Oil and Gas Well/ Facility Site

Erosion Management

(Year 2 Summary)

A 2 year project of the
Science and Community Environmental Knowledge (SCEK) Fund

Charlie Lake Conservation Society

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August 2006

1. Summary

The Charlie Lake Conservation Society (CLCS)[1] in the development of its 2004 strategic plan identified erosion caused by oil and gas activity as one of the land-uses potentially contributing to degradation of water quality.

The 2005 Oil and Gas Well/Facility Site Erosion Management (Year 1 Summary) assessed 79 wells and access roads for erosion problems. Types of erosion found were rills, gullies and scour from dyke drains and road culverts. Regulations regarding erosion on oil and gas leases are not well defined.

This document (Year 2 Summary) is the final report of a two year project. Few of the issues identified in the 2005 report had been addressed by June 2006 due to a variety of factors including company mergers, personnel changes and lack of knowledge of best management practices. CLCS has developed suggestions for a Best Management Practices Guide, and a checklist for developing an Erosion Control Plan. This can be a starting point for companies to develop erosion control practices. Tools such as guidelines, performance standards and enhanced regulations may be considered for clarifying regulatory expectations for erosion management of oil and gas well and facility sites.

Primary funding was obtained through the Science and Community Environmental Knowledge (SCEK) fund established by the BC Oil and Gas Commission.

2. Table of Contents

3. List of Figures

4. List of Tables

5. Introduction

In 2004, CLCS published *A Long-Term Strategic Plan for the Improvement of Water Quality in the Charlie Lake Watershed*. This plan focused on improving water quality and habitat in the watershed and improving aesthetic and recreational potential of the watershed as a whole. Through the strategic planning process, CLCS is designing specific projects and community-level initiatives that will address the watershed level factors that are thought to be affecting perceived deterioration in water quality in Charlie Lake. The strategic plan identified erosion[2] caused by oil and gas activity as one of the land-uses potentially contributing to degradation of water quality.

The primary objectives of the project were to identify and document erosion issues on wellsites and access roads in the watershed and to raise awareness of the impact of erosion and sedimentation on Charlie Lake water quality among oil and gas companies, landowners and the general public.

The 2005 Oil and Gas Well / Facility Site Erosion Management (Year 1 Summary) assessed 79 wells and access roads for erosion problems. Types of erosion found were rills, gullies and scour from dyke drains and road culverts. Regulations regarding erosion on oil and gas leases are not well defined.

Following the 2005 assessments, CLCS approached oil companies in 2006 to determine actions taken as a result of the 2005 assessments. This report describes the methods and results of the follow-up work completed in 2006.

6. Study Area[3]

Charlie Lake is located in northeastern British Columbia, approximately 9 km northwest of the City of Fort St. John. The Charlie Lake watershed is valued for its natural beauty and residential suitability, angling, hunting and boating opportunities, fertile soils that support a thriving agricultural industry and substantial oil and gas reserves. In addition to supporting a wide range of recreational and industrial endeavours, Charlie Lake is the backup water supply for the City of Fort St. John (about 17,500 people) and surrounding areas.

Charlie Lake has a watershed area (Figure 1) of approximately 281 km^2 (surface area of the lake not included). Having a length of 15 km, a shoreline perimeter of 38 km, a surface area of 19 km^2 and a base volume of about 136,800 dam^3, Charlie Lake is considered to be a medium-sized lake. As are most naturally eutrophic lakes (i.e., lakes characterized by high biological productivity, particularly in terms of algae) of glacial-scour origin (Rawson, 1955; Hutchinson, 1957), Charlie Lake is comparatively shallow, having mean and maximum depths of 7 and 15 m. Charlie Lake has 21 direct tributaries. Most of these tributaries are ephemeral and typically only carry flows during spring melt and rainy periods. The two largest tributaries (Stoddart Creek that drains 171 km^2 and Coffee Creek that drains 25 km^2) enter from the north and together, drain nearly 80% of the watershed area.

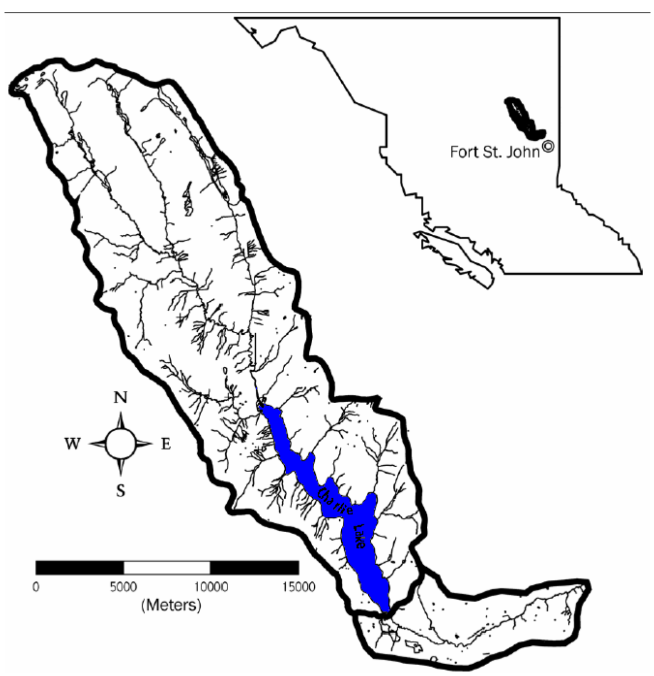

Figure 1 – Charlie Lake Watershed

Data provided by the Oil and Gas Commission (OGC) in May 2005 showed that there are a total of 239 wellsites in the watershed - 138 are active Most of the active wells are operated by six companies (Figure 2). These numbers fluctuate regularly, due to the continual dynamic growth of the oil and gas industry.

