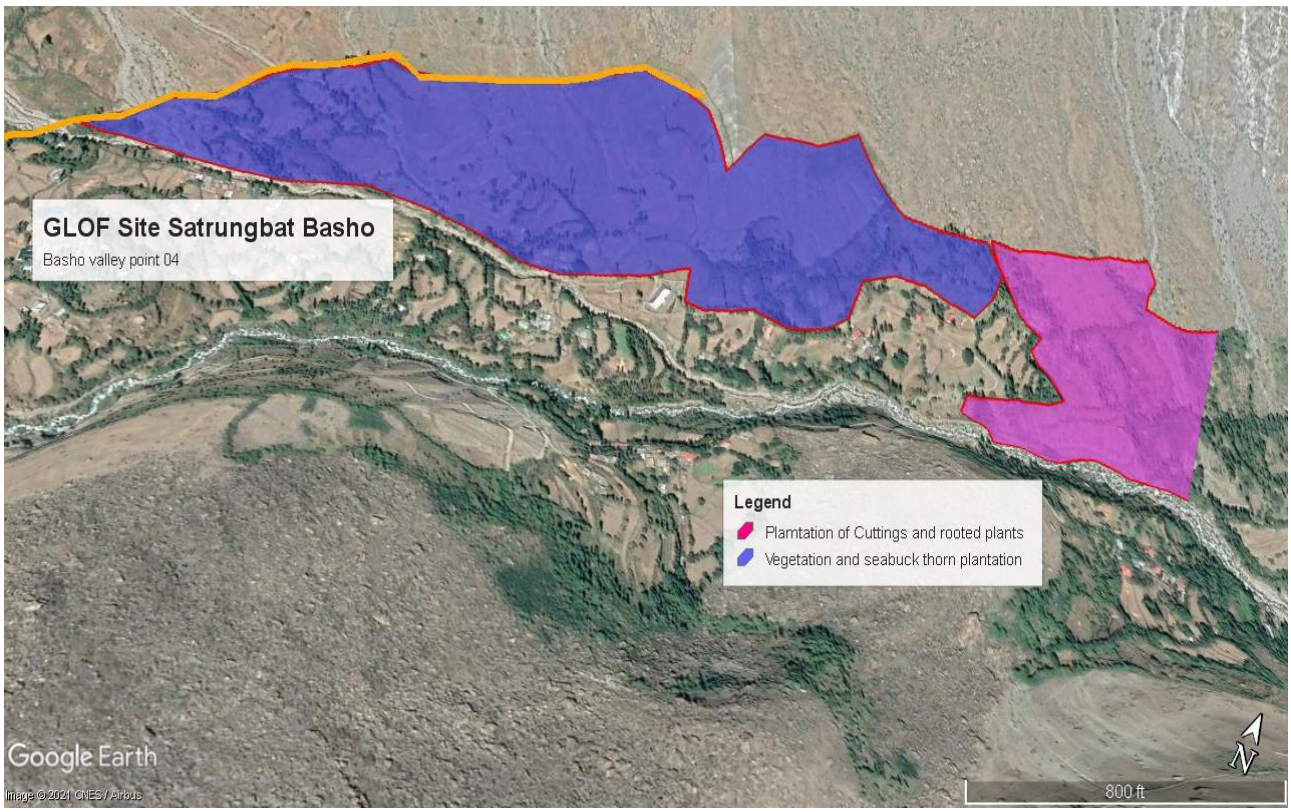
1000 ft


GLOF Site Satrungbat Basho
Basho valley point 04
Legend
Plamtation of Cuttings and rooted plants
Vegetation and seabuck thorn plantation
Google Earth
Image © 2021 CNES / Airbus
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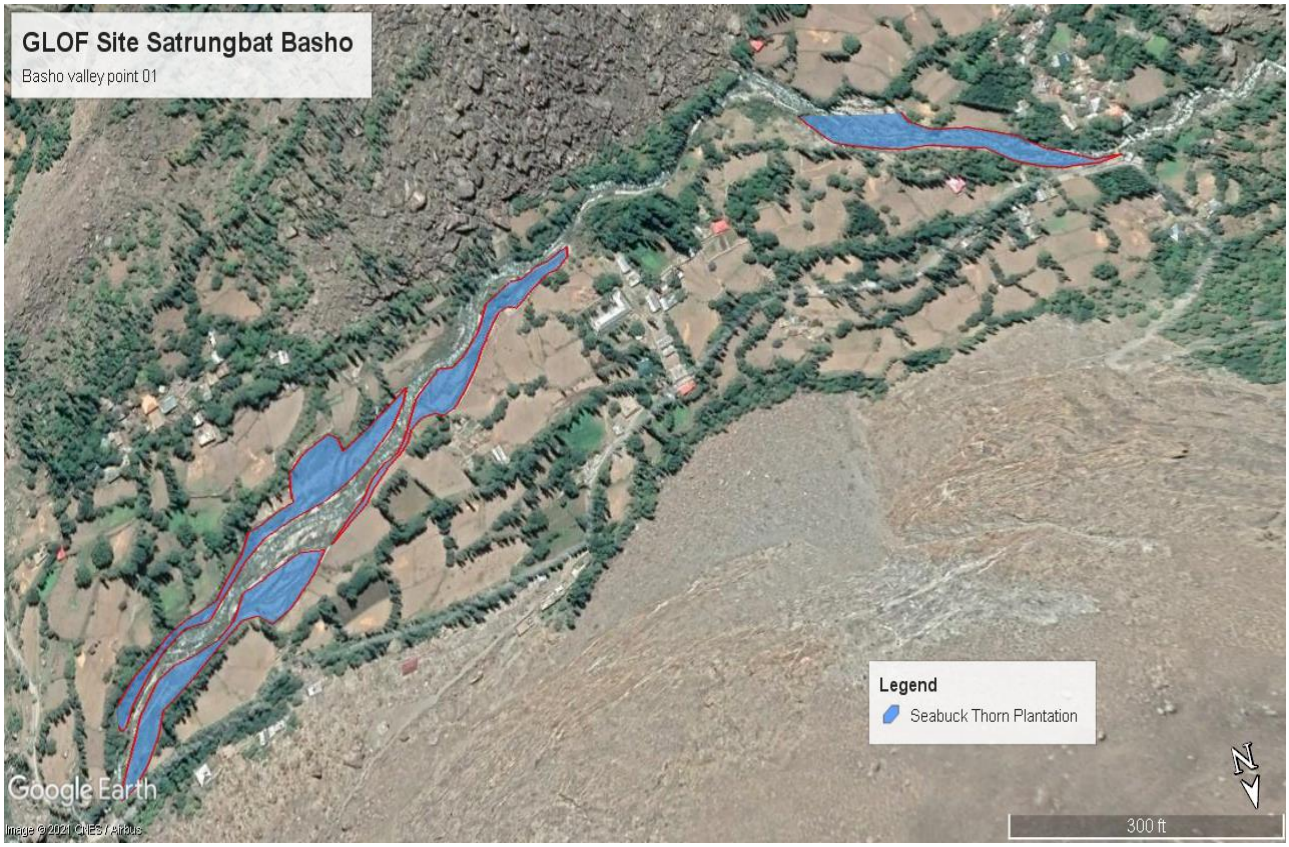
800 ft


GLOF Site Satrungbat Basho
Basho valley point 02
Legend
Seabuck Thorn Plantation
Google Earth
Image © 2021 CNES / Airbus
100 ft


GLOF Site Satrungbat Basho
Basho valley point 01
Legend
Seabuck Thorn Plantation
Google Earth
Image © 2021 CNES / Airbus
300 ft

Introduction of the Consultancy Company
Premier Mountain Communities Consultants (Private) Limited

PMCC is a research, planning, policy, monitoring, evaluation, and training consultancy, servicing governments, entrepreneurs, nonprofits, and donors with innovative solutions within the development context. It monitors and evaluates the relevancy, efficiency, and effectiveness, of the operations, policies, strategies, programs, organizations and projects to improve the performance and outcomes. Our work provides the research, monitoring & evaluative evidence to help the donors, governments, implementing agencies and entrepreneurs to maximize the effectiveness of their investment. We do so by generating lessons from past experiences, contextual study, and accountability to investors, shareholders and stakeholders at large. We provide expert services for developing management plans, need identification, project design, monitoring, evaluation, assessment, and capacity building of the implementing partners to increase the effectiveness of their investment.

Our Team of Consultants has expertise in all areas of MER design including program, plan & policy development, logic modeling, and grant writing.

We strive to add value to public and private sector partners, donors, investors, and development organizations, by providing accurate, insightful and cost effective solutions to enhance performance and effectiveness. We have evaluated donor/government funded projects of all sizes, from small community initiatives to large multimillion Euro/dollar & multi-year projects.

Our Approach Includes:

Our approach includes thoroughly understand the client's objectives, requisites, and context in a particular area of development.

- To bring together a well-qualified, skilled team that offers to work in the development context
- To comprehensively understand the clients' context in a particular area of development
- To evidently and completely comprehend the clients' objectives and requisites of the task

PMCC
Premier Mountain Communities Consultants