Agency: Commerce, Community and Economic Development

Grants to Municipalities (AS 37.05.315)

Grant Recipient: Yakutat **Federal Tax ID:** 92-6001319

Project Title: **Project Type:** Planning and Research

Yakutat - Renewable Energy Self Sufficiency Project

State Funding Requested: $1,200,000 **House District:** 5 / C

Future Funding May Be Requested

Brief Project Description:

CBY and other concerned local parties are engaged in an MOU to investigate biomass electrical generation plant for the near term energy needs and are researching wave energy technology for the long term and supplemental electrical generation.

Funding Plan:

Total Project Cost:	$17,200,000
Funding Already Secured:	($249,000)
FY2013 State Funding Request:	($1,200,000)
Project Deficit:	$15,751,000

Funding Details:

FY 2010 AEA Grant for planning $249,000

Detailed Project Description and Justification:

Project background:

Recognizing that a healthy, local cash economy is not sustainable while dependent on diesel fuel for power generation, the City and Borough of Yakutat joined with the Yak-tat Kwaan and the Yakutat Tlingit Tribe and agreed to work together to bring affordable alternative energy to the community. These three organizations are under the direction of an elected board which is representative of the complete political and economic demographic of the community. As a major land owner in the Borough and as a source of information on biofuels, the local United States Forest Service office has been made an important fourth partner in our community coalition.

As the owner of the local electrical utility, the City and Borough of Yakutat secured a $249,000 grant (with the help of the legislature and the AEA) to explore ways to utilize forest products as a fuel source to replace or subsidize diesel. Approximately fifty thousand dollars of grant funds have been directed toward a study of biofuel feasibility, including growing and delivering an energy crop for the electrical generation plant. We now have estimates of annual biofuel quantities necessary to produce the 1.5 to 2.0 megawatts of electricity the community requires as well as estimates of the delivered costs for the fuel. We also have estimates of the acreage necessary to maintain a five year crop rotation based on growth rates in the existing literature.

The Yak-Tat Kwaan Native Corporation has agreed to make approximately 5,700 acres available for biomass cultivation. While this is approximately forty percent more land than we estimate is necessary, excess product would be marketable as

Contact Name: Kaci Schroeder Hotch
Contact Number: 465-3732

For use by Co-chair Staff Only:

$1,200,000 Approved

4:17 PM 5/2/2012

a domestic heating fuel. The acreage is adjacent to other Kwaan and USDA land holdings assuring the availability of additional acreage for future expansion. Various types of willow, poplar, and alder are being considered as a fuel crop. Additionally, we are looking to utilize landfill materials as an additional fuel source. Second growth spruce is available for the initial five year fuel source in the form of thinning byproduct. A study is being planned to research what plant species would be fit the needs for this system.

A Technical Feasibility Study was submitted by private contractor WMB Enterprises on January 2, 2010. The total project cost for the design and construction of the 2.0 MW biomass power plant including the design, equipment, and building is estimated at $11 Million. The total biomass power production cost is estimated to be $0.12/kWh including fuel, fuel processing, labor, operation and maintenance. Assuming that the current diesel power production cost is $0.49 kWh, the simple payback is 3.43 years before incentives such as renewable energy credits or other federal and state tax credits. The final cost will depend upon the final system specifications and equipment selections.

We estimate an additional $2.5M in funding will be eventually be needed for carbon capture greenhouses, district heating, pellet production, biodiesel production, and cold/cool storage facilities associated with the biomass power plant. Crop production land preparation and machinery will cost approximately $2 million. Setting up experimental plots to identify species best suited to Yakutat growth conditions would cost $250K for 5 years. Total project cost is estimated at $15-16 Million.

We anticipate approximately 20 jobs would be created through this system, including power, energy crop, greenhouse, and other operations.

We anticipate the design work of the biomass electrical system with existing funding will be complete by July 2010. The remaining two hundred thousand dollars of state grant funds will be directed toward design of an ORC electrical generation plant that will interface with our existing diesel plant.

Wave energy: initial study was completed by industry consultants in November 2009.
Second stage will involve cooperative pilot project with AEA funding (hopefully through Emerging Technology Grant Fund) private foundation funding, and partnership with National Renewable Energy Lab and appropriate universities.

Barriers for this overall energy project include funding, engineering expertise, equipment design, and research of species for energy crop production. We are looking for funding sources through state and federal assistance in the form of grants or low cost loans. We have one engineer familiar with biomass production but additional biomass engineering expertise is needed. We have received assistance from Alan Brackley, Pacific Northwest Research Station and personnel from the National Renewable Energy Laboratory. Equipment design work is being provided from our engineer but additional design work will be needed as we initiate additional components for this project. Some NEPA work may be required for plant production, should Forest Service land be needed.

Summary:
There is a large economic benefit from locally produced fuel. Paramount to this is the idea that money spent on fuel will circulate in the local economy instead of 2 million dollars annually siphoning out to petroleum companies. Furthermore, the planting and harvest of fuel crops will create important, stable well-paying jobs, the cost of electricity will decrease, freeing up business income and increasing disposable incomes in modest and low income households. The model developed from this project could be used in other remote areas of Alaska and elsewhere.

Contact Name: Kaci Schroeder Hotch
Contact Number: 465-3732

For use by Co-chair Staff Only:

4:17 PM 5/2/2012

The ultimte benefit is community confidence. Energy independence will empower the local citizens. This, in turn, will foster efforts to initiate cluster industries related to the biomass plant including; greenhouses to produce local food, algae tanks to create biodiesel for existing generators and the fishing fleet and cold storage for affordable value-added marketing of seafood, Yakutat's primary export.

Yakutat is a small isolated community surrounded by one of the biggest protected ecosystems on the planet loosely combined in a UN World Heritage site, 24 million acres in size. It is an ideal place to create a model of self sufficiency and sustainability illustrating the very real possibility that a group of people can have profitable lives in a robust local economy while maintaining healthy surroundings.

Project Timeline:

Significant investigations into the feasibility of various renewable energy technologies have been accomplished over the past 5+years.
Analyses of wind, hydro, biomass and wave energy have been done or are in progress. Yakutat will continue to pursue any options that have potential to solve the local energy crisis.

Entity Responsible for the Ongoing Operation and Maintenance of this Project:

Yakutat Power, CBY-owned power utility

Grant Recipient Contact Information:

Name:	Frank L. Ryman
Title:	Borough Manager
Address:	Box 347
	Yakutat, Alaska 99689
Phone Number:	(907)784-3323
Email:	sryman@yakutatak.us

Has this project been through a public review process at the local level and is it a community priority? [X] Yes [ ] No

For use by Co-chair Staff Only:

4:17 PM 5/2/2012

Contact Name: Kaci Schroeder Hotch
Contact Number: 465-3732

Yakutat CIP List FY 13
Alternative Energy Project: Wave Energy Update

The City and Borough of Yakutat Assembly has consistently identified as its number one priority the need for a renewable and independent municipal electrical power generation source. Yakutat currently is 100% dependent on diesel fuel for power generation, leaving the community at the mercy of economic factors well beyond any local control. Current power costs are over $0.50/kWh, making energy heating and power costs prohibitively high for both homes and businesses, and inhibiting economic development. With oil prices liable to continue to increase, power costs will continue to be a major obstacle to economic growth and to the viability of the community as a whole. Residents are challenged to keep up with these rising costs for their home budgets, businesses are challenged to keep pace with competitors in other areas with lower costs, and the municipal government budget is faced with high energy costs.

A solution to the electrical generation problem in Yakutat has not been easy to identify. The CBY, in conjunction with the local Native Village Corporation Yak-tat Kwaan, and the Yakutat Tlingit Tribe, has undertaken several examinations of renewable power sources. Well-proven renewable technologies were first examined. A wind power study in 2007 found that Yakutat's wind energy profile is not suitable for current turbine technology. Local water sources and geography do not lend themselves to hydroelectric power projects. Therefore, alternative emerging technologies present the best chances of success in developing energy affordability and independence.

Biomass energy using local available land to grow an energy crop continues to be investigated and wave energy is a promising source that CBY is pursuing to meet the community priority. Wave power has shown considerable promise in test sites in North America and Europe. Yakutat is uniquely situated to be a participant in this field, while also seeking a viable renewable power source for local needs.

WAVE ENERGY CONVERSION

A wave energy conversion (WEC) project has been identified for the Yakutat area and proposed by Aquamarine Power, based in Scotland. The project has gone through the reconnaissance and feasibility study phases and received a recommendation from the AEA for full funding in the amount of $1.2 million for the final design and permitting phase during Round 3 of the REGF6 process.

The feasibility study funded by the City and Borough of Yakutat and conducted by the Electric Power Research Institute (EPRI) titled, "Yakutat Conceptual Design, Performance, Cost and Economic Wave Power Feasibility Study," dated November 30, 2009, indicated that the wave energy near Yakutat was ideal for WEC.

Given Yakutat's relatively low generation needs, it was decided that the project should utilize near-shore technology rather than deep-water technology. With the small-scale technology, the majority of the costs of the project are attributed to installation and operation of the subsea cable, as opposed to capital cost of the power generating equipment. The major project elements include: (1) the Aquamarine Oyster WEC device, (2) a high-pressure (120 bar) supply subsea pipeline and low pressure (3 bar) return subsea pipeline, (3) an onshore turbine generator power station, and (4) a distribution line extension to connect the power station to the city electrical grid network. The Aquamarine Oyster was chosen as the equipment to be used at the site. The Oyster is a wave-actuated hydraulic pump that pumps fresh water to shore at a pressure level of about 120 bars, where it is converted into electricity using a conventional hydroelectric system and then returns it to the Oyster in a closed loop. Figure 11-7, taken from the EPRI study illustrates the Oyster technology and proposed application at Yakutat. Figure 11-8, also taken from the EPRI study, illustrates an overhead view of the project site and project element.

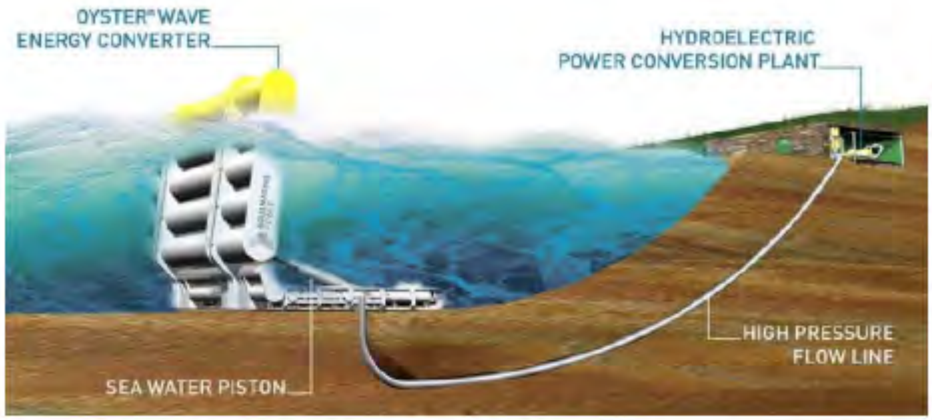


Figure 11-7 Oyster Wave Energy Converter Yakutat Application

Figure 11-8 Project Site Overhead View

Table 11-1 Yakutat Wave Energy Cost and Performance Characteristics

	1 UNIT		2 UNITS		4 UNITS		8 UNITS	
CAPITAL COST	**$**	**$/KW**	**$**	**$/KW**	**$**	**$/KW**	**$**	**$/KW**
Device Structure	$3,955,200	$5,071	$7,119,360	$4,564	$12,814,848	$4,108	$23,066,726	$3,697
Water Pipeline	$1,384,320	$1,775	$2,491,776	$1,598	$4,485,197	$1,438	$8,073,354	$1,294
Power House	$1,399,770	$1,794	$2,552,340	$1,636	$4,857,480	$1,557	$9,467,760	$1,517
Installation Cost	$2,417,616	$3,099	$3,386,640	$2,171	$4,866,132	$1,559	$7,153,350	$1,146
Total Cost	$9,156,906	$14,087	$15,550,116	$11,961	$27,023,657	$10,394	$47,761,191	$9,185
Annualized OpEx	$339,900	$523	$525,300	$404	$834,300	$321	$1,442,000	$277
Performance								
Rated Power	650	kW	1,300	kW	2,600	kW	5,200	kW
Capacity Factor	48%		48%		48%		48%	
Availability	95%		95%		95%		95%	
Annual Energy Output	2,596	MWh	5,193	MWh	10,386	MWh	20,772	MWh
Cost of Electricity (constant $)	46.5	cents/kWh	39.1	cents/kWh	33.3	cents/kWh	29.3	cents/kWh

Continuing with the momentum from the EPRI study, in 2011, the City and Borough of Yakutat applied to the AEA Emerging Energy Technology Grant Fund (EETGF) for a pilot project in conjunction with the Alaska Center for Energy and Power (University of Alaska) that would assist Yakutat in becoming a test site for wave energy technology development. The request is currently awaiting the development of regulations by AEA for this new grant fund. AEA staff and ACEP have been encouraging in the concept of this test site, which would help to put Alaska on the map in the global development of wave energy systems. Yakutat stands to gain from this effort by examining the feasibility of the numerous technologies being developed by domestic and foreign firms. The local geography, situated immediately next to a famous wave break in an open ocean environment, and including the close proximity of an airport with daily jet service and an existing small scale municipal power grid, makes Yakutat an attractive test site for wave energy technology. Additionally, the waters along the relatively protected shores of Yakutat Bay and Monti Bay also can be used to test systems that may be more applicable to waves of shorter period.