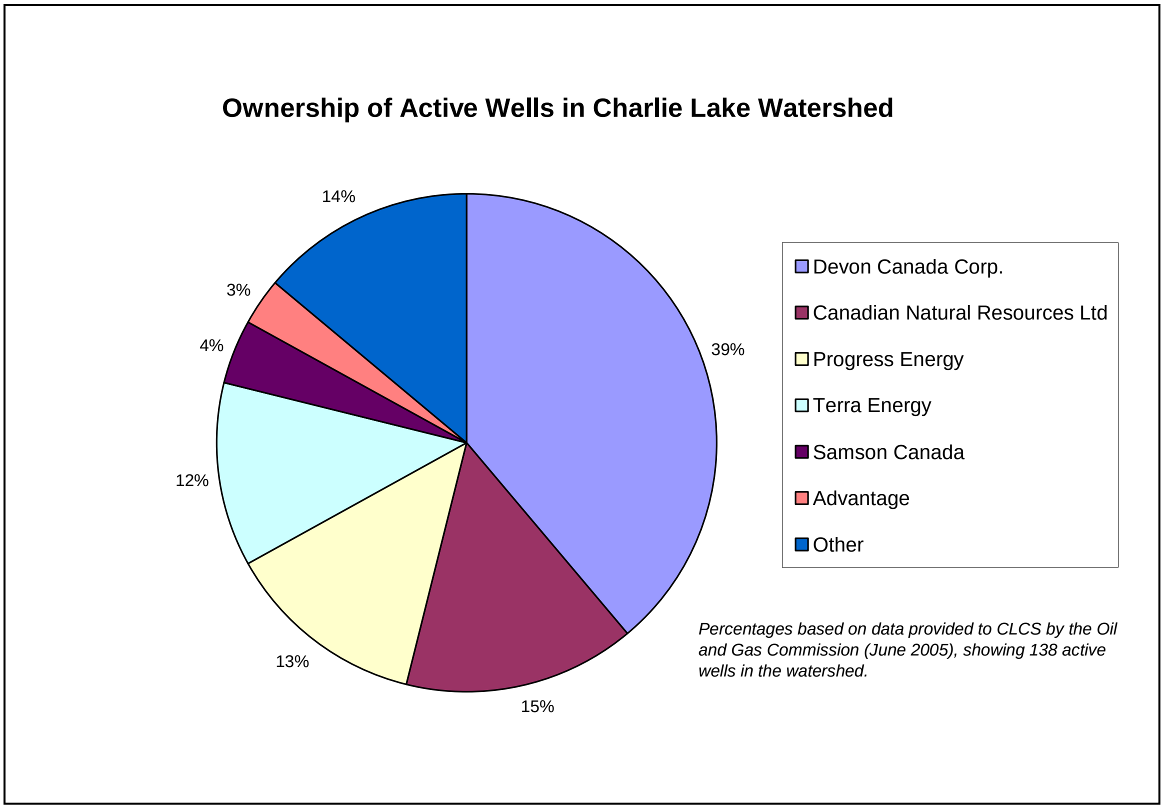

Figure 2 - Ownership of active wells in the Charlie Lake Watershed

7. Methods

The project began in May 2005. Field visits to oil and gas wellsites and access roads were undertaken over the period June to August 2005. Visits involved a qualitative assessment of erosion problems using the assessment form and photographs[4]. In May 2006, companies that participated in the 2005 assessments were contacted for follow-up purposes. CLCS wanted to determine if the level of awareness and commitment to erosion control had improved. First, companies were asked if they had a corporate policy on erosion control. A list of company endorsed erosion mitigation action plans for specific wellsites was to be compiled as well.

The erosion control workshop organized in 2005 was well received. Because of this, the CLCS workplan for 2006 included offering an applied workshop. The 2006 workshop would include a field trip to view wellsites and roads where good work had been done.

Research into erosion control best practices for clay/silt soils was done, with the intent of developing a broad-reaching erosion control checklist for oil and gas companies to use as a template for developing their own company specific guidelines.

8. Results and Discussion

Follow-up to 2005 Assessments

The second year of this project was intended to be a follow-up to the assessments completed in 2005.

Table 1 – Erosion issues observed June-August 2005

Wellsite Location	Type of Erosion	Locations (%)
Lease site	Rills	81
	Gullies	35
	Scour around dyke drain outflow	32
	Erosion outside dyke perimeter	11
Access Road	Rills	51
	Gullies	16
	Scour around culverts	16

CLCS had hoped to compile a list of wellsites where company endorsed erosion mitigation action plans had been developed.

Despite all companies involved still expressing interest in erosion control, and the efforts being put forth by CLCS, none of the companies had developed site-specific action plans directly as a result of the 2005 assessments.

Two of the six companies that participated in the 2005 assessment were going through mergers/acquisitions at the time of contact (May 2006), so stated that limited erosion control work had been carried out since 2005, and it was unlikely anything would be done throughout the summer of 2006, due to funds being frozen until the mergers/acquisitions were completed. New erosion control policies would also not be developed until mergers finalized.

For two of the remaining four companies, the main contact for the project changed. In one case this was the environmental advisor, in the other, the area foreman was new. These two staff members were still in a transition stage to their areas of responsibility, so had to be briefed on 2005 work.

Another major obstacle to the immediate development of remedial action plans was that the 2005 reports did not reach the necessary recipients (environmental advisors/area foreman) until spring 2006. This happened in a few cases with smaller companies where the recipient staff member was located in Calgary, AB. The report was delivered to the Fort St. John offices, but never made it through the necessary channels. So it is still possible that plans will be developed for 2007.

Some remedial erosion and stormwater control work was completed. Most of this work included berm repairs and replacement of broken culverts, and addition of rip-rap to culvert outlets (Figure 3).

Figure 3 – Culvert rip-rap and berm repairs to control water

Many problems observed on unpaved roads in 2005 included rills and the beginnings of gully formations. These issues were normally addressed by re-grading the road to smooth out the ruts. This is a maintenance issue that will have to be repeated every year.

There were a few cases noted where the drainage pathways for dyke drains had been reinforced using geotextile fabric and rip-rap (Figure 4).

Figure 4 – Drainage pathway reinforced by geotextile and rip-rap

An attempt was made to remedy the problem on one wellsite where cattle had exacerbated erosion issues in road ditches. One ditch was rebuilt. Another was seeded and covered by erosion control blankets. Unfortunately, the blankets were incorrectly installed, and cattle were not kept out of the area. The majority of the seeds had not germinated as of June 2005, and the erosion control blanket appeared to be ineffective.

Erosion Control Workshops

An erosion control workshop was delivered by Malaspina University College (Malaspina). This course was recommended to CLCS by Ministry of Transportation in Prince George and by EnCana Corporation. EnCana currently requires all of its construction foremen and contractors in BC and Alberta to take this particular course. With such a ringing endorsement from someone within the oil and gas industry, CLCS decided to work with Malaspina to bring its 3-day “Erosion and Sediment Control (ESC)” course to Fort St. John. Malaspina has tried to offer the ESC course in Fort St. John in the past, but was unable to register enough participants to run it.

The Malaspina ESC course was a great success. CLCS acted as a local coordinator, identifying and contacting potential interested parties, and assisting the Malaspina coordinator to determine the dates best suited for a Fort St. John audience. There were participants from a variety of backgrounds, including CLCS, the Oil and Gas Commission, two oil companies, forestry, hydro, and environmental consultants who provide services to the oil and gas industry. One day was spent in the classroom, with two days spent on fieldwork, learning how to properly install ESC's. Details on some of the Best Management Practices discussed can be found in Appendix I.

CLCS highly recommends that oil companies consider making this course mandatory for construction departments and contractors, and perhaps for area foremen who manage production. Once construction is complete, the maintenance of roads and wellsites falls under the production foreman's responsibility, so it is imperative that erosion and sediment control best management practices are understood. The Participant's Manual provided by Malaspina University College is an excellent resource, and describes Best Management Practices in detail.

For production staff, a different approach would be recommended. After speaking with area foremen at oil companies operating in the Charlie Lake watershed, it was determined that the ESC course was too in-depth for production staff. CLCS had hoped to hold a one day workshop in partnership with an erosion control materials company. The workshop would consist of presentations and open discussion in the morning, and a site visit to a demo project in the afternoon.
Unfortunately after repeated attempts by CLCS to organize the demonstration project, it finally became apparent that the sponsoring erosion control materials company was no longer interested in pursuing the partnership. This is unfortunate, because all oil and gas companies involved were very interested in hosting the demonstration project on their wellsites. One company in particular stated a willingness to apply applicable erosion control to all sites where needed, if successful on the demonstration site. Despite the conclusion of the SCEK funded CLCS project in 2006, it would be useful for CLCS to again pursue the demonstration project for 2007, time and funding permitted. Company field staff are anxious for practical solutions appropriate for their operating areas.

Wellsite Erosion Control Project – Lessons Learned

This two year project has shown that erosion problems existing in the oil and gas industry persist because of a lack of awareness and a lack of knowledge. . Erosion control work is still being done, in many cases for remedial works, on a trial and error basis. In most cases it appears that companies are interested in fixing erosion problems, but often they don't know how. This was evident by the well attended erosion control workshops and courses. Audiences consisted of people from a wide range of backgrounds, including outside the oil and gas industry. The project was successful in raising awareness of erosion control issues among industry and regulators.

The oil and gas companies involved were helpful and cooperative for the duration of the project, and show a willingness to work collaboratively on issues of common interest. That said, it is a challenge to convince producers of the importance of erosion control, when environmental impacts are not immediately evident and highest priorities include maximizing production. Comprehensive guidelines/performance standards related to erosion and sediment control will increase understanding of regulatory expectations.

There were a number of reasons for this, including mergers of companies (causing “frozen funds”), personnel changes, and lack of knowledge of BMP's

The 2005 interim report found that erosion issues related to oil and gas activity are not covered adequately in current regulations. Guidelines for compliance inspectors reporting erosion issues are therefore quite vague and lead to inconsistencies. Revision of current regulations should be considered to address the need for clarity and accountability related to erosion management.

Meeting Project Deliverables

As described previously, the second year of this project was intended to be a follow-up to the assessments completed in 2005. No companies had developed action plans for specific wellsites, however remedial work had been done on a case by case basis and with a few exceptions – mostly consisted of repairing blown out berms. Companies did not have internal policies specific to erosion control, although most have a general statement regarding commitment to maintaining environmental quality in general. A few of the companies whose Canadian headquarters are located in Calgary use environmental regulations monitored by the Alberta Energy and Utilities Board (www.eub.gov.ab.ca) as guidelines, since they are often stricter than current BC regulations.

There were not many sites to report on in terms of level of success of applied mitigative measures. Some of the work done was completed this spring; so long term success will not be apparent until the Spring 2007 freshet has occurred.

Erosion control workshops were not part of the original workplan submitted during the SCEK fund application process, but were added after the fact with the permission of OGC. This is where CLCS has the most success. Attendance was high, and the response from participants was positive. Presentations describing the oil and gas erosion control project were given to other groups concerned with water quality, in an effort to share awareness and knowledge with people working outside of the Charlie Lake watershed.

A presentation will be made to the newly formed North East Energy and Mines Advisory Committee (NEEMAC) in September 2006. The purpose of this presentation will be to present ongoing concerns, and a generic erosion control checklist that could be used by oil companies to determine mitigative strategies (Appendix II).

9. Conclusion

Erosion and sedimentation from oil and gas activity may contribute to water quality issues in the Charlie Lake watershed. The majority of problems found in 2005 were related to a lack of vegetation, interruption of natural drainage channels, or concentration of flow that resulted in scouring. The erosion assessment undertaken during this project was qualitative in nature.

Oilfield operators and others having a role in monitoring the industry could benefit from increased knowledge in recognizing indications of erosion and erosion control technology. Early identification will keep sediment out of Charlie Lake, help maintain infrastructure integrity and potentially reduce maintenance costs of constantly repairing berms and roads.

Oil and gas companies showed a willingness to fix the problems identified in the 2005 erosion assessment project, but not many of the points brought up in the report have been addressed yet. This was due to a number of reasons, including multiple staff changes, and frozen funds due to mergers taking place in 2005/2006. The main issue now is still to determine management techniques appropriate to the environmental conditions in the watershed. A combination of management techniques will be most effective.

It was also noted in 2006 that none of the companies participating in the assessment have corporate erosion control policies. It would be useful to have procedure in place for developing erosion control plans. CLCS hopes that the Best Management Practices and Erosion Control checklist described in the appendices of this report will provide a starting point.

The Malaspina University College Erosion and Sediment Control course was very useful and applied in nature. CLCS recommends that oil and gas producers consider making this course mandatory for construction staff and contractors. EnCana has already done this for BC and Alberta locations. The erosion control demonstration workshop did not happen, due to issues coordinating schedules with the company donating materials. Producers would still like the opportunity to participate in this kind of workshop.

New guidelines and regulations should be developed to make clear what is expected of oil and gas companies for erosion control.

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10. Appendix I - Erosion and Sediment Control Best Management Practices

Erosion is a natural process that is exacerbated by human activity. Agents of erosion include water, wind, and when humans are involved – construction equipment. Factors to consider when looking for potential erosion and sedimentation problems include rainfall, topography, soil erodibility, and vegetation cover. Erosion potential increases with an increase in rainfall and runoff volume and intensity, slope steepness and length, and the smoothness of the soil surface. Non-cohesive silts and fine sands are usually the most erosive particle sizes. Clays and fine silts are very hard to remove from water once they become suspended. Fort St. John area soils typically contain a large proportion of silt and clay, so this definitely needs to be considered[5].

Soil vegetation cover is the easiest erosion factor to manage. Existing vegetation should be retained where possible. Temporary soil covers such as mulch can be used, but maintaining a permanent vegetation cover is the most effective erosion control practice.[6] Establishing a permanent vegetation cover is often the cheapest option for erosion control as well.

Erosion control is source control – control is implemented where erosion is occurring or is expected to occur. The purpose of erosion control is to prevent soil particle detachment, entrainment and transport. This is achieved by using soil covers, and managing runoff volumes and velocities. Sediment control is non-source control – the control is implemented downslope or downstream of where erosion is occurring or expected to occur. The purpose of sediment control is to capture and retain sediment being transported by water. This is achieved by forcing deposition to occur by pooling water and decreasing flow velocity.

Sediment control is not very effective for fine silt and clay particle sizes, because it takes a very long time for these particles to settle out of water once suspended. Because of this, sediment control should not be used as a replacement for erosion control. The initial cost of installing sediment controls is cheaper than erosion controls, but sediment controls require a lot of on-going maintenance, are relatively ineffective when compared with erosion controls, and create potential liability issues because of their ineffectiveness. After considering all of these factors, erosion controls appear more cost effective in the long term.

Erosion Control Best Management Practices (EC-BMP)[7]

EC-BMP #1 – Mulch and Seeding

As mentioned above, establishment of a vegetation cover is the most effective erosion control. This is not possible on the wellsite areas that must be blackened for fire hazard control, but is certainly an option for the backside of berms, and road ditches. Seed types selected will depend on the surrounding area (i.e. agricultural, forested, etc.)

Mulch can be used on slopes or flat surfaces. Mulch will prevent soil particle detachment, decrease runoff velocities, promote water infiltration into the soil and prevent surface compaction. Mulch protects the seeds underneath, and moderates soil moisture and temperature, encouraging optimal growth.

Various organic materials can be used, including straw, wood chips, wood fibre, recycled paper and compost. However, long-term erosion control will not be achieved unless vegetation is established as the mulch decomposes. Also, caution must be taken when using certain mulches like wood chips, as the decomposition process may produce substances that will reduce water quality and be harmful to fish and other wildlife.

Since the Fort St. John area tends to be very windy at times, lightweight mulches like straw should be anchored by using a tackifier, to prevent movement. When tacked down, straw can be excellent for promoting good grass cover quickly, but can also be a fire hazard (City of Calgary, 2001)

EC-BMP #2 – Rolled Erosion Control Products (Blankets)

Erosion control blankets are more expensive and more labour intensive to install than mulch, but may be more effective on steep slopes exposed to wind and runoff. Erosion control blankets usually consist of a biodegradable soil covering, such as straw or coconut fibre, encased in biodegradable or photodegradable netting.

Erosion control blankets provide similar benefits to mulch, as they will protect seeds and maintain desirable growing conditions, while holding soil in place. These blankets can be used in a variety of situations, including steep slopes, slopes where soils are highly erodible (silts and sand), and in low-flow channel areas (some road ditches).

In order to be effective, erosion control blankets must be installed correctly (Figure 5) [8] [9] . They should be placed in the up-down direction on a slope, rather than across in a lateral direction. If installed correctly, they may persist for 6 months to 3 years. Seeding must be completed prior to placement of the erosion control blanket.

Erosion control blankets may be appropriate for wellsite locations on a hillslope, and in low-flow road ditches.

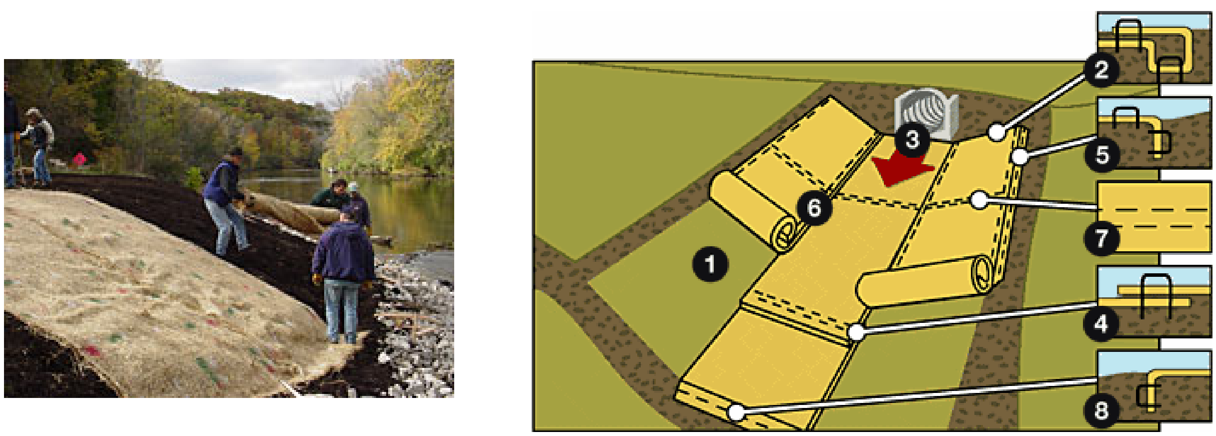


Figure 5 - Installation of Erosion Control Blanket on a slope and in a drainage channel

EC-BMP #3 – Ditches

Ditches are described here as an EC-BMP, since certain ditch designs will minimize erosion. Roadside ditches should not be used to channelize natural watercourses.

Ditches must be sized for the expected flows. A wide and nearly flat bottomed or rounded v-shape cross sections are preferred, and a straight v-shaped ditch should be avoided (Figure 6). V-shaped ditches can maximize water flow velocity and will exacerbate any erosional problems already present. U-shaped ditches are also undesirable, because they have less drainage capacity than other shapes and the sides tend to cave in, causing more erosion and sedimentation problems. (US-EPA, 2006)

A low gradient is desirable to prevent erosion (1-2%). If gradients will be steeper, ditches can be lined with geotextile and rock. If the ditch is subject only to periodic flows (not permanently wetted), seeding and covering with an erosion control blanket (EC-BMP #2) will help prevent erosion until vegetation is established.

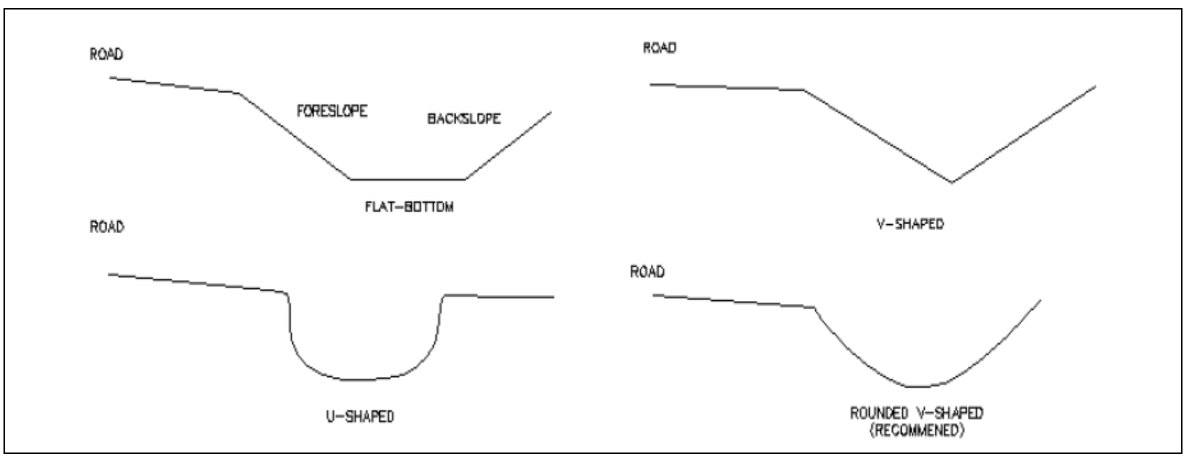


Figure 6 – Common Ditch Shapes (US EPA, 2006)

EC-BMP #4 – Check Dams

Check dams are constructed across a defined ditch or channel. Check dams are used where the capability of the earth or vegetative measures are exceeded in the safe handling of water at permissible velocities, where excessive slope conditions occur, or where water is to be lowered from one elevation to another (City of Calgary, 2001).

Their purpose is to control erosion by slowing water velocities and decreasing the effective grade of the ditch. A secondary purpose would be to detain runoff and retain large sediment particles. Check dams are suitable for relatively low volume, low gradient ditches. They are not effective for the retention of fine suspended sediments like silt and clay.

Check dams are often constructed using graded rock, sandbags, or straw bales. The instructor of the Erosion and Sediment Control course discouraged the use of straw bales, as they are the most difficult to install correctly. The center of the check dam should be at least 20-30 cm lower than the outer edges. Check dams should be space so that the crest of each downstream dam (at centerline) is slightly higher than the elevation of the base of the next upstream dam (Figures 7, 8) [10] [11].

If constructed with sandbags, the strength and effectiveness of the check dam can be enhanced by wrapping the structure with geotextile fabric. The fabric must be anchored along the upslope side of the dam and along the edges to prevent displacement. Extending the fabric 1-5m downslope of the dam with prevent erosion of the ditch at the transition area between the dam and the ditch. Rip-rap can also be used to protect the ditch bed (Whatcom County, 2006).

Check dams need to be monitored for performance and sediment accumulation, especially after heavy rainfall. Sediment should be removed when it reaches one half the depth of the check dam (Whatcom County, 2006).

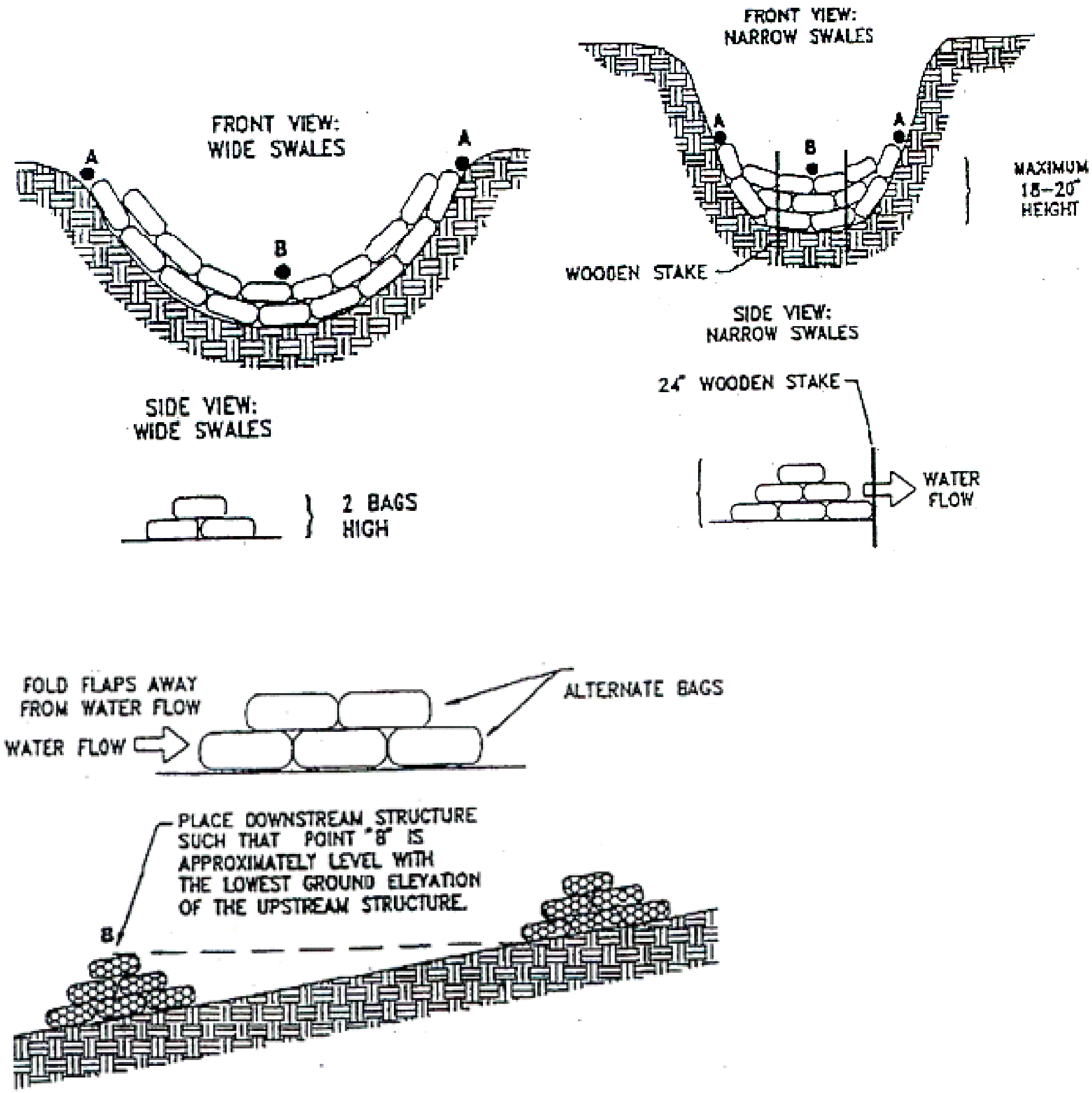
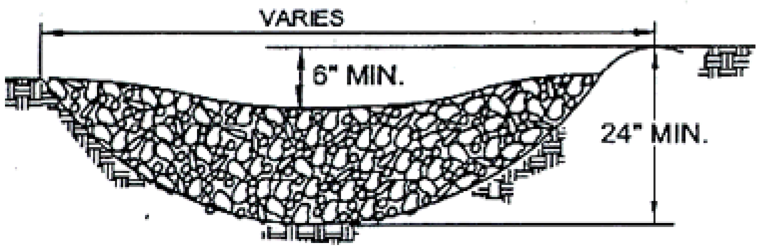


Figure 7 - Sand Bag Check Dams (temporary)



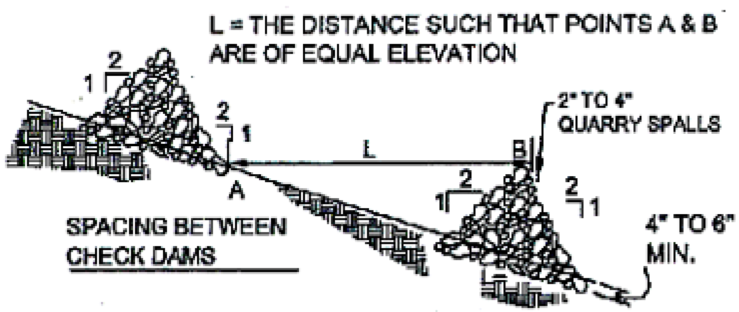


Figure 8 – Rock Check dams (temporary or permanent)

EC-BMP #5 – Rock-lined Ditch

A rock-lined ditch is a loosely packed continuous blanket of angular rock of specified sized and gradation placed in a defined, constructed ditch. Its purpose is to prevent erosion of a ditch by placing a continuous rock blanket that prevents the detachment of soil particles. Angular rock (rip-rap) is preferred to rounded rock, because it enhances surface roughness, further decreasing effective flow velocities.

This BMP is effective in ditches subject to higher flow velocities (2-5 m/s), and in ditches exceeding a 2% gradient. It is also highly suitable for easily eroded soil conditions (such as those in the Fort St. John area). This is also a useful BMP for use in dyke drain drainage areas that are steep, and prone to erosion problems (Figure 9).

The rock layer should be 1.5 to 2 times thickness of the mean rock size. To prevent entrainment of fine grained sediments, place a geotextile liner between the rock blanket and the ditch bed. Avoid placing fines with the rock, because the fines will contribute to sediment loading.

Figure 9 - Lining of drainage pathway from dyke drain

EC- BMP #6 – Soil Bioengineering Techniques

Soil bioengineering uses live plant materials to provide erosion control, slope and streambank stabilization (Washington Department of Transportation). Less heavy machinery is required than traditional engineering methods, resulting in lower costs and environmental impacts. Small-scale erosion problems can be mitigated before they become large problems. Once plants are established, root systems reinforce the soil mantle and remove excess moisture from the soil profile.

Willows are frequently used in soil bioengineering applications, as they develop an excellent root mass (Polster, 2001). Live-staking with willows has been very successful at maintaining integrity of shoreline properties along Charlie Lake (Blair, 2005). Staking with willows could be applied to the backside of berms around lease sites, as well as around road ditches, where possible. Use the following steps to correctly install live stakes[12]:

1. Locate a source of appropriate live stake material. These species may be easiest to locate when leafed out during the growing season prior to installation. Mark with flags, as necessary, to relocate.

2. Plan to install the live stakes as soon as the frost is out of the ground in the spring. A maul, 3' length of rebar, lopper, pruning sheers, and bucket will be needed.

3. Cut 1'-3' lengths of branches that are 1/2"-1" in diameter. Mark the top end by cutting it straight across and the bottom end by cutting it at an angle. Smaller side branches can be pruned back to the main branch.

4. Put the cut branches, bottom end down, in a bucket of water. Keep them in cool, dark, wind-free conditions during transport (and also during storage if unable to plant the same day). The survival rate of live stakes is greatest if they are cut and installed the same day.

5. To plant, drive a pilot hole using the rebar and maul and insert the live stake. Trim the stake tops to within 2"-4" of the ground, making sure only 2 buds remain on the exposed part of the stake (Figure 10). These will later sprout and form branches.

6. Water to ensure good contact between the soil and the live stake.

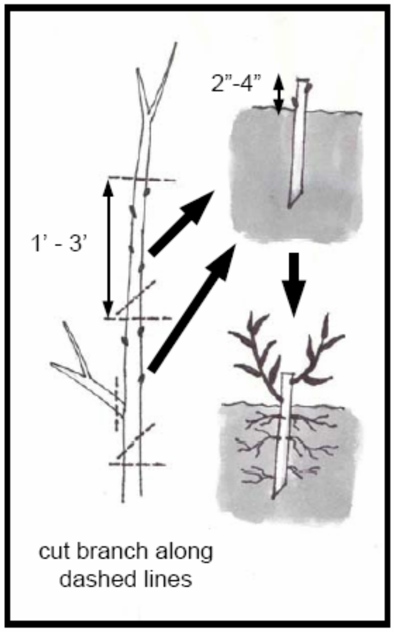


Figure 10 Preparation and installation of live stakes

Willow-staking can be used in combination with other EC-BMP's for greatest effectiveness. An example of this is to use live willow stakes to hold erosion control blanket overtop of a seeded area. The stakes will hold the blanket in place, and form a root mass that will contribute to soil stabilization. This technique was used successfully by Terra Erosion Control Ltd to stabilize exposed side-cast material, prevent sedimentation into a creek, and to prevent surface erosion and establish vegetation (Figures 11-13)[13].

Figure 11 Site prior to work being done – 1998

Figure 12 Installation of grass seed, coconut erosion control blanket and live willow stakes

Figure 13 Established grasses and willows – Fall 2003

Sediment Control Best Management Practices (SC-BMP)

SC-BMP #1 – Silt Fencing

Silt fencing is permeable geotextile fabric anchored into the soil and erected vertically by attaching fabric to regularly spaced posts. Its purposes are to collect and detain runoff and sediment, and to force water to pool so that suspended sediment can drop out of suspension.

Silt fences can provide effective sediment control for soils consisting primarily of coarse silt and sand size particles, if installed correctly. Runoff is usually not detained for a period of time sufficient to allow the settling of medium silt and finer particles.

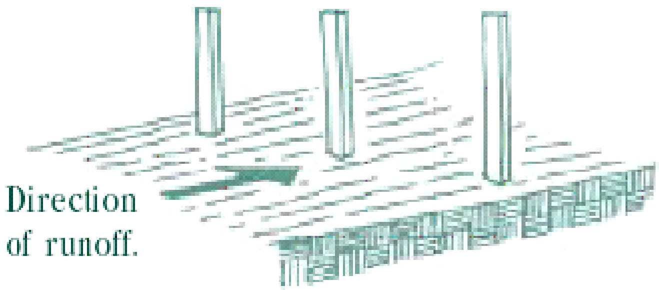
Silt fencing should not be used at locations where high discharge is likely to occur. Silt fencing does not filter sediment out of running water, because the pore sizes in the fabric used are often larger than fine sand (0.250 to 0.125mm) and smaller grain sizes like silt and clay.

Silt fencing must be firmly anchored into the soil, and firmly attached to the supporting posts. Posts should be driven a minimum of 0.3 m into undisturbed ground (preferably 0.6m depth), deeper, if the ground has been disturbed. Prevent scouring around the ends of the fence by ensuring the elevation of the bottom of the silt fence and the fence ends is higher than the top elevation of the rest of the fence. Install the fence in a “J” shape or smile on contour to maximize the ponding efficiency (Figure 10).

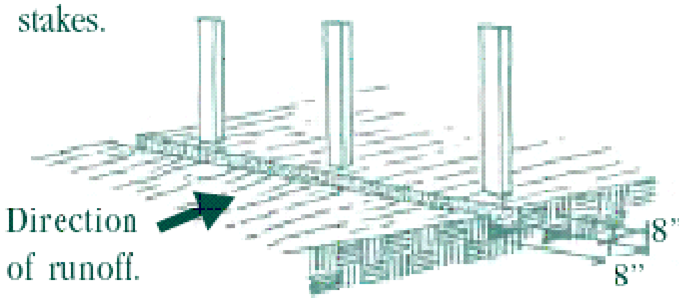
Figure 14 – Silt fence installed in a J-shape

Figure 15 - Installation of a Silt Fence – Four Steps

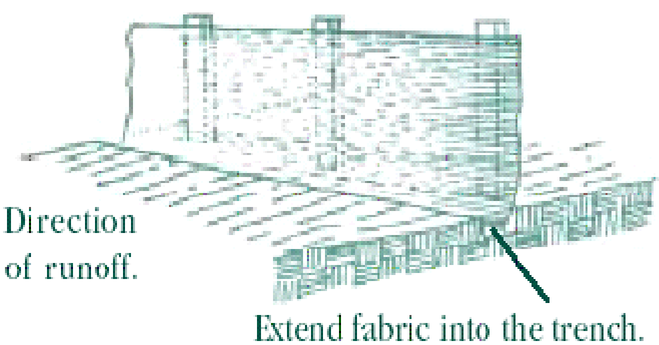
1) Set the stakes a maximum of 6' apart and at a depth of 30" when physically possible.



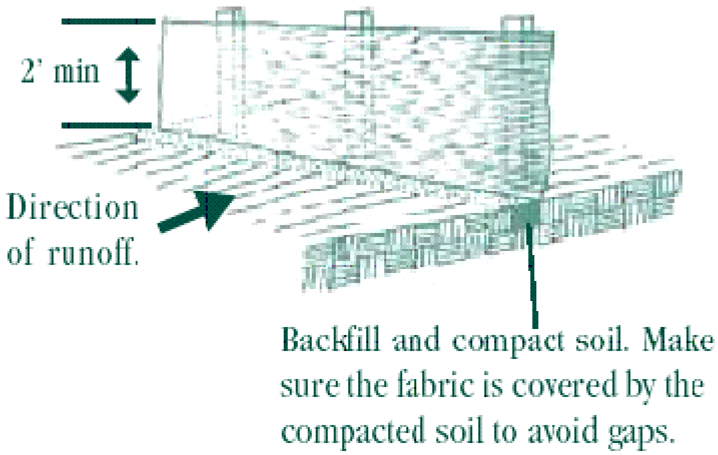
2) Excavate a 8" x 8" trench upslope along the line of stakes.



3) If the filter fabric did not come attached to the posts, staple the filter material to the posts. Extend the fabric into the trench.



4) Backfill and compact the excavated soil.



11. Appendix II - Oil and Gas Erosion and Sediment Control Checklist – Creating a Plan

Location map
Note the location of critical features including streams, ponds, wetlands, roads, agricultural fields
Make special note of fish-bearing watercourses

Existing Conditions (map)
Existing topographic contours
Drainage way and water features
General vegetative cover types within 200 feet of water features (e.g. field, hardwood forest, grass, etc.)
Vegetative cover types in all proposed disturbance areas and areas receiving and treating runoff from wellsite (during and post construction)
Soil map
Identified sensitive areas (e.g. steep slopes, erodible soils, wet areas)
Structures, roads, utilities
North arrow, scale, date, elevation datum
Property lines

Conditions following construction:
Proposed topographic contours
Limits of soil disturbance
Proposed structures and roads
Boundaries for undisturbed riparian buffers (if necessary)

Erosion Prevention and Sediment Control Plan (map)
Limits of soil disturbance
Riparian conservation buffer limits
Location of all structural erosion and sediment control measures and details
Location of areas to be seeded and mulched
Stormwater pathways
Maintenance schedule of all controls

Narrative portion of report
(General description of project)

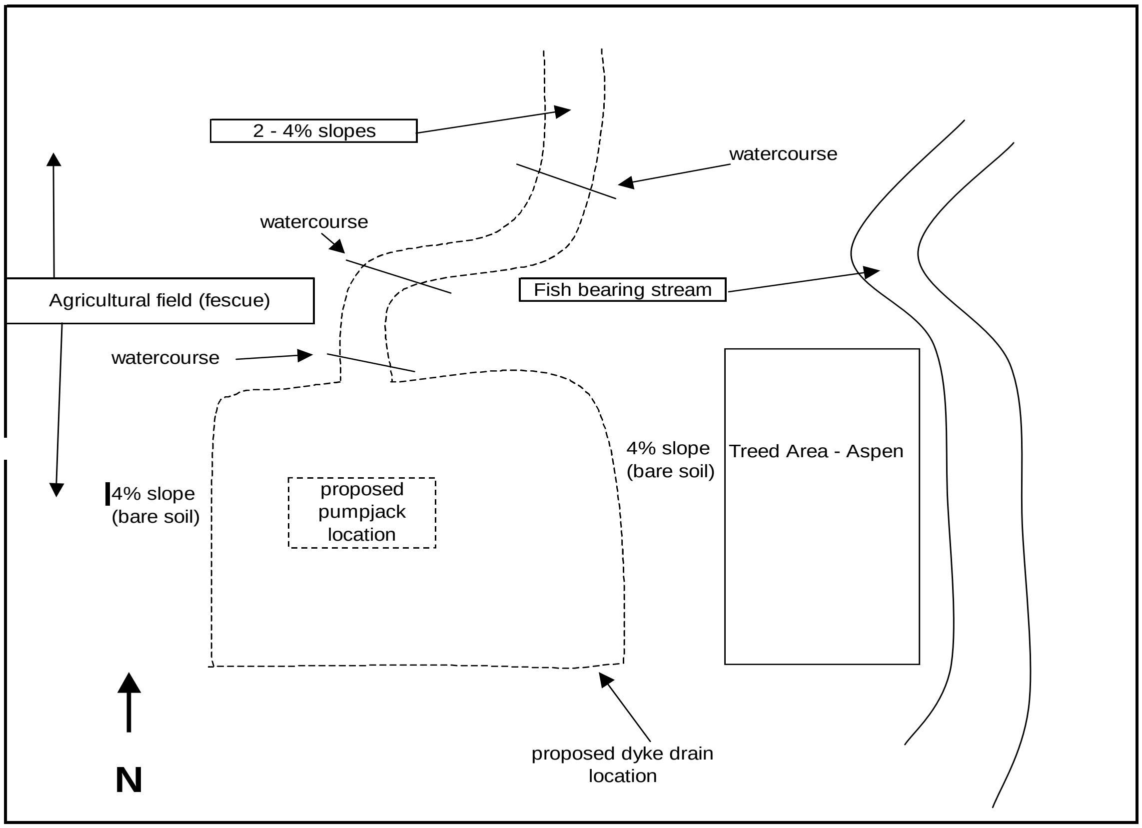
Site Inventory and Analysis
Site drainage characteristics
Drainage, waterways, bodies of water
Topography, existing roads, buildings, utilities
Vegetation
Soils
Proximity to natural or man-made water features

Erosion Prevention and Sediment Control Plan and Timetable
Description of strategies of control plan and why it will be effective in protecting water resources
Description of seeding and mulching plan for ditches and berms (backside of berms)
Description of all structural erosion and sediment control measures
Description of inspection and maintenance program for all control measures

Best Management Practices – Options to Consider
Mulch and Seeding
Erosion control blanket and seeding
U-Shaped or wide and flat-bottomed ditches for roadside
Check-dams in ditches
Rock lined ditch
Rock lined drainage area (below dyke drain)
Silt fences

12. Appendix III – Erosion Management for a Sample Wellsite

Figure 16 - Site Map Prior to Construction



Site Details

Prior to construction of a new wellsite, company x surveyed existing site conditions and noted the following:

- The new lease would be situated below an agricultural field that was normally planted with fescue.
- Slope of the land from the field to the wellsite, and the wellsite to a forested area was approximately 4%.
- Aspen dominated the forested area
- There was a fish bearing stream located 40m east of the wellsite, beyond the forested area.
- Runoff from the field during spring freshet could potentially cause erosion of the bare soil above the wellsite
- The wellsite would be 100m x 100m in size following construction of the perimeter berm

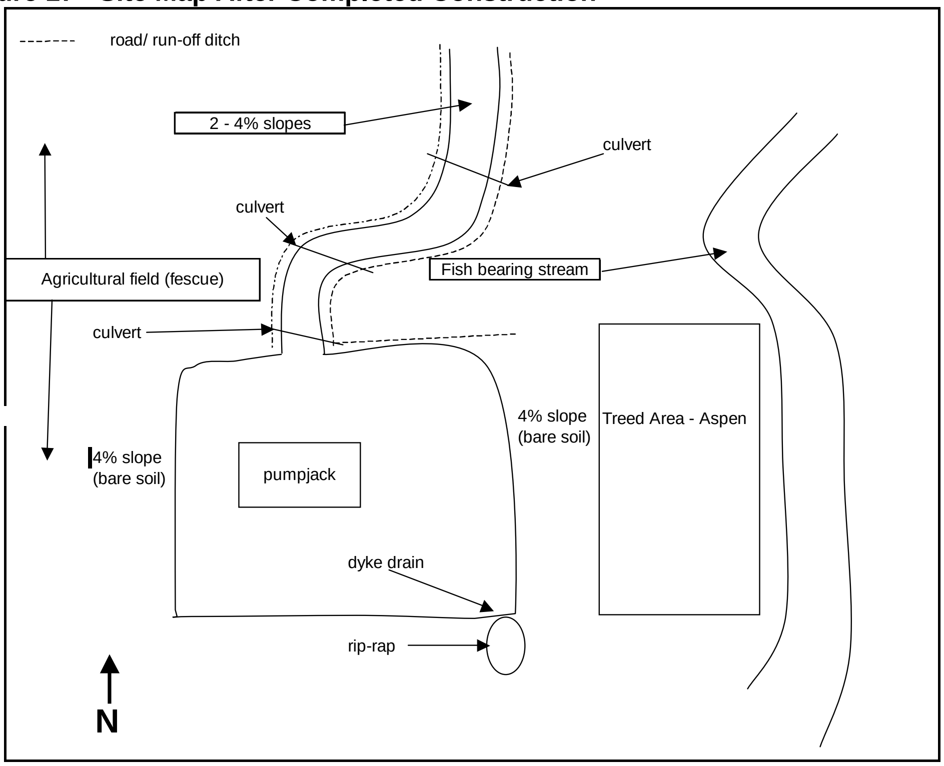
- The soil had a clayey silt texture (highly erodible)
- An 20 x 100 area of bare soil would be present on the east facing slopes above and below the wellsite following construction
- The lease road slopes would range from 2 – 4%.
- Ditches would be constructed on either side of the road
- There were two watercourses identified that would cross the proposed road surface

Initial Erosion and Sediment Control Plan

- Seeding of bare slopes and backsides of berm with pedigree fescue seed; following completion of seed analysis[1]
- Ditches constructed in a rounded v shape and seeded
- Small amount of angular rip-rap placed at outflow end of dyke drain
- Treed area covers 20m from the shoreline of the fish bearing stream to the bare soil, so should sufficiently capture escaping sediment.
- Appropriately sized culverts installed where watercourses intersect with road surface

[1] Any seed used should have a seed analysis completed to ensure it is free of weeds and non-native plant species. Pedigreed seed can still have some residual weed contamination. Landowners should be provided with the seed analysis prior to seeding.

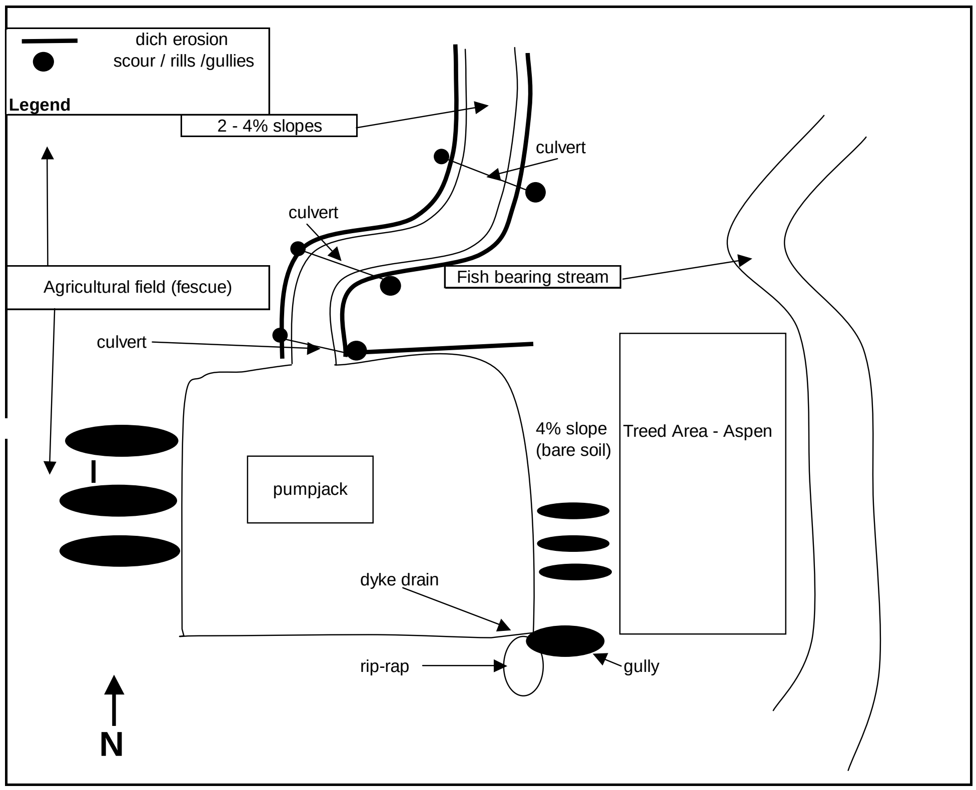
Figure 17 - Site Map After Completed Construction



Five months later, a 1-in-100 year rainfall event occurred……Six Month Inspection of Erosion Control Effectiveness

- Erosion occurred in ditches, most seed did not germinate successfully
- Water from agricultural fields caused large rills to form upslope of wellsite, some successful germination
- Large rills formed downslope of wellsite on east facing slope as well
- Gully formed at mouth of dyke drain, from the force of water flow from the rain event
- Scouring occurred on both ends of the road culvert

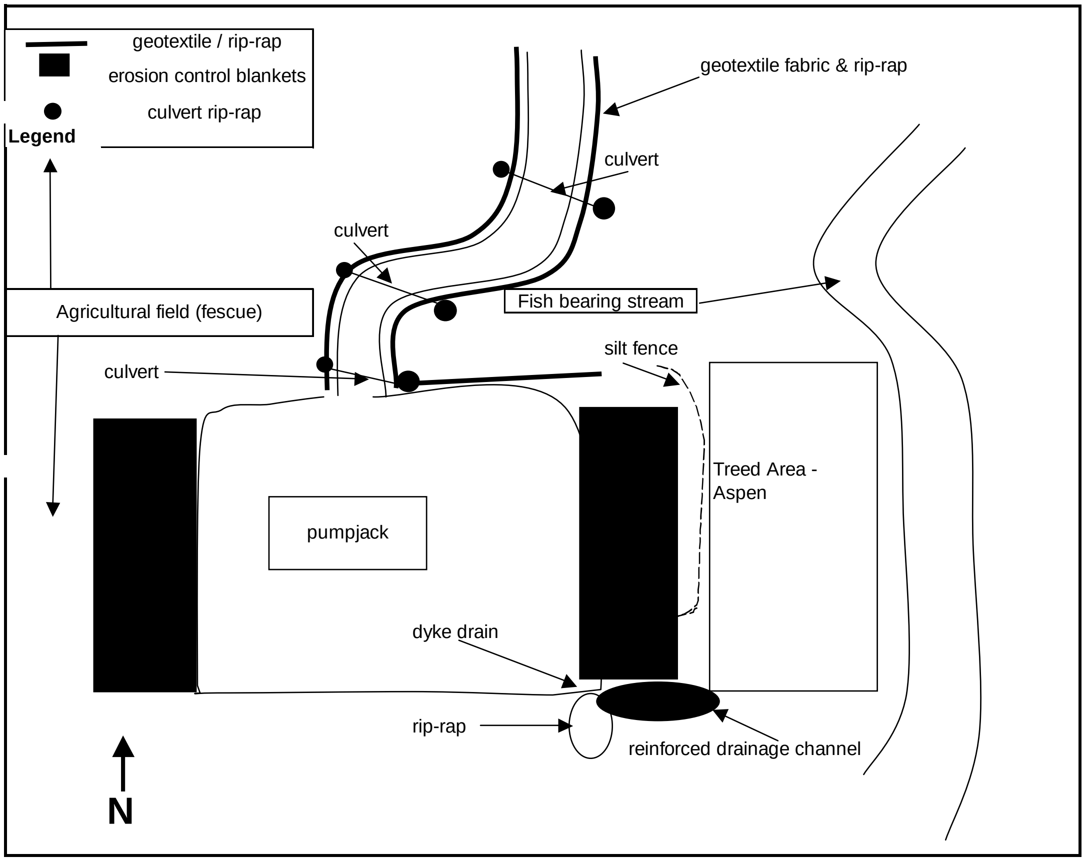
Figure 18 Site Map – After a 1-in-100 year rainfall event



Erosion and Sediment Control Mitigation Plan

- Regrade east facing slopes above and below wellsite
- Install erosion control blankets on east facing slopes, following reseeding with fescue.
- Use live willow stakes to hold erosion control blankets in place. Willow stakes should germinate and provide a strong root system to anchor soil along with the fescue.
- Reshape road ditches back to a rounded v-shape. Install geotextile fabric in ditches, and cover with appropriately sized rip-rap.
- Create a wide-shallow drainage channel from dyke drain outflow. Lay down geotextile fabric and appropriately sized rip-rap. Ensure reinforcements are made around the mouth of the culverts
- Silt fence installed in a j-shape at the base of the lower slope, to catch any residual sediment, and prevent further liability issues with fish-bearing stream
- Silt fence will be inspected monthly and after major rainfall events. Will potentially be removed when vegetation is properly established on the currently bare slopes

Figure 19 - Site Map - Erosion and Sediment Control Mitigation Plan



13. Acknowledgements

This project would not be possible without generous funding from the Oil and Gas Commission's Science and Community Environmental Knowledge (SCEK) fund and the Peace River Regional District. Funding and in-kind donations were also provided by the Ministry of Transportation, Mike and Pat Smith, Greywest Office Centre, Alpine Environmental, Falkenberg Agencies, Murray Chev-Olds, Smith Fuel Services (Husky), Hamilton Stationary, McElhanney, Urban Systems, Duke Energy, Meridian Environmental and Canadian Tire.

Cooperation of landowners and oil companies was also greatly appreciated. Charlie Lake Conservation Society would like to thank the many staff from the Oil and Gas Commission, Ministry of Environment, Ministry of Agriculture and Lands, Devon Energy, Samson Canada, Progress Energy, Terra Energy, Canadian Natural Resources Ltd and Advantage Oil and Gas who assisted with the completion of this project.

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Editing of final report was completed by Allan Blair, Edward Stanford and Bruce Kosugi.

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16. Endnotes

[1] Charlie Lake Conservation Society, Box 720, Charlie Lake, BC V0C 1H0, info@charlielakeconservationsociety.ca
[2] Appendix I – Primer on Erosion and Watershed Impacts
[3] Most information from French and Booth, 2004, unless otherwise referenced.
[4] See the 2005 report for assessment methods: Oil & Gas Well/ Facility Site Erosion Management (Year 1 Summary): A 2 Year Project of the Science, Community & Environmental Knowledge (SCEK) Fund. Submitted by the Charlie Lake Conservation Society to the BC Oil & Gas Commission. November, 2005.
[5] Erosion and Sediment Control Study Guide. Malaspina University College. Nanaimo, BC. July, 2006. www.mala.bc.ca
[6] ibid.
[7] Much of the information in this section has been summarized from the Participant's Manual provided by Malaspina University College for the Erosion & Sediment Control course, unless otherwise referenced.
[8] Image from the Soft Engineering & Conservation Buffers Initiative website. http://semircd.org
[9] Image from North American Green website. http://www.nagreen.com/installation/channels.html
[10] Diagrams from Lake Whatcom Management Program website. http://lakewhatcom.wsu.edu/display.asp?ID=104
[11] Diagrams from Lake Whatcom Management Program website. http://lakewhatcom.wsu.edu/display.asp?ID=104
[12] From the Minnesota Shoreland Management Resource Guide http://www.shorelandmanagement.org/downloads/erosion_control.pdf#search=%22installation%20of%20willow%20wattles%22
[13] Images from http://www.terraerosion.com/projects/work/road-deactivation/project2-giveout/deactivation-project2.htm