The City and Borough of Yakutat intends to continue pursuing the EETGF as a potential source of funds for initial WEC technology testing. However, due to the relatively small capitalization of this fund and the high number of applicants to the program, Yakutat continues to pursue private interest in WEC development. CBY personnel met in 2011 with Atmocean Inc, an American WEC developer. This firm expressed great interest in testing equipment in Yakutat, and is interested in pursuing a joint project with Yakutat, the University of Alaska, and the State. Another wave energy developer from Massachusetts will be travelling to Yakutat in March of 2012 to meet with local officials and Yakutat Power Company.

Soil Mapping of Yakutat Kwan Land

A cooperative project with the Yakutat Salmon Board
and the USDA Forest Service

September 2006

Technical contact: Jacqueline Foss, Sitka Ranger District

Table of Contents

Introduction and background

The purpose of this report is to provide soil information in support for rehabilitation efforts on the Yakutat Kwan Lands and to provide basic soil information for future gravel pit development. Survey efforts were focused on areas proposed for restoration efforts and the proposed expansion of the existing gravel pit. These areas are closely approximated by the proximal outwash south of the Redfield Moraine near Yakutat Bay (Shephard, 1995). The Survey was completed on portions of the Ophir, Tawah, Lost, Day Glow, Middle Situk and West Middle Situk Watersheds.

Previous mapping

The soils of the Yakutat forelands were previously mapped by the Forest Service. "Ecosystem mapping" was conducted in the 1960s and 1970s by Billings and others (1970). The mapping identified soils and associated ecosystems at a coarse scale. The mapping included lands that later became Yakutat Kwan lands. A later soil survey describing soils of the Yakutat Forelands remains unfinished. The later survey did not include lands currently owned by the Yakutat Kwan.

Yakutat soils

The Yakutat forelands soils are a mélange of glacial outwash gravels interspersed with water-laid sediments. The survey area focused on the proximal outwash plain on the west forelands. Most of the proximal outwash plain consists of coarse texture, cobbly glacial outwash. In some areas glaciolacustrine or glacial lake sediments consisting of silt and fine sand textured sediments overlie the coarse-textured soils. These finer-textured soils drain water more slowly than the common coarse textured soils covering much of the forelands. Most soils in the project area are managed for timber production. The fine textured soils are much more susceptible to soil compaction than the coarser-textured soils.

Methods

The sites proposed for watershed restoration consist of temporary roads on areas of fine textured soils or where the water table was interrupted by road construction. Sites for detailed soil investigation (backhoe pits) were selected based on their proximity to a road and proposed restoration site, and the likelihood of encountering a change is soil textures and drainage. The soils were described in each backhoe pit. Later, a transect with hand-dug holes at regular intervals near each pit was completed to determine the extent of the soils described.

Soil Series

Within the project area the soils can be grouped into three different soil series. (See maps, Appendix F) This section will describe the concept, technical criteria, interpretations, and practical limitations of each of the three soil series.

Yakutat Soil Series

Description

Yakutat soils are the most common glacial outwash soils on the forelands. They are deep, moderately well drained, coarse-textured soils. Generally, these soils are greater than 50% gravels throughout the profile. Drainage can sometimes reach excessively well drained. Since these soils have no bedrock contact, the water table location determines the drainage. The thin organic mat at the surface is the primary nutrient source for the vegetation.

These soils support mature Sitka Spruce forests, and are managed for timber production. They are also used as gravel sources. Yakutat soils have good bearing strength for ground based logging operations and road building.

Concept

Stable, well drained coarse textured soils formed in glacial outwash. Vegetation is generally highly productive forested sites.

Limitations

These soils are nutrient poor in the mineral soil layers. The primary nutrient source is the duff layer and upper horizon of the mineral soil. The soils can be subject to nutrient losses through leaching.

Classification

TAXONOMIC CLASS: Sandy-skeletal, mixed Oxyaquic Haplocryods

Setting

DEPTH CLASS: Very deep generally deeper than 150 cm

DRAINAGE CLASS: Moderately well

PERMEABILITY: Rapid

LANDFORMS: Proximal glacial outwash plains

LANDSCAPE POSITION: All areas?

PARENT MATERIAL: Glacial outwash

CLIMATIC DATA (AVERAGE ANNUAL):

Pedon Description

Oi—0 to 6 cm;

A—0 to 5 cm; very dark grayish brown (10YR3/2) loam; weak coarse granular structure; many fine and very fine roots; strongly acid (pH 5.5); clear wavy boundary.

Bh—5 to 13 cm; very dark brown (7.5YR2.5/3) very gravelly loamy coarse sand; single grained; 55 percent well rounded gravels; common fine and few medium roots; very strongly acid (pH 5.0); clear wavy boundary.

Bhs—13 to 27 cm; very dark brown (7.5YR2.5/2) extremely gravelly coarse sand; single grained; 10 percent well rounded cobbles and 52 percent well rounded gravels; few fine and very fine roots; strongly acid (pH 5.5); gradual wavy boundary.

Bs—27 to 43 cm; dark brown (10YR3/3) very gravelly coarse sand; single grained; 50 percent well rounded gravels; few fine roots; moderately acid (pH 6.0); clear wavy boundary.

C_1—43 to 54 cm; dark olive brown (2.5Y3/3) coarse sand; massive; 5 percent well rounded very fine gravels; very few very fine roots; few fine faint strong brown (7.5YR4/6) mottles; moderately acid (pH 6.0) clear wavy boundary.

C_2—54 to 138+ cm; dark olive brown (2.5Y3/3) extremely gravelly coarse sand; single grained; 70 percent well rounded gravels; moderately acid (pH 6.0).

Range in Characteristics

THICKNESS OF SOLUM: 43 to 73 cm
REACTION: Extremely acid to moderately acid

A HORIZON
Color = hues from 7.5YR to 10YR
Texture = loam and fine sandy loam
Rock Fragments = 0 to 30% gravels

E Horizon (when present)
Color = moist values of 4 or 5, moist chromas of 1 or 2
Rock fragments = 8 to 20 percent

Bh HORIZON (when present)
Color = hues of 7.5YR or 5YR, values moist of 2.5, chromas moist of 2 or 3
Textures = loam, loamy coarse sand
Rock fragments = 25 to 55 percent gravels

Bhs HORIZON
Color = hues of 5YR, 7.5YR, 2.5YR, moist values of 2 to 3, moist chromas of 2 or 4 few fine distinct mottles are sometimes present
Texture = coarse sand, loamy coarse sand, coarse sandy loam, sandy loam
Rock fragments = 5 to10 percent cobbles, 17 to 80 percent gravels

Bs HORIZON (when present)
Color = moist chromas of 2 or 3, few medium faint mottles are sometimes present
Texture = coarse sand or loamy coarse sand
Rock fragments = 0 to 10 percent cobbles, 50 to 65 percent gravels

BC HORIZON (when present)
Color = moist chromas 2 or 3, few fine faint or distinct mottles present
Rock fragments = 10 to 15 percent cobbles, 35 to 55 percent gravels

C HORIZON

Color = hues of 2.5Y or 10YR, moist values of 3 or 4, moist chromas of 2 or 3, few fine faint, many medium faint , or many coarse distinct mottles present
Texture = coarse sand, loamy coarse sand or coarse sandy loam
Rock fragments = 5 to 40 percent cobbles, 40 to 75 percent gravels

Ahrnklin Soil Series

Description

Ahrnklin soils are fine textured (silt or fine sandy loam) on the surface. Depth of fine material ranges from less than 10 cm to well over 100 cm. These soils were formed in stratified lacustrine or slow-moving alluvial deposits over the generally coarse glacial outwash.

Ahrnklin soils have been managed for their timber resources. Their productivity is not as high as the Yakutat soils due to the somewhat poorly drained conditions.

The bearing strength of the silty surface layers is not adequate for log trucks or ground based yarding equipment. Roads constructed on these soils should be constructed with rock overlay. Below grade roads are possible, but as the thickness of the silt layers increases the chance of intercepting the ground water table increases. If not fully excavated, fine textured material can plug the pores in the gravels creating a pond instead of a road.

Concept

Somewhat poorly drained, fine-textured soils over a gravelly substratum supporting moderately productive forest sites.

Limitations

The soils have low bearing strength in the fine textured surface layers. Ground-based yarding systems can compact or disturb the soil surface; roads constructed below grade can intercept the water table, creating surface streams or ponds and divert water from natural flow paths.

Classification

TAXONOMIC CLASS: Coarse-silty over sandy or sandy-skeletal, mixed, superactive Aquic Haplocryods

Setting

DEPTH CLASS: Very deep generally deeper than 150 cm

DRAINAGE CLASS: somewhat poorly

PERMEABILITY: moderate

LANDFORMS: Proximal glacial outwash plains

LANDSCAPE POSITION: old glacial lakes

PARENT MATERIAL: Glacial outwash

CLIMATIC DATA (AVERAGE ANNUAL):

Pedon Description

Oi—10 to 7 cm; partially decomposed forest litter; many roots; very strongly acid; abrupt smooth boundary.

Oe—7 to 0 cm; dark reddish brown (5YR 2/2) mixed finely divided organic matter and fine sandy loam; many roots; very strongly acid; abrupt smooth boundary.

E—0 to 2 cm; dark gray (10YR 4/1) fine sandy loam; weak fine subangular blocky structure; very friable; common roots; very strongly acid; abrupt smooth boundary.

Bs_1—2 to7 cm; dark reddish brown (5YR 3/2) fine sandy loam; weak subangular blocky structure; very friable; common roots; very strongly acid; abrupt wavy boundary.

Bs_2—7 to 15 cm; brown (10YR 4/3) silt loam; few patches of olive (5Y 5/3); weak subangular blocky structure; very friable; few roots; slightly acid; gradual boundary.

BC—15 to 30 cm; light olive brown (2.5Y 5/4) sandy loam with patches of olive (5Y 5/3); weak subangular blocky structure; few roots; slightly acid; gradual boundary.

C—30 to 76 cm; gray (5Y 5/1) silt loam, with roughly horizontal bands of yellowish brown (10YR 5/6); weak subangular blocky structure; no roots; slightly acid; abrupt wavy boundary.

2C—76 to 122 cm; olive gray (5Y 5/2) very gravelly coarse sand; single grain; 80 percent gravel and cobbles; no roots; slightly acid.

Range in Characteristics:

THICKNESS OF SOLUM: 30 to 89 cm Depth to the very gravelly substratum ranges from 12 to 35 inches.

A HORIZON
Sometimes present

E HORIZON
Color = moist chroma of 1 or 2
Texture = Silt loam to fine sandy loam

B Horizons
Color = moist hues of 2.5Y, 5YR, 10YR, moist values of 3 or 4, moist chromas of 2 or 3
Texture = fine sandy loam to silt loam. Thin lenses of coarse sandy loam are common.

BC HORIZON
Sometimes present

C HORIZONS
Color = moist hues of 5Y or 10YR, moist values of 3 to 5, moist chromas of 1 to 3
Textures = Silt loam to coarse sand
Rock Fragments = 0 to 65 percent gravels

Situk Soil Series

Description

Situk soils are found in abandoned outwash channels and floodplains on the forelands. They are very similar to Yakutat soils, except Situk soils have a lens of sandy loam over the outwash gravels.

Concept

Somewhat poorly drained, fine-textured soils found on moderately productive forest sites.

Limitations

These soils are nutrient poor in the mineral soil layers. The primary nutrient source is the duff layer and upper horizon of the mineral soil. The soils can be subject to nutrient losses through leaching.

Classification

TAXONOMIC CLASS: Sandy-skeletal, mixed Oxyaquic Dystrocyrepts

Setting

DEPTH CLASS: Very deep generally deeper than 150 cm

DRAINAGE CLASS: Moderately well

PERMEABILITY: Rapid

LANDFORMS: Proximal glacial outwash plains

LANDSCAPE POSITION: Alluvial terraces, stream terraces, flood plains

PARENT MATERIAL: Glacial outwash

CLIMATIC DATA (AVERAGE ANNUAL):

Pedon Description

Oi—0 to 1 cm; sticks and herbaceous material

Oe—1 to 5 cm; hemic

A—5 to 9 cm; very dark brown (10YR2/2) loam; weak fine granular over weak medium subangular blocky structure; few fine and common very fine roots; neutral (pH 6.8); abrupt wavy boundary.

Bw_1—9 to 12 cm; dark grayish brown (2.5Y4/2) fine sandy loam; weak medium subangular blocky structure; few fine and common very fine roots; neutral (pH 6.8); abrupt wavy boundary.

Bw_2—12 to 23 cm; gray (5Y5/1) silt loam; moderate medium subangular blocky structure; few fine and common very fine roots; common medium distinct mottles; neutral (pH 6.8); abrupt wavy boundary.

Bw_3—23 to 33 cm; very dark grayish brown (2.5Y3/2) coarse sand; weak fine subangular blocky structure; 2 percent fine gravels; very fine roots; neutral (pH 6.8); abrupt smooth boundary.

Bw_4—33 to 36 cm; dark grayish brown (2.5Y4/2) very fine sandy loam; moderate medium platy structure; few fine and common very fine roots; neutral (pH 6.8); abrupt broken boundary.

$2C_1$—36 to 50 cm; very dark grayish brown (2.5Y3/2) coarse sand; single grained; 50 percent gravels; few very fine roots; neutral (pH 6.8); abrupt smooth boundary.

$2C_2$—50 to 124 cm; very dark grayish brown (2.5Y3/2) coarse sand; single grained; 15 percent cobbles 60 percent gravels; neutral (pH 6.8).

Soil Map Units

Six different map units were described in the project area. The soil series described above, Yakutat, Ahrnklin and Situk, are three soil map units. The others are two undifferentiated groups, moraine soils and organic soils, and one mosaic of Ahrnklin and undifferentiated organic soils. A full description of the soil map units is in Appendix B

Map

The ecosystem mapping completed in the 1960s and 1970s was found to be quite accurate and few changes were required. All maps can be found in Appendix F.

Rehabilitation Methods

Soil or site rehabilitation is a long-term task, with a need for long-range planning and monitoring. The coarse and fine textured soils on the Proximal Outwash plain require different methods and approaches to rehabilitation. It is important to consider both the hydrologic function and the soil productivity of the sites.

Hydrologic function

The hydrologic function of the coarse-textured soils is easily rehabilitated. Pulling the berm from road construction back into the roadbed will be adequate.

Restoring the hydrologic function of the fine-textured soils is akin to rehabilitating a drained wetland. Prior to disturbance, these areas functioned as groundwater storage for adjacent streams. When roads were cut into these areas, the groundwater hydrology was interrupted and water was diverted from the streams and natural drainage paths. Returning the fine-textured material to the roadbed would help restore some of the hydrologic function. Over time, the filled roads will function more similar to their pre-managed state.

In both coarse and fine texture soil, it is important to rebuild stream crossings. Use geotextile, coir logs, or other fiber matting to rebuild the channel. When reconstructing crossings in fine-textured soils use fiber or vegetative filters to keep the silt from filling in the stream. Large woody debris, rock riprap and vegetation should all be used to rebuild the crossing. Refer to the Colorado Road EA for methods of stream crossing rehabilitation (USFS, 2006),

Soil productivity

The soil productivity on the proximal outwash is entirely held in the surface organics. Often this layer was disturbed during logging. The loss in productivity in these areas is reflected in the poor tree growth. Rehabilitating roads and other areas would leave a large area of bare mineral soil. Placing organics on the surface of rehabilitated areas will help with early plant growth and improve soil productivity in the long term. Replanting with native vegetation is also recommended.

Gravel Pit

The current gravel pit is more than twenty acres, located at the base of the terminal moraine, on glacial outwash along Forest Highway 10 (see maps, Appendix F #). The material is extremely cobbly and gravelly coarse sands. There are very few fines in the material and the water table is several meters deep—well below the current excavated grade. It is the ideal place for a gravel pit.

Future gravel pit development should take place in the areas where Yakutat soils are dominant and where the water table is sufficiently low. These areas lie north of FH 10, near the moraine. Creating gravel pits three to eight acres in size and oval or elliptical shapes would help them appear as kettle ponds a blend into the landscape. Gravel pits should not be placed near streams or in areas of Ahrnklin soils.

Conclusion and Future Needs

The soil map completed from this project is a refinement of the Billings (1970) report. More fine-textured soil was encountered on this survey than in Billings' 1970 survey. A thorough soil survey of the entire forelands should be completed at a future date in conjunction with USFS mapping efforts.

Rehabilitation efforts on the Yakutat Forelands are still new and experimental. Any site rehabilitation should be monitored for effectiveness, so as to improve future practices.

Appendix A: References

Billings R.F., T.M Collins, C.R. Gass. 1970. Soil management report for the Yakutat Forelands based on reconnaissance soil survey. USDA forest Service, Tongass National Forest.

Shephard, Michael E. 1995. Plant community ecology and classification of the Yakutat Foreland, Alaska. USDA Forest Service, Chatham Area, Tongass National Forest.

USDA Forest Service, Yakutat Ranger District. 2006. Watershed Rehabilitation on Upper Colorado Trail Environmental Assessment. R10-MB-588.

Appendix B Soil Map Unit Descriptions

MAP UNIT SYMBOL/ % SLOPE	SOIL TAXA (landscape position)	% COMPO- SITION	SAMPLE SOIL PEDON DESCRIPTION (cm)	SOIL DRAINAGE/ PERMEABILITY/ PARENT MATERIAL/ SOIL DEPTH	PLANT ASSOCIATION OR COMMUNITY
1 0-5%	**Yakutat** Sandy-skeletal, mixed Oxyaquic Haplocryods	90%	6-0 dark brown peat 0-5 very dark grayish brown loam 5-13 very dark brown very gravelly loamy coarse sand 13-27 very dark brown extremely gravelly coarse sand 27-43 dark brown very gravelly coarse sand 43-54 dark olive brown coarse sand 54-138+ dark olive brown extremely gravelly coarse sand	moderately well drained/ rapid/ glacial outwash/ very deep/ occasional, brief flooding	PICSIT/SERAL PICSIT/VACCIN PICSIT/VACCIN-ECHHOR
Inclusions: sandy skeletal, mixed Oxyaquic Haplocryods, fine phase					
2 0-5%	**Ahrnklin** Coarse-silty over sandy or sandy-skeletal, mixed, superactive Aquic Haplocryods	90%	2-0 dark brown peat 0-4 very dark grayish brown silt loam 4-8 dark grayish brown very fine sandy loam 8-11 dark brown loam 11-28 dark olive brown very fine sandy loam 28-41 very dark grayish brown very gravelly coarse sand 41-52 very dark grayish brown very gravelly coarse sand 52-56 brown coarse sand 56-106 very dark grayish brown extremely gravelly loamy coarse sand 106-116 brown coarse sand 116-226+ very dark grayish brown extremely gravelly coarse sand	somewhat poorly drained/ moderate/ glacial outwash/very deep/ occasional, brief flooding	PICSIT/SERAL PICSIT/VACCIN PICSIT/VACCIN-ECHHOR
Inclusions: sandy skeletal, mixed Oxyaquic Haplocryods,					
3 0-5%	**Situk** Sandy-skeletal, mixed Oxyaquic Dystrocryepts	90%	1-0 herbaceous material 0-4 dark brown peat 4-8 very dark brown loam 8-11 dark grayish brown fine sandy loam 11-22 gray silt loam 22-32 very dark grayish brown coarse sand 32-35 dark grayish brown very fine sandy loam 35-49 very dark grayish brown very gravelly coarse sand 49-123+ very dark grayish brown gravelly coarse sand	moderately well drained/ moderately rapid/ alluvium/ very deep/ occasional, brief flooding	PICSIT/SERAL PICSIT/VACCIN PICSIT/VACCIN-ECHHOR
Inclusions: sandy skeletal, mixed Oxyaquic Haplocryods, coarse phase					

MAP UNIT SYMBOL/ % SLOPE	SOIL TAXA (landscape position)	% COMPO-SITION	SAMPLE SOIL PEDON DESCRIPTION (cm)	SOIL DRAINAGE/ PERMEABILITY/ PARENT MATERIAL/ SOIL DEPTH	PLANT ASSOCIATION OR COMMUNITY
4 0-5%	**Ahrnklin** Coarse-silty over sandy or sandy-skeletal, mixed, superactive Aquic Haplocryods	50%	2-0 dark brown peat 0-4 very dark grayish brown silt loam 4-8 dark grayish brown very fine sandy loam 8-11 dark brown loam 11-28 dark olive brown very fine sandy loam 28-41 very dark grayish brown very gravelly coarse sand 41-52 very dark grayish brown very gravelly coarse sand 52-56 brown coarse sand 56-106 very dark grayish brown extremely gravelly loamy coarse sand 106-116 brown coarse sand 116-226+ very dark grayish brown extremely gravelly coarse sand	somewhat poorly drained/ moderate/ glacial outwash/very deep/ occasional, brief flooding	PICSIT/SERAL PICSIT/VACCIN PICSIT/VACCIN-ECHHOR
	Undifferentiated Organic Soils Cryohemists				

Inclusions: sandy skeletal, mixed Oxyaquic Haplocryods,

5	**Undifferentiated Organic Soils** Cryohemists				
6	**Undifferentiated Moraine Soils**				

Appendix C: Other Soils Documented

CLASSIFICATION

TAXONOMIC CLASS: Sandy-skeletal, mixed Oxyaquic Cryorthents

Setting

DEPTH CLASS: Very deep generally deeper than 150 cm

DRAINAGE CLASS: Moderately well

PERMEABILITY: Rapid

LANDFORMS: Proximal glacial outwash plains

LANDSCAPE POSITION:

PARENT MATERIAL: Glacial outwash

CLIMATIC DATA (AVERAGE ANNUAL):

Pedon description

Oi—6 to 0 cm; sticks and herbaceous material

Oe—0 to 2 cm; hemic

A—2 to 24 cm; very dark brown (10YR2/2) sandy loam; weak medium subangular blocky; 15 percent cobbles 32 percent gravels; few fine, medium and very fine roots; strongly acid (pH 5.5); clear wavy boundary.

Bw—24 to 44 cm; olive brown (2.5Y4/3) loamy coarse sand; single grained; 10 percent cobbles and 65 percent gravels; few fine roots; common medium distinct mottles; strongly acid (pH 5.5); clear wavy boundary.

C—44 to 120 cm; dark grayish brown (2.5Y4/3) coarse sand; single grained; 5 percent cobbles and 70 percent gravels; few fine roots; strongly acid.

Appendix D Field Notes and Photos

GPS points

1. Turn off to pit 2
2. Sand noted in road
3. Sand and Silt at an intersection. The rig got stuck
4. Site 2 pit (Card 3)
5. Site 2 pit: Large, open wetland nearby, created by/in intersection of the road. Plants: white bog orchid, carex ssp, swamp horsetail. (Card 3)
6. Extra pit, halfway up road to site 2, high spot with poor regeneration. (Card 4)
7. Turn off
8. Site 1. Silt present in pit (Card 1)
9. Extra pit, extent of the silt (Card 2)
10. Turn
11. turn
12. turn
13. turn
14. turn
15. turn
16. Pit 6. This was a moderately important pit that was dug because the others were too difficult to get to (poor road condition) (Card 6)
17. Pit 9 (Card 5)
18. Silt pit, dug in liu of others thanks to Bill and Mike's local knowledge (card 7)
19. Pit 8 (Card 9)
20. Pit to look for silt (Card 8)
21. additional pit in trees: 8" = O, 2" = A then silt/sands and gravels. Not more silt than in card 1
22. Extra pit. Same as card 3
23. Extra pit, similar to card 3 but the soil is finer…closer to Si
24. Extra pit. Thicker O and A horizons with 2 feet of CoS, sands and gravels were 3' below surface
25. Near card 5. Drainage is MW with a few distinct redox concentrations. Spruce regen is poor/low stocking = wider spacing and more grasses and fireweed.

3"	0	
1"	A	fSL
3"		LfS
2"		LS
2"		LfS or SiL
3"		LS

26. Extra pit in "stream" channel. This was dry. The soil is an entisol
    0-10" Histic and fSL A horizon
    10-14" gravelly parent material, fSL
27. Low spot: organics over gravels the 1 inch E horizon was fSL
28. Micro topographical high, the same as 27
29. Road? Old stream? What is this?? SiL mixed with gravels
30. Micro topographical high, organics over gravels spodosol. A Little bit of fSL in the E horizon in 1 foot of developed soil before grCoS.
31. wetland
32. wetland

33. wetland
34. wetland
35. In a drainage, down low by card 9. Will and ladyfern are dominant plants. Gravels are under 3 inches of organics, SL in the matrix
36. in a drainage, few organics over exgr/coSL very slightly siltier than 35
37. Slightly wetter than previous points (35 and 36) deeper organic horizons and a few lenses of fSL or SiL
38. No Silt, gravels are present at surface, could be an old stream channel
39. Silt: Channels do not have silt, so they cut through the silt and are exactly like the trench roads.
40. Noted multiple dissections "steps" down away from FH 10. soil has 6-8" CoS below organics, but above the outwash sands and gravels
41. Fine sands in road cut
42. Upward fining sequences of CoS-fSL-SiL. "Varving?" weak platy structure, close to 3 feet of fines, no coarse fragments present in top 3' of soils. Darren thinks this is lacustrine.
43. stream; 12" fSL over coarse fragments
44. 3-4" CoS over the gravels
45. Sands in the roadcut. SiL down, 3' silts with organics over the gravels (lakeshore sediments?)
46. Low spot, 14" fines over gravels (7" fSL over 7" LCoS)
47. Gravels
48. Gravels
49. Start
50. 1 foot total fines over gravels. 1 inch of SiL resting right on top of gravels, downward fining.
51. Thinner Si/S layer than 50
52. Off road, 13" fS over gravels. Lense of SiL between fS and gravels
53. End of road. 18" SiL to gravels
54. Deep sandy soil in the roadcut. Same as pt 45. Sands and fine sands 30" deep to gravels
55. 18" fS over gravels
56. 18" SiL-fSL over gravels
57. 6-10" SiL over gravels
58. End of road
59. 8" SL over gravels
60. 8-10" SL over gravels
61. Did they have to cut the road deeper here? 15" SiL
62. End of road
63. end of road
64. 18" LfS over gravels, Spodic development
65. "Remnant beach" like others (45, 54) CoS indicates low dune or beach, fining upward sequences that vary from fine gravels to medium sands.
    0-10" fSL
    10-24" medium sands
    24"-48" grCOS
66. Photos 42-44
    0-12" SiL
    8-20" LFS SWPD
    20+ Gravels
67. adjacent to stream 3-4 feet upward fining sequences CoS to SiL
68.
    0-4" CoSL
    4-6 SiL

6-10 LS
10+ gravels

69. 1” SiL between sandy layers
70. “Meadow” 6” SiL over grCoS Calimigrosis wetland
71. Highly variable texture, medium sands to SiL to a depth of 4 feet
72. “Stream” crossing. Crossing from foad, deep 4-6 feet of fine material (sands and silts) over gravels. Road is acting like a stream and moving water down from pts 71 to 72
73. More of the CoS beach deposit

Card 1

Card 2.

Card 3.

Card 4:

Card 5:

Card 6

Card 7:

Card 8

Card 9

Appendix E: Soil Data Cards

USDA FOREST SERVICE - TONGASS NATIONAL FOREST - CHATHAM AREA - ALASKA

SOIL PROFILE AND ENVIROMENT DESCRIPTION

1. MAPPING UNIT	WATERSHED NO.	CARD NO. 1	DATE 7/17/06	BY JF, DBS	AIR PHOTO NO.	SITE NO.
2. CLASSIFICATION Sandy-Skeletal, Mixed Oxyaquic Dystrocrept				LOCATION SE1/4 Sec 33 T27S R34E CRM		USGS QUAD C-5
3. PARENT MATERIAL Outwash	BEDROCK N/A	DEPTH TO/TYPE OF IMPERMEABLE LAYER cm N/A	FRACTURING / WEATHERING			
4. LANDFORM Proximal outwash Plain	SLOPE % 1	ASPECT	ELEVATION 56'	SAMPLED / PHOTOGRAPHS		
5. O HORIZON DEPTH 5CM	ROOTING DEPTH 50 CM	SOIL TEMPERATURE	DRAINAGE CLASS MW	ASSOCIATED DATA CARDS (INITIALS / SITE) mu / wv / /		

6. HORIZON	DEPTH (cm)	1 / COLOR MATRIX	1 / COLOR Redox ~~MOTTLING~~	TEXTURE %clay %sand	STRUCTURE	CONSISTENCE	COARSE FRAGMENTS % vol.	ROOTS	ph	BOUNDARY	% Clay	Sand
Oi	0-1			Sticks & herbaceous								
Oe	1-5			hemic								
A	5-9	10YR 2/2	None	loam	1-M-sbk 1-f-gr	friable	0	1-F 2-vf	6.8	AW	8%	45
Bw1	9-12	2.5Y 4/2	None	fsL	1-M-sbk	friable	0	1-f 1-vf	6.8	AW		65
Bw2	12-23	5Y 5/1	C-2-D 7.5YR 4/6	sil	2-M-sbk	friable	0	1-f 1-vf	6.8	AW		30
Bw3	23-33	2.5Y 3/2	None	COS	1-F-sbk	v friable	2% fine gravel	1-f 1-vf	6.8	AS		94
Bw4	33-36	2.5Y 4/2	None	vfsl	2-M-PL	friable	0	1-f 2-vf	6.6	AB		55
2C1	36-50	2.5Y 3/2	None	vgrCS	0-SG	Loose	50% gr	1-vf	6.6	AS		50
2C2	50-124+	2.5Y 3/2	None	exgr CS	0-SG	Loose	15% Co 60% gr	0	6.6			24
	- - -											

1 / ALL COLORS GIVEN FOR MOIST CONDITIONS UNLESS OTHERWISE INDICATED

☆ GPO 1982-594-602

7 HORIZON	DEPTH (cm)	COLOR			FIBER CONTENT		BOTANICAL ORIGIN OF FIBER	SODIUM PYROPHOSPHATE	BOUNDARY	MINERAL CONTENT (%)	pH	
		BROKEN	RUBBED	PRESSED	UNRUBBED	RUBBED						

	---											

8. EPIPEDON
Ochric

DIAGNOSTIC HORIZON(S)
Cambic

CONTROL SECTION AND PARTICLE SIZE
25-100 cm Sandy-Skeletal

9. FIELD CLASSIFICATION Sandy-Skeletal, mixed, Oxyaquic Dystrocryept

10. ~~HOW DID THIS SOIL DIFFER FROM MODAL~~

N 59.52813°, W 139.64393 WGS 84

N 59° 31′ 42.7″ W 139° 38′ 48.8″ NAD 24

11. ASSOCIATED COMMUNITY TYPE

Old clear cut adjacent to landing

NOTES

Water table @ 119 cm

BwZ - BPF+RPO, SLF; P; few

Salix
fireweed
Ribes
Salmonberry
Rosey twisted Stalk
Vacc- alaska
Lady fern
foam flower

five leaf bramble
Oak fern
viola

USDA FOREST SERVICE - TONGASS NATIONAL FOREST - CHATHAM AREA - ALASKA

SOIL PROFILE AND ENVIROMENT DESCRIPTION

1. MAPPING UNIT	WATERSHED NO.	CARD NO. 2	DATE 7/17/06	BY J F, DRS	AIR PHOTO NO.	SITE NO.
2. CLASSIFICATION Sandy-Skeletal, mixed Oxyaquic Haplocryod				LOCATION S1/2 Sec 33 T27S R34E CRM.		USGS QUAD C-5
3. PARENT MATERIAL Glacial Outwash	BEDROCK		DEPTH TO/TYPE OF IMPERMEABLE LAYER cm		FRACTURING / WEATHERING	
4. LANDFORM Proximal Outwash Plain			SLOPE % 1	ASPECT	ELEVATION	SAMPLED / PHOTOGRAPHS
5. O HORIZON DEPTH 6cm	ROOTING DEPTH 54cm	SOIL TEMPERATURE	DRAINAGE CLASS Well	ASSOCIATED DATA CARDS (INITIALS / SITE) mu / wv / /		

6. HORIZON	DEPTH (cm)	1 / COLOR MATRIX	1 / COLOR Redox ~~MOTTLING~~	TEXTURE %clay %sand	STRUCTURE	CONSISTENCE	COARSE FRAGMENTS % vol.	ROOTS	ph	BOUNDARY	% clay	% Sand
Oi	6-0											
OA	0-5	10YR 3/2	None	loam	1-Co-GR	friable	0	3-F 3-vf	5.5	CW	8	45
Bh	5-13	7.5YR 2.5/3	None	GRV LCS	0-SG	loose	55% gr WR	2-F 1-M	5.0	CW		80
Bhs	13-27	7.5YR 2.5/2	None	GRX COS	0-SG	loose	10% Co 52% gr	1-F 1-vf	5.5	GW		95
Bs	27-43	10YR 3/3	None	GRV COS	0-SG	loose	50% gr WR	1-F	6.0	CW		95
C1	43-54	2.5Y 3/3	1-F-F 7.5YR 4/6	COS	Mass	v. friable	5% fgr WR	v few fine	6.0	CW		97
C2	54-138+	2.5Y 3/3	None	GRX COS	0-SG	loose	70% gr WR	None	6.0			98

	---											

1 / ALL COLORS GIVEN FOR MOIST CONDITIONS UNLESS OTHERWISE INDICATED

☆ GPO 1982-594-602

7 HORIZON	DEPTH (cm)	COLOR			FIBER CONTENT		BOTANICAL ORIGIN OF FIBER	SODIUM PYROPHOSPHATE	BOUND-ARY	MINERAL CONTENT (%)	pH	
		BROKEN	RUBBED	PRESSED	UNRUBBED	RUBBED						

	---											

8. EPIPEDON
Ochric

DIAGNOSTIC HORIZON(S)
Spodic

CONTROL SECTION AND PARTICLE SIZE
25-100 cm Sandy- skeletal

9. FIELD CLASSIFICATION

10. HOW DID THIS SOIL DIFFER FROM MODAL
N 59.53378 W 139.62818 WGS 84

N 59° 31' 57.3" W-139° 39' 1.5" NAD27

11. ASSOCIATED COMMUNITY TYPE Old Clear cut Spruce Upto 20' high, discontinuous stocking

NOTES

Fireweed
Bunchberry
Salmon berry
Oak fern
Devils Club
foam flower
alas blueberry

ribes
Lady fern
grasses
false helborne

USDA FOREST SERVICE - TONGASS NATIONAL FOREST - CHATHAM AREA - ALASKA

SOIL PROFILE AND ENVIROMENT DESCRIPTION

1. MAPPING UNIT | WATERSHED NO. | CARD NO. 3 | DATE 7/17/06 | BY JF, DRS | AIR PHOTO NO. | SITE NO.

2. CLASSIFICATION Sandy-Skeletal, mixed Oxyaquic Cryorthent | LOCATION NW1/4 S.35 T27S R34E CRM | USGS QUAD C5

3. PARENT MATERIAL Glacial Outwash | BEDROCK N/A | DEPTH TO/TYPE OF IMPERMEABLE LAYER cm | FRACTURING / WEATHERING

4. LANDFORM Proximal Outwash Plain | SLOPE % 1 | ASPECT | ELEVATION | SAMPLED / PHOTOGRAPHS

5. O HORIZON DEPTH 8 CM | ROOTING DEPTH 120 CM | SOIL TEMPERATURE | DRAINAGE CLASS MW | ASSOCIATED DATA CARDS (INITIALS / SITE) mu / wv / /

6. HORIZON	DEPTH (cm)	1 / COLOR MATRIX	~~MOTTLING~~ Redox	TEXTURE %clay %sand	STRUCTURE	CONSISTENCE	COARSE FRAGMENTS % vol.	ROOTS	ph	BOUND-ARY		% S
Oi	6 - 0											
Oe	0 - 2			hemic								
A	2 - 24	10YR 2/2	None	GRV SL	1-M-sbk	~~f~~riable	32 gr 15 co WR	1-F, 1-M 1-vf	5.5	CW		
Bw	24 - 44	2.5Y 4/3	C-2-D 5YR 3/4	GRX LCOS	0-SG	loose	10% Co 65% gr	1-f	5.5	CW		86
C	44 - 120	2.5Y 4/2	None	GRX COS	0-SG	loose	5 co WR 70 gr	1-f	5.5			

	---											

1 / ALL COLORS GIVEN FOR MOIST CONDITIONS UNLESS OTHERWISE INDICATED

7 HORIZON	DEPTH (cm)	COLOR			FIBER CONTENT		BOTANICAL ORIGIN OF FIBER	SODIUM PYROPHOSPHATE	BOUND-ARY	MINERAL CONTENT (%)	pH	
		BROKEN	RUBBED	PRESSED	UNRUBBED	RUBBED						

	---											

8. EPIPEDON	DIAGNOSTIC HORIZON(S)	CONTROL SECTION AND PARTICLE SIZE
UMBRIC	None	25-100 cm Sandy-Skeletal

9. FIELD CLASSIFICATION

~~10. HOW DID THIS SOIL DIFFER FROM MODAL~~

N 59.54536 W 139.61691 WGS 84

N 59° 32' 2.9" W -139° 37' 5.6" NAD27

11. ASSOCIATED COMMUNITY TYPE

NOTES Water table @ 119cm

Oak fern willow
Lady fern alder
Salmon berry five leaf bramble
foam flower bane berry
horse tail
Bunch berry

USDA FOREST SERVICE - TONGASS NATIONAL FOREST - CHATHAM AREA - ALASKA

SOIL PROFILE AND ENVIROMENT DESCRIPTION

1. MAPPING UNIT	WATERSHED NO.	CARD NO.	DATE	BY	AIR PHOTO NO.	SITE NO.
		4	7/17/06	JF, DRS		

2. CLASSIFICATION: Sandy-Skeletal, mixed, Oxyaquic Haplocryod
LOCATION: W 1/2 S. 26 T27S R34E C.R.M.
USGS QUAD: C-5

3. PARENT MATERIAL: glacial outwash
BEDROCK: N/A
DEPTH TO/TYPE OF IMPERMEABLE LAYER cm: N/A
FRACTURING / WEATHERING:

4. LANDFORM: Proximal outwash plain
SLOPE %: 1-2
ASPECT:
ELEVATION:
SAMPLED / PHOTOGRAPHS:

5. O HORIZON DEPTH: 2cm
ROOTING DEPTH: 36cm
SOIL TEMPERATURE:
DRAINAGE CLASS: Well
ASSOCIATED DATA CARDS (INITIALS / SITE): mu / wv / /

6. HORIZON	DEPTH (cm)	1 / COLOR MATRIX	~~MOTTLING~~ Redox	TEXTURE %clay %sand	STRUCTURE	CONSISTENCE	COARSE FRAGMENTS % vol.	ROOTS	ph	BOUNDARY	% C	% Sand
Oi	2 - 0											
A	0 - 6	10YR 3/2	None	loam	1-fsbk	friable	None	3-F,vf 2-M		CW	9	40
Bhs1	6 - 21	5YR 2.5/2	None	gr SL	1-fsbk	v friable	20% gr WR	2-vf		GW	11	
Bhs2	21 - 36	5YR 3/2	None	GRV LCOS	0-SG	Loose	45% gr WR 5 Co	1-vf		CW		
BC	36 - 52	2.5Y 3/3	F-1-F 5YR 4/6	GRX COS	0-SG	loose	52% gr WR 10% Co	None		CW		
C	52 - 120	2.5Y 3/3	None	GRX COS	0-SG	loose	60 gr WR 10 co	None				
	- - -											
	- - -											
	- - -											
	- - -											

1 / ALL COLORS GIVEN FOR MOIST CONDITIONS UNLESS OTHERWISE INDICATED

☆ GPO 1982-594-602

7 HORIZON	DEPTH (cm)	COLOR			FIBER CONTENT		BOTANICAL ORIGIN OF FIBER	SODIUM PYROPHOSPHATE	BOUND-ARY	MINERAL CONTENT (%)	pH	
		BROKEN	RUBBED	PRESSED	UNRUBBED	RUBBED						

	---											

8. EPIPEDON
Ochric

DIAGNOSTIC HORIZON(S)
Spodic

CONTROL SECTION AND PARTICLE SIZE
25-100cm Sandy-skeletal

9. FIELD CLASSIFICATION

10. HOW DID THIS SOIL DIFFER FROM MODAL

N 59° 32' 44.7" W -139° 36' 50.8" NAD 27

11. ASSOCIATED COMMUNITY TYPE
Clearcut 15' regeneration

NOTES

Lady fern — blue berry
Fireweed — devils club
salmon berry — fern leaf goldthread
bunch berry — twisted stalk
oak fern — viola
foam flower — alder
Salix

USDA FOREST SERVICE - TONGASS NATIONAL FOREST - CHATHAM AREA - ALASKA

SOIL PROFILE AND ENVIROMENT DESCRIPTION

1. MAPPING UNIT	WATERSHED NO.	CARD NO. 5	DATE 7/18/06	BY JVF, DES	AIR PHOTO NO.	SITE NO.
2. CLASSIFICATION Sandy-Skeletal, mixed Oxyaquic Haplocryod				LOCATION S½ S12 T27S R34E CRM		USGS QUAD G5
3. PARENT MATERIAL Glacial Outwash	BEDROCK N/A		DEPTH TO/TYPE OF IMPERMEABLE LAYER cm	FRACTURING / WEATHERING		
4. LANDFORM Proximal Outwash Plain			SLOPE % 1	ASPECT	ELEVATION	SAMPLED / PHOTOGRAPHS
5. O HORIZON DEPTH 3cm	ROOTING DEPTH 112cm	SOIL TEMPERATURE	DRAINAGE CLASS Well	ASSOCIATED DATA CARDS (INITIALS / SITE) mu / wv / /		

6. HORIZON	DEPTH (cm)	1 / COLOR MATRIX	1 / COLOR ~~MOTTLING~~ Redox	TEXTURE %clay %sand	STRUCTURE	CONSISTENCE	COARSE FRAGMENTS % vol.	ROOTS	ph	BOUNDARY	% C	% S
Oi	3-0									AW		
A	0-3	10YR 3/2	None	fsl	1-M-GR	Friable	5% gr	3,f,vf 2,m	5.0	AW	10	65
E	3-8	2.5Y 5/2	None	grfsl	1-F-sbk	Friable	20% gr	3,f, 3vf 1,m	4.5	AW	10	65
Bhs1	8-13	2.5YR 2.5/2	None	GRX COSL	1-M-GR	Friable	65% gr	3vf, 2f	4.0	CW	7	70
Bhs2	13-26	5YR 2.5/2	None	GRX LCOS	1-f-sbk	v friable	80% gr	2vf, 2f,	4.5	CI	2	80
Bs	26-60	10YR 3/2	2-M-F 5YR 4/6	GRX COS	0-SG	Loose	55% gr 10% Co	2vf		CW		90
C	60-112	2.5Y 3/2	1-M-F 5YR 4/6	GRX LCOS	0-SG	loose	75% gr 5% Co	1vf				

	---											

1 / ALL COLORS GIVEN FOR MOIST CONDITIONS UNLESS OTHERWISE INDICATED

☆ GPO 1982-594-602

7 HORIZON	DEPTH (cm)	COLOR			FIBER CONTENT		BOTANICAL ORIGIN OF FIBER	SODIUM PYROPHOSPHATE	BOUNDARY	MINERAL CONTENT (%)	pH	
		BROKEN	RUBBED	PRESSED	UNRUBBED	RUBBED						

	---											

8. EPIPEDON
Ochric

DIAGNOSTIC HORIZON(S)
Spodic

CONTROL SECTION AND PARTICLE SIZE
25-100 cM sandy- skeletal

9. FIELD CLASSIFICATION

10. HOW DID THIS SOIL DIFFER FROM MODAL

N 59° 34′ 12.8″ W --139° 36′ 13.6″ NAD27

11. ASSOCIATED COMMUNITY TYPE
Clear cut, regeneration 12ft spruce

NOTES
No water table within 112 cm

Bunch berry
blueberry foam flower
fireweed devils club
salmon berry five leaf bramble
wood fern Lady fern
Oak fern twisted stalk

USDA FOREST SERVICE - TONGASS NATIONAL FOREST - CHATHAM AREA - ALASKA

SOIL PROFILE AND ENVIROMENT DESCRIPTION

1. MAPPING UNIT	WATERSHED NO.	CARD NO. 6	DATE 7/18/06	BY JVF, DRS	AIR PHOTO NO.	SITE NO.

2. CLASSIFICATION: Sandy-Skeletal, Mixed Oxyaquic Haplocryod
LOCATION: NE 1/4 Sec 23 T27S R34E CRM
USGS QUAD: C5

3. PARENT MATERIAL: Glacial Outwash
BEDROCK:
DEPTH TO/TYPE OF IMPERMEABLE LAYER: cm
FRACTURING / WEATHERING:

4. LANDFORM: Proximal Outwash Plain
SLOPE %: 1
ASPECT:
ELEVATION:
SAMPLED / PHOTOGRAPHS:

5. O HORIZON DEPTH: 6 cm
ROOTING DEPTH: 132 cm
SOIL TEMPERATURE:
DRAINAGE CLASS: MW
ASSOCIATED DATA CARDS (INITIALS / SITE): mu / wv / /

6. HORIZON	DEPTH (cm)	1 / COLOR MATRIX	1 / COLOR ~~MOTTLING~~ Redox	TEXTURE %clay %sand	STRUCTURE	CONSISTENCE	COARSE FRAGMENTS % vol.	ROOTS	ph	BOUNDARY	% Clay
Oi	6 - 0										
A	0 - 10	10YR 3/2	None	loam	1-M-GR	friable	10% gr	3f, 3m, 2C	5.0	CW	11
Bhs	10 - 38	7.5YR 2/2	5YR 4/6 F-1-D	loam	2-M-sbk	friable	17% gr	3f, 3m, 1C, 3vf	4.5	CW	10
Bs	38 - 50	7.5YR 2.5/3	↓	GRV LCOS	1-F, GR	friable	45% gr	3vf, 2f,	5.0	CW	
BC	50 - 73	2.5Y 3/2	5YR 4/6 F-1-D	GRV COS	0-SG	loose	15% Co 35% gr	2vf	5.0	CW	
C	73 - 132	2.5Y 4/2	5YR 4/6 F-1-F	GRX COS	0-SG	loose	15 Co 50 gr	2vf			
	- - -										
	- - -										
	- - -										
	- - -										

1 / ALL COLORS GIVEN FOR MOIST CONDITIONS UNLESS OTHERWISE INDICATED

☆ GPO 1982-594-602

7

HORIZON	DEPTH (cm)	COLOR			FIBER CONTENT		BOTANICAL ORIGIN OF FIBER	SODIUM PYROPHOSPHATE	BOUNDARY	MINERAL CONTENT (%)	pH	
		BROKEN	RUBBED	PRESSED	UNRUBBED	RUBBED						

	---											

8. EPIPEDON
Ochric

DIAGNOSTIC HORIZON(S)
Spodic

CONTROL SECTION AND PARTICLE SIZE
25-100 cm Sandy-skeletal

9. FIELD CLASSIFICATION

10. HOW DID THIS SOIL DIFFER FROM MODAL

N 59° 34' 5.1" W -139° 35' 47.3" NAD27

11. ASSOCIATED COMMUNITY TYPE
Clear cut 20' high spruce

NOTES
No Water table within 132 cm

Salmon berry
fireweed devils club
bunch berry oak fern
viola grasses
five leaf bramble foam flower
blue berry
Lady fern

USDA FOREST SERVICE - TONGASS NATIONAL FOREST - CHATHAM AREA - ALASKA

SOIL PROFILE AND ENVIROMENT DESCRIPTION

1. MAPPING UNIT	WATERSHED NO.	CARD NO. 7	DATE 7/18/06	BY JVF, DRS	AIR PHOTO NO.	SITE NO.
2. CLASSIFICATION Sandy-skeletal, Mixed Oxyaquic Haplocryod				LOCATION SE 1/4 sec 13 T27S R34E CRM		USGS QUAD C5
3. PARENT MATERIAL Glacial Outwash		BEDROCK N/A	DEPTH TO/TYPE OF IMPERMEABLE LAYER cm		FRACTURING / WEATHERING	
4. LANDFORM Proximal outwash Plain				SLOPE % 1	ASPECT	ELEVATION	SAMPLED / PHOTOGRAPHS
5. O HORIZON DEPTH 2 CM	ROOTING DEPTH 106 cm	SOIL TEMPERATURE	DRAINAGE CLASS MW	ASSOCIATED DATA CARDS (INITIALS / SITE) mu / wv / /		

6. HORIZON	DEPTH (cm)	1 / COLOR MATRIX	~~MOTTLING~~ Redox	TEXTURE %clay %sand	STRUCTURE	CONSISTENCE	COARSE FRAGMENTS % vol.	ROOTS	ph	BOUNDARY	% Clay	
Oi	2 - 0											
A	0 - 4	10YR 3/2	None	sil	1-f-GR	Friable	None	3vf, 3f 2m	5.0	AW		
E	4 - 8	10YR 4/2	None	vfsl	1-M-sbk	Friable	None	1f		AW		
Bhs	8 - 11	10YR 3/3	None	loam	2-M-sbk	Friable	None	2 f, 1C	4.5	CB	10	
Bw	11 - 28	2.5Y 3/3	C-2-D 5YR 3/4 root channels	vfsl	Massive	Friable	None	1f, 1vf		AW		
2Bs	28 - 41	10YR 3/2	C-2-D 7.5YR 4/6	grv COS	0-SG	Loose	50% gr	1vf	5.0	CW		
2C1	41 - 52	10YR 3/2	7.5YR 3/4	grv COS	0-SG	Loose	45% gr	1vf		AW		
2C2	52 - 56	10YR 4/3	None	COS	0 SG	Loose	0 gr	None	6.0	AW		
2C3	56 - 106	10YR 3/2	F-2-D 5YR 3/4	grx LCOS	0-SG	Loose	65	1vf		AW		
2C4	106 - 116	10YR 4/3	None	COS	0-SG	Loose	0 gr	None		AW		
2C5	116 - 226	10YR 3/2	None	grx LCOS	0-SG	loose	65	None				

1 / ALL COLORS GIVEN FOR MOIST CONDITIONS UNLESS OTHERWISE INDICATED

☆ GPO 1982-594-602

7 HORIZON	DEPTH (cm)	COLOR			FIBER CONTENT		BOTANICAL ORIGIN OF FIBER	SODIUM PYROPHOSPHATE	BOUND-ARY	MINERAL CONTENT (%)	pH	
		BROKEN	RUBBED	PRESSED	UNRUBBED	RUBBED						

	---											

8. EPIPEDON
Ochric

DIAGNOSTIC HORIZON(S)
Spodic

CONTROL SECTION AND PARTICLE SIZE
25-100 cM sandy-skeletal

9. FIELD CLASSIFICATION

10. HOW DID THIS SOIL DIFFER FROM MODAL

N 59° 34' 17.0" W 139 34' 58.1" NAD27

11. ASSOCIATED COMMUNITY TYPE
Clearcut

NOTES

Lady fern	blue berry
salmon berry	foam flower
fireweed	grasses
devils club	five leaf bramble
Oak fern	viola
horsetail	sedges

USDA FOREST SERVICE - TONGASS NATIONAL FOREST - CHATHAM AREA - ALASKA

SOIL PROFILE AND ENVIROMENT DESCRIPTION

1. MAPPING UNIT	WATERSHED NO.	CARD NO. 8	DATE 7/18/06	BY JVF, DRS	AIR PHOTO NO.	SITE NO.
2. CLASSIFICATION Sandy-Skeletal, Mixed Typic Haplocryod				LOCATION SW 1/4 Sec 13 T27SR34E		USGS QUAD C5
3. PARENT MATERIAL glacial outwash		BEDROCK N/A	DEPTH TO/TYPE OF IMPERMEABLE LAYER cm N/A		FRACTURING / WEATHERING	
4. LANDFORM Proximal Outwash Plain				SLOPE % 1	ASPECT	ELEVATION	SAMPLED / PHOTOGRAPHS
5. O HORIZON DEPTH 9 cm	ROOTING DEPTH 109	SOIL TEMPERATURE	DRAINAGE CLASS Well		ASSOCIATED DATA CARDS (INITIALS / SITE) mu / wv / /	

6. HORIZON	DEPTH (cm)	1 / COLOR		TEXTURE %clay %sand	STRUCTURE	CONSISTENCE	COARSE FRAGMENTS % vol.	ROOTS	ph	BOUNDARY		
		MATRIX	~~MOTTLING~~ Redox									
Oi	4 - 0											
Oe	0 - 5									AW		
E	5 - 13	2.5Y 4/1	None	fsl	1-C-GR	Friable	8% gr	3f, 3vf 1M, 1C	4.5	AW		
Bhs	13 - 30	5YR 2.5/2	None	GRX COSL	1-fsbk	V Friable	65% gr	1f, 1vf	5.2	CW		
Bs	30 - 44	10YR 2/2	None	GRX LCOS	0-SG	Loose	65% gr	2vf	5.5	CW		
C	44 - 109	2.5Y 3/2	None	GRV COS	0-SG	loose	50 gr	1vf, 1f	5.5			
	-											
	-											
	-											
	-											

1 / ALL COLORS GIVEN FOR MOIST CONDITIONS UNLESS OTHERWISE INDICATED

☆ GPO 1982-594-602

7 HORIZON	DEPTH (cm)	COLOR			FIBER CONTENT		BOTANICAL ORIGIN OF FIBER	SODIUM PYROPHOSPHATE	BOUND-ARY	MINERAL CONTENT (%)	pH	
		BROKEN	RUBBED	PRESSED	UNRUBBED	RUBBED						

	---											

8. EPIPEDON
Ochric

DIAGNOSTIC HORIZON(S)
Spodic

CONTROL SECTION AND PARTICLE SIZE
25-100 CM Sandy-Skeletal

9. FIELD CLASSIFICATION

10. HOW DID THIS SOIL DIFFER FROM MODAL

N 59° 34' 21.3" W -139° 35' 1.2" NAD27

11. ASSOCIATED COMMUNITY TYPE

NOTES
No water table within 109 cm

grasses
five leaf bramble — foam flower
salmon berry — devils club
Oak fern — bunch berry
Nagon berry — twisted stalk
sedges

USDA FOREST SERVICE - TONGASS NATIONAL FOREST - CHATHAM AREA - ALASKA

SOIL PROFILE AND ENVIROMENT DESCRIPTION

1. MAPPING UNIT: | WATERSHED NO.: | CARD NO. 9 | DATE 7/19/06 | BY JVF, DRS | AIR PHOTO NO.: | SITE NO.:

2. CLASSIFICATION: Sandy-skeletal, mixed Oxyaquic Haplocryod | LOCATION: SE1/4 Sec 14 T27S R34E CRM | USGS QUAD: C-5

3. PARENT MATERIAL: glacial outwash | BEDROCK: N/A | DEPTH TO/TYPE OF IMPERMEABLE LAYER cm: N/A | FRACTURING / WEATHERING:

4. LANDFORM: Proximal Outwash Plain | SLOPE %: 1 | ASPECT: | ELEVATION: | SAMPLED / PHOTOGRAPHS:

5. O HORIZON DEPTH: 3cm | ROOTING DEPTH: 107 | SOIL TEMPERATURE: | DRAINAGE CLASS: MW | ASSOCIATED DATA CARDS (INITIALS / SITE): mu / wv / /

6. HORIZON	DEPTH (cm)	1 / COLOR MATRIX	1 / COLOR Redox ~~MOTTLING~~	TEXTURE %clay %sand	STRUCTURE	CONSISTENCE	COARSE FRAGMENTS % vol.	ROOTS	ph	BOUND-ARY		
Oi	3 - 0											
Ap	0 - 12	7.5YR 3/2	None	gr loam	1-F-GR	friable	30% gr	3vf, 3f 3m, 1C	5.5	CI		
Bh	12 - 34	5YR 2.5/2	None	gr loam	1-F-GR	friable	25% gr	3vf, 3f 2m, 1C	4.0	CW		
Bhs	34 - 56	5YR 3/4	None	VGR LCOS	1-F-sbk	friable	45% gr	2vf, 1f	4.5	AW		
C1	56 - 85	10YR 4/2	M-3-D 7.5YR 3/4	XCB COSL	1-F-sbk	v friable	40% Cob 40% gr	1vf	5.0	CW		
C2	85 - 107+	10YR 4/2	None	XCB LCOS	0-SG	loose	40% Co 40% gr	1vf				
	- - -											
	- - -											
	- - -											
	- - -											

1 / ALL COLORS GIVEN FOR MOIST CONDITIONS UNLESS OTHERWISE INDICATED

☆ GPO 1982-594-602

7 HORIZON	DEPTH (cm)	COLOR			FIBER CONTENT		BOTANICAL ORIGIN OF FIBER	SODIUM PYROPHOSPHATE	BOUNDARY	MINERAL CONTENT (%)	pH	
		BROKEN	RUBBED	PRESSED	UNRUBBED	RUBBED						

	---											

8. EPIPEDON
Ochric

DIAGNOSTIC HORIZON(S)
Spodic

CONTROL SECTION AND PARTICLE SIZE
25-100 CM Sandy skeletal

9. FIELD CLASSIFICATION

10. HOW DID THIS SOIL DIFFER FROM MODAL

N 59° 34' 20.1" W -139° 35' 35.0" NAD27

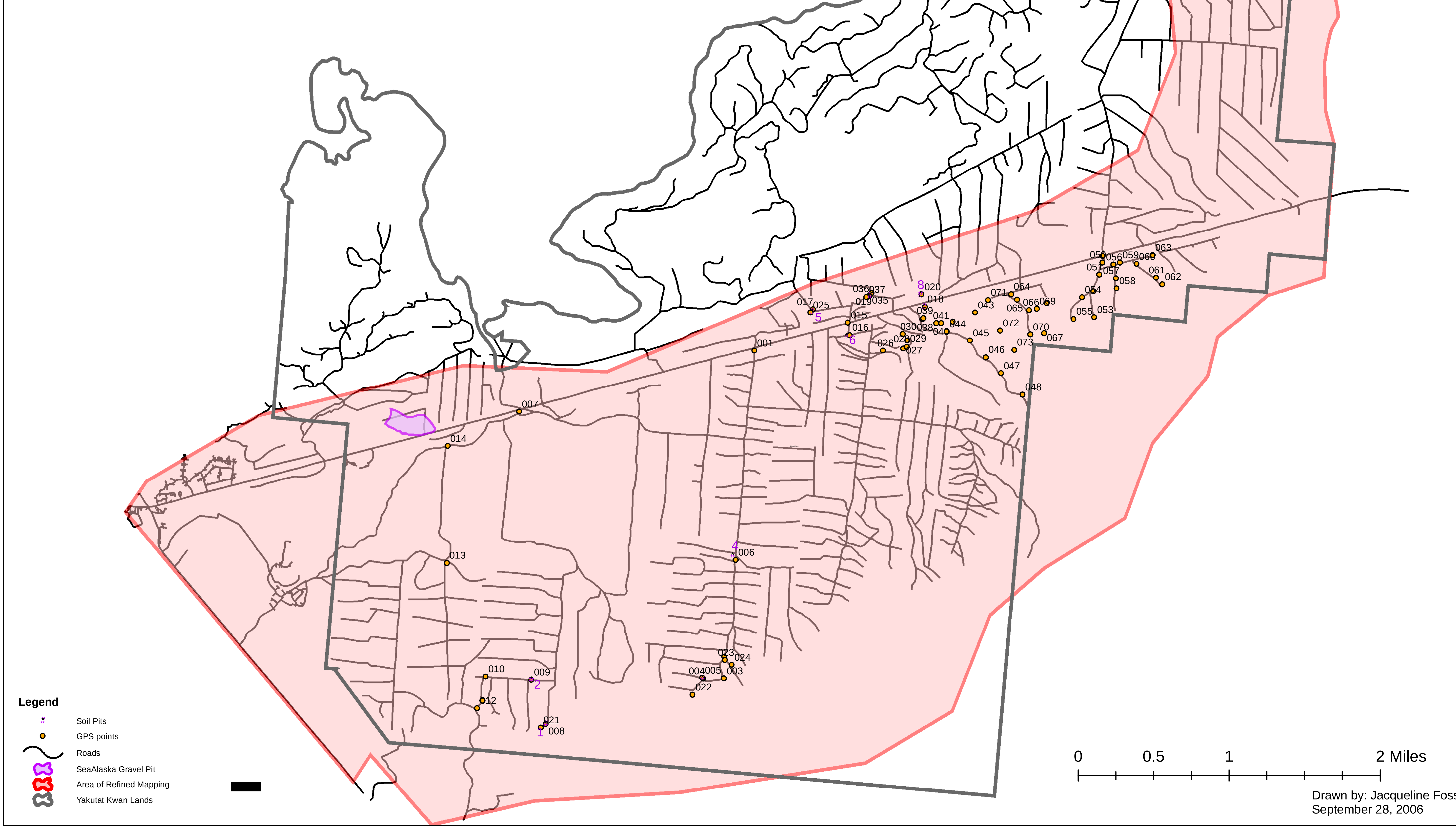
11. ASSOCIATED COMMUNITY TYPE Clearcut 15' spruce

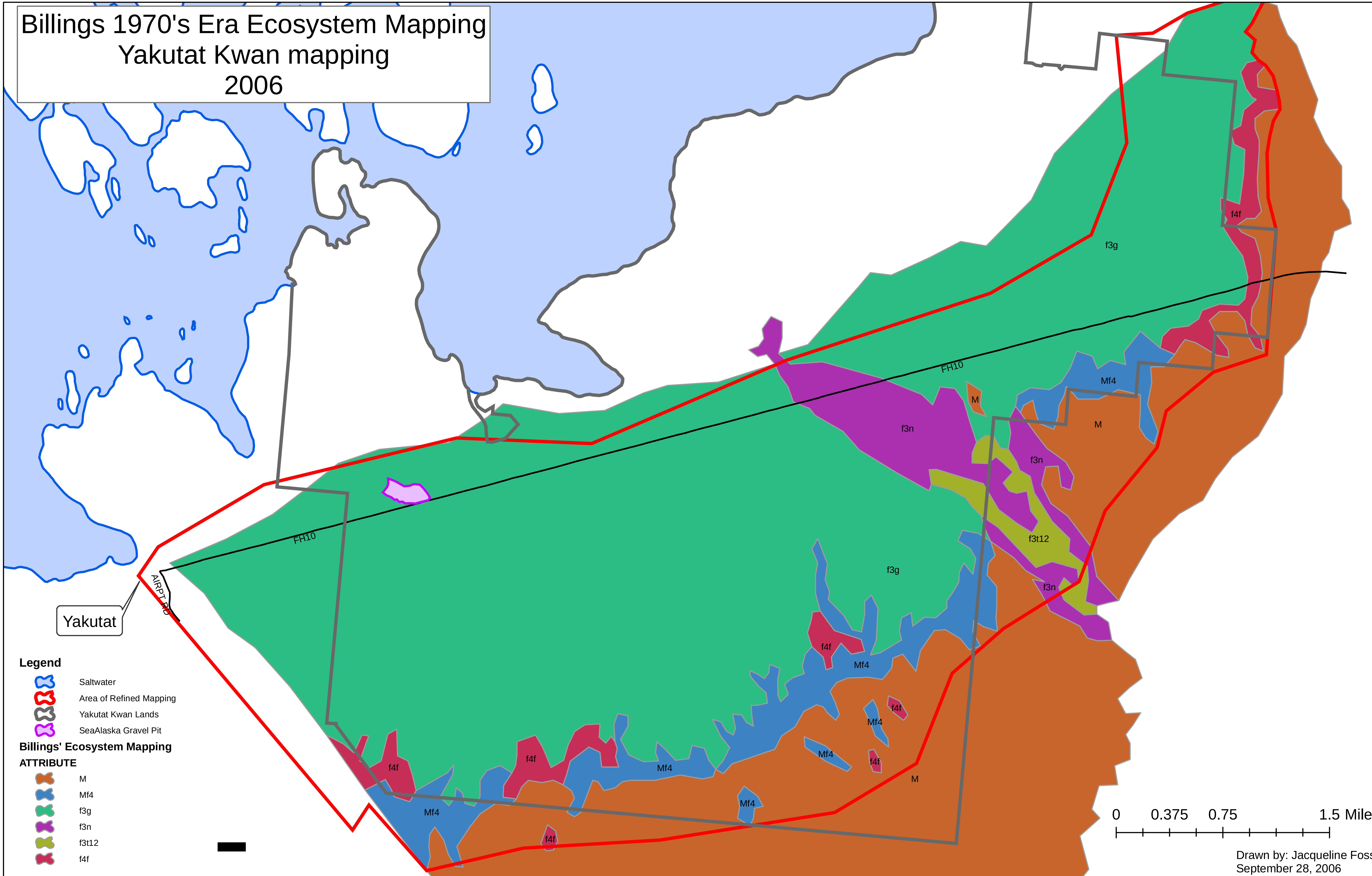
NOTES
Ap is disturbed from past logging wind row

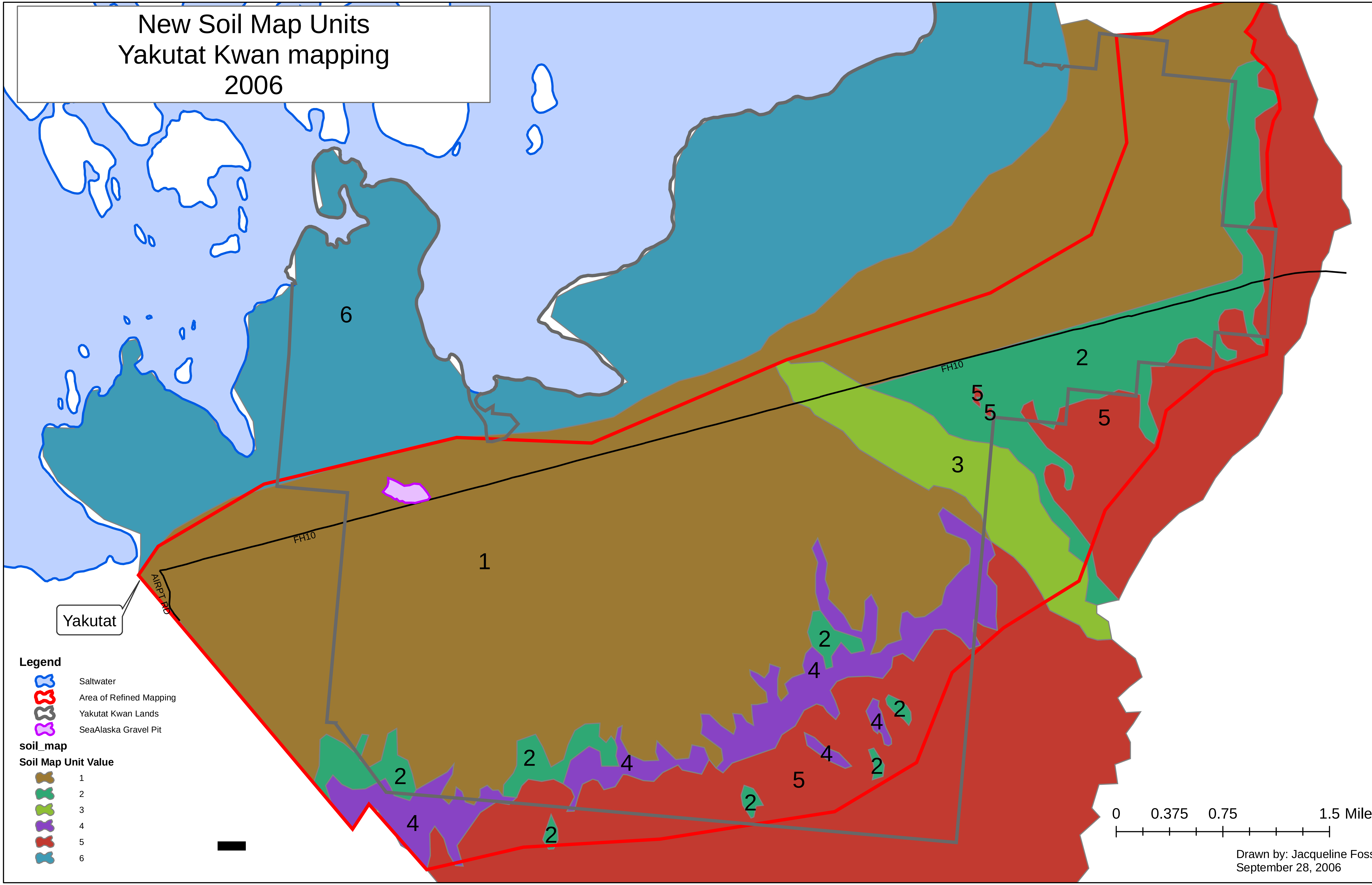
salmon berry
fireweed Lady fern
lady fern bunchberry
devils club Oak fern
blueberry Salix
grasses alder

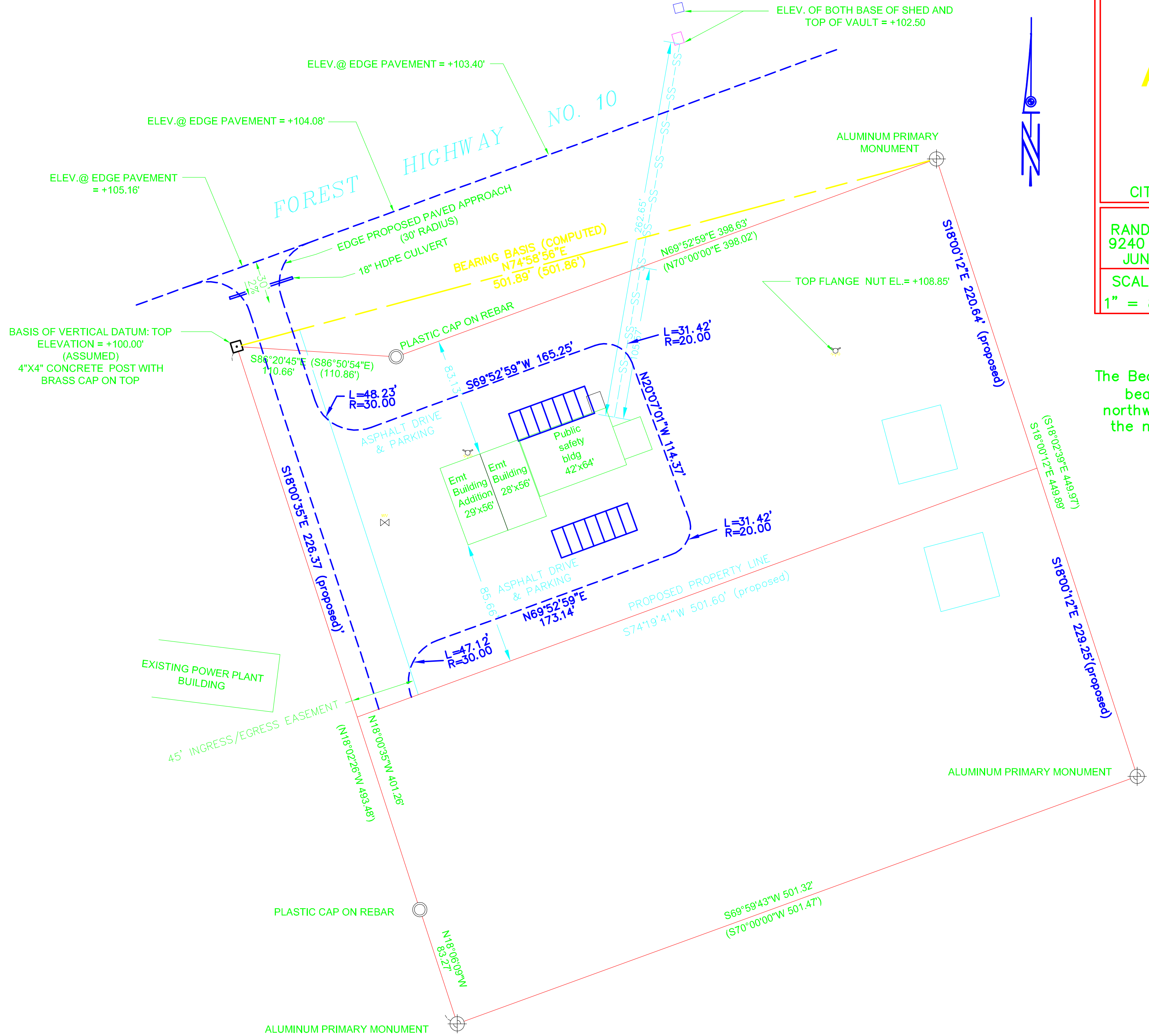
Appendix F: Maps

Soil Pit Locations, GPS Points and Surveyed Gravel Pit
Yakutat Kwan mapping
2006




Billings 1970's Era Ecosystem Mapping
Yakutat Kwan mapping
2006
Yakutat
FH10
AIRPT RD
f3g
f3n
f3t12
f4f
Mf4
M
Legend
Saltwater
Area of Refined Mapping
Yakutat Kwan Lands
SeaAlaska Gravel Pit
Billings' Ecosystem Mapping
ATTRIBUTE
M
Mf4
f3g
f3n
f3t12
f4f
0 0.375 0.75 1.5 Miles
Drawn by: Jacqueline Foss
September 28, 2006


New Soil Map Units
Yakutat Kwan mapping
2006
6
1
2
3
4
5
FH10
AIRPT RD
Yakutat
Legend
Saltwater
Area of Refined Mapping
Yakutat Kwan Lands
SeaAlaska Gravel Pit
soil_map
Soil Map Unit Value
1
2
3
4
5
6
0 0.375 0.75 1.5 Miles
Drawn by: Jacqueline Foss
September 28, 2006



SITE PLAN of A PARCEL WITHIN ASLS 87-133

WITHIN LOT 5, U.S. SURVEY 5630
ANCHORAGE RECORDING DISTRICT
CITY AND BOROUGH OF YAKUTAT, ALASKA

SURVEYOR:	OWNER:
RANDAL V. DAVIS, PLS 9240 N. DOUGLAS HWY. JUNEAU, AK 99801	CITY OF YAKUTAT 309 MAX ITALIO DRIVE YAKUTAT, AK 99689

SCALE:	DATE:	DRAWN BY:	CHECKED BY:	SHEET
1" = 80'	JAN. 2009	RVD	RVD	1 OF 1

BEARING BASIS

The Bearing Basis for this survey is the computed bearing of N74°58'56"E, between the most northwesterly and most northeasterly corners of the most easterly parcel of land within Alaska State Land Survey No. 87–133.

DRAWING SCALE: 1"=100'

Alaska Energy Authority Grant Agreement			ALASKA ENERGY AUTHORITY		
Grant Agreement Number 2195424			Amount of Funds: $249,600		
Project Code(s) 402035	Encumbrance Number/AR PBO00383		Period of Performance: From: August 20, 2008 To: September 30, 2010		
Project Title: Yakutat Biomass Feasibility					
Grantee			**Grantor**		
Name Yakutat Power, [illegible]			Alaska Energy Authority		
Street/PO Box P.O. Box 129			Street/PO Box 813 W. Northern Lights Blvd		
City/State/Zip Yakutat, Alaska 99689			City/State/Zip Anchorage, AK 99503		
Contact Person Scott Newlun, General Manager			Contact Person Lenny Landis, Project Manager		
Phone: 907-784-3242	Fax: 907-784-3922	E-mail: yakpower@ptialaska.net	Phone: 907-771-3068	Fax: 907-771-3044	E-mail: llandis@aidea.org

AGREEMENT

The Alaska Energy Authority (hereinafter 'Authority') and Yakutat Power, [illegible]. (hereinafter 'Grantee') agree as set forth herein.

Section I. The Authority shall grant funds to pay for expenses incurred by the Grantee under the terms and conditions of this Agreement, in an amount not to exceed $249,600, unless the grant amount is amended as provided herein.

Section II. The Grantee shall apply the grant funds to the Project and perform all of the work and other obligations required by this Agreement.

Section III. Performance under this agreement begins August 20, 2008 and shall be completed no later than September 30, 2010.

Section IV. The agreement consists of this page and the following:

Appendices

Appendix A: General Provisions
Appendix B: Standard Provisions
Appendix C: Grantee Proposal/Scope of Work
Appendix D: Project Management & Reporting Requirements
Appendix E: Project Budget & Reimbursement Provisions

Attachments/Forms (As required)

Attachment 1: Financial Report/Request for Reimbursement Form
Attachment 2: Progress Report Form
Attachment 3: Notice of Project Closeout

AMENDMENTS: Any amendments to this Agreement must be signed by authorized representatives of Grantee and the Authority and should be listed here.

Grantee	**Authority Project Manager**	**Executive Director or Designee**
Signature Scott Newlun	Signature	Signature
Printed Name and Title Scott Newlun, General Manager	Printed Name and Title Lenny Landis, Project Manager	Steve Haagenson, AEA Executive Director
Date 7-31-2009	Date	Date

Table of Contents
Grant No. 2195424

APPENDIX A GENERAL PROVISIONS

1. Definitions

In this Grant Agreement, attachments and amendments:

a) "Authority" means the Alaska Energy Authority, a public corporation of the State of Alaska.

b) "Authorized Representatives" means those individuals or entities authorized by an entity to act on its behalf, with delegated authority sufficient to accomplish the purposes for which action is needed.

c) "Executive Director" means the Executive Director of the Authority or the Executive Director's authorized representative.

d) "Matching contributions" means the cash, loan proceeds, in-kind labor, equipment, land, other goods, materials, or services a grantee provides to satisfy any match requirements of a grant or to complete the Project.

e) "Project" means Yakutat Biomass Feasibility as defined in Appendix C (Scope of Grant) for which funds have been made available.

f) "Project Manager" means the employee of the Authority responsible for assisting the Grantee with technical aspects of the Project and is one of the Grantor's contacts for the Grantee during all phases of the Project.

g) "State" means the State of Alaska.

2. Authority Saved Harmless

As a condition of this Grant, the Grantee agrees to defend, indemnify, and hold harmless the Authority and the State of Alaska, and their agents, servants, contractors, and employees, from and against any and all claims, demands, causes of action, actions, and liabilities arising out of, or in any way connected with this grant or the project for which the grant is made, howsoever caused, except to the extent that such claims, demands, causes of action, actions or liabilities are the proximate result of the sole negligence or willful misconduct of the Authority or the State of Alaska.

3. Workers' Compensation Insurance

The Grantee shall provide and maintain Workers' Compensation Insurance as required by AS 23.30 for all employees engaged in work under this Grant Agreement. The Grantee shall require any contractor to provide and maintain Workers' Compensation Insurance for its employees as required by AS 23.30.

4. Insurance

The Grantee is responsible for obtaining any necessary insurance and endorsements as defined in Appendix B Standard Provisions.

5. Equal Employment Opportunity (EEO)

The Grantee may not discriminate against any employee or applicant for employment because of race, religion, color, national origin, age, physical handicap, sex, marital status, changes in marital status, pregnancy, or parenthood. The Grantee shall post in a conspicuous place, available to employees and applicants for employment, a notice setting out the provisions of this paragraph.

The Grantee shall state in all solicitations or advertisements for employees to work on Authority funded projects, that it is an Equal Opportunity Employer (EEO) and that all qualified applications will receive consideration for employment without regard to race, religion, color, national origin, age, physical handicap, sex, marital status, changes in marital status, pregnancy or parenthood.

The Grantee shall include the provisions of this EEO article in every contract relating to this Grant Agreement and shall require the inclusion of these provisions in every agreement entered into by any of its contractors, so that those provisions will be binding upon each contractor and subcontractor.

6. Public Purposes

The Grantee agrees that the Project to which this Grant Agreement relates shall be dedicated to public purposes and any project constructed or equipment or facilities acquired, shall be owned and operated for the benefit of the general public. The Grantee shall spend monies appropriated under this grant only for the purposes specified in the Grant Agreement. The benefits of the Project shall be made available without regard to race, religion, color, national origin, age, physical handicap, sex, marital status, changes in marital status, pregnancy or parenthood.

7. Officials Not To Benefit

No member of or delegate to Congress or the Legislature, or officials or employees of the Authority or Federal government may share any part of this agreement or any benefit to arise from it.

8. Governing Law

This Grant Agreement is governed by the laws of the State of Alaska. Any civil action arising from this Agreement shall be brought in the Superior Court for the Third Judicial District of the State of Alaska at Anchorage.

9. Compliance with Applicable Law and Funding Source Requirements

The Grantee shall comply with all applicable local, state and federal statutes, regulations, ordinances and codes, whether or not specifically mentioned herein. Refer to Appendix B Standard Provisions for more specific requirements.

10. Severability

If any section, paragraph, clause or provision of this Agreement is held invalid or unenforceable, the remainder of this Agreement shall be unaffected and enforced to the fullest extent possible, and the invalid or unenforceable provision shall be deemed replaced with a valid and enforceable provision that is as similar as possible to such invalid or unenforceable provision.

11. Non-waiver

The failure of either party at any time to enforce a provision of this Agreement shall in no way constitute a waiver of the provision, nor in any way affect the validity of this Agreement, or any part hereof, or the right of such party thereafter to enforce each and every provision hereof.

12. Integration

This instrument and all appendices, amendments, and attachments hereto embody the entire Agreement of the parties concerning the grant funds granted hereunder. There are no promises, terms, conditions, or obligations regarding said funds other than those contained in the documents described above; and such documents shall supersede all previous communications, representations or agreements, either oral or written, between the parties hereto. To the extent there is any conflict between the provisions of Appendix A and B the Grantee's application or proposal, the provisions of Appendix A & B prevail.

13. Grantee Not Agent of Authority

The Grantee and any agents and employees of the Grantee act in an independent capacity and are not officers or employees or agents of the Authority in the performance of this Grant Agreement.

14. Disputes

Any dispute arising under this Grant Agreement which is not disposed of by mutual agreement must be raised to the Executive Director and will be decided by the Executive Director or the Executive Director's designee consistent with 3 AAC 108.910. The decision shall be in writing and mailed or otherwise furnished to the Grantee. The decision of the Executive Director or Designee is final and conclusive.

15. Termination

a) The Grantee shall have no rights to compensation or damages for termination except as provided in this Section.

b) In addition to all other rights available under law, the Authority may terminate this Agreement or stop work on the Project for the convenience of the Authority or for cause upon ten (10) days written notice.

c) "Cause" for termination shall exist when the Grantee has failed to perform under this Agreement, has provided incorrect or misleading information or has failed to provide information which would have influenced the Authority's actions. In order for termination to be for cause, the Grantee's failure to perform or the Grantee's provision of incorrect, misleading, or omitted information must be material.

d) If this Agreement is terminated for cause the Grantee shall be entitled to no compensation. The Grantee shall reimburse the Authority for all grant funds expended

22. *Remission of Unexpended Funds*

The Grantee shall return all unexpended grant monies to the Authority within 90 days of the Project completion.

23. *Tax Compliance Responsibilities of Grantee*

The Grantee is responsible for determining applicable federal, state, and local tax requirements, for complying with all applicable tax requirements, and for paying all applicable taxes. The Authority may issue an IRS Form 1099 for Grant payments made. The Grantee shall pay all federal, state and local taxes incurred by the Grantee and shall require the payment of all applicable taxes by any contractor or any other persons in the performance of this Grant Agreement.

24. *Lobbying Activities*

In accepting these funds, the Grantee agrees and assures that none of the funds will be used for the purpose of lobbying activities before the United States Congress or Alaska Legislature. No portion of these funds may be used for lobbying or propaganda purposes as prohibited in AS 37.05.321, 18 U.S.C. 1913, 31 U.S.C. 1352, or other laws as applicable.

25. *Financial Management and Accounting*

The Grantee shall establish and maintain a financial management and accounting system that conforms to generally accepted accounting principles. In addition, the accounting system must keep separate all grant funds awarded under this grant agreement.

26. *Procurement Standards*

Grantees will follow competitive purchasing procedures that: 1) provide reasonable competitive vendor selection for small dollar procurements; 2) provide for competitive bids or requests for proposals for contracts and procurements greater than $100,000; 3) provide a justification process for non-competitive procurements or contracts; 4) document the source selection methods used for all contracts, equipment, or material transactions greater than $10,000; 5) and comply with other procurement requirements as defined in Appendix B. Grantees who have questions about their procurement procedures or a specific procurement should contact the Authority's Grant Manager.

27. *Reporting Requirements*

The Grantee shall submit progress reports to the Authority according to the schedule established in Appendix D of this Grant Agreement.

28. *Ownership of Documents and Products*

All designs, drawings, specifications, notes, artwork, computer programs, reports and other work developed with grant funds in the performance of this agreement are public domain and will be used by the Authority and/or public without notice or compensation to the Grantee. The Grantee agrees not to assert any rights and not to establish any claim under the design patent or copyright laws. Except as otherwise specifically agreed, and without limiting any Intellectual Property requirements of a federal funding agency, the Authority shall have unlimited rights to use and to disseminate any data produced or delivered in the performance of the contract.

29. Inspections and Retention of Records

The Grantee shall keep a file for financial, progress and other records relating to the performance of the grant agreement. The file must be retained for a period of four years from the fully executed close out of the grant agreement or until final resolution of any audit findings claim or litigation related to the grant. The Authority may inspect, in the manner and at reasonable times it considers appropriate, records and activities under this Grant Agreement.

30. Audits

This Grant Agreement is subject to 2 AAC 45.010 single audit regulations for State Grants. The Grantee must comply with all provisions of 2 AAC 45.010 and any additional audit requirements outlined in Appendix D.

31. Legal Authority

The Grantee certifies that it possesses legal authority to accept grant funds under the State of Alaska and to execute the Project described in this Grant Agreement by signing the Grant Agreement document. The Grantee's relation to the Authority and the State of Alaska shall be at all times as an independent Grantee.

32. Grant Close out

Upon completion of the all work or expenditure of all grant funds related to the Project the Authority will provide written notice to the Grantee that the Grant will be closed out with an effective date that the grant will be closed out.

The Grant will be considered closed out by the effective date in the notice unless the Grantee provides written notice to the Project manager within 30 days after receipt of notice of Grant close out that they disagree.

No additional reimbursements will be made to the Grantee after the grant is closed out.

Appendix B Standard Provisions

1. Grant Funding Sources

This Grant is subject to appropriation and availability of funds as listed below:

State of Alaska	$	249,600	Renewable Energy Fund AR 04685-13
Local Match	$	17,652	Yakutat Power cash match
Total Grant Funding	$	267,252	

Grantee acknowledges that if additional grant funds are made available they are subject to the terms and conditions of this Agreement and any amendment.

2. Governing Laws

The Grantee shall perform all aspects of this Project in compliance with all applicable state, federal and local laws and the Renewable Energy Fund Request for Applications dated 9/03/2008.

3. Eligible Costs

The Authority, as Grantor, shall have sole discretion to determine which project costs are eligible to be paid from Grant monies under this agreement. Only direct costs of the Project are eligible for payment or reimbursement from grant funds. Indirect costs are not allowed under this grant unless approved by the Authority in Appendix E.

4. Insurance Requirements

The following insurance requirements are in effect for this Project. Grant funds will be used to procure Project related insurance and the Authority will work with the Grantee to ensure that these requirements are met. Insurance will be obtained with an insurance carrier or carriers covering injury to persons and property suffered by the State of Alaska or by a third party as a result of operations under this grant. The insurance shall provide protection against injuries to all employees of the Project engaged in work under this grant. All insurance policies shall be issued by insurers that (i) are authorized to transact the business of insurance in the State of Alaska under AS 21 and (ii) have a Bests Rating of at least A-VII and be required to notify the Authority, in writing, at least 30 days before cancellation of any coverage or reduction in any limits of liability.

Where specific limits and coverage are shown, it is understood that they shall be the minimum acceptable and shall not limit the Grantee's indemnity responsibility. However, costs for any coverage in excess of specific limits of this agreement are the responsibility of the Grantee and may not be charged to this grant agreement.

The following policies of insurance shall be maintained with the specified minimum coverage and limits in force at all times during the performance work under this Project:

1. Workers' Compensation: as required by AS 23.30.045, for all employees engaged in work under this Project. The coverage shall include:

a. Waiver of subrogation against the State and Employer's Liability Protection at $500,000 each accident / each employee and $500,000 policy limit;

2. Commercial General Liability: on an occurrence policy form covering all operations under this Project with combined single limits not less than:

a. $1,000,000 Each Occurrence;
b. $1,000,000 Personal Injury;
c. $1,000,000 General Aggregate; and
d. $1,000,000 Products-completed Operations Aggregate.

The State of Alaska shall be named as an individual insured.

3. Automobile Liability: covering all vehicles used in Project work, with combined single limits no less than $1,000,000 each occurrence.

All of the above insurance coverage shall be considered to be primary and non-contributory to any other insurance carried by the State of Alaska, whether self-insurance or otherwise.

The Authority's acceptance of deficient evidence of insurance does not constitute a waiver of Grant requirements.

Appendix B1 Standard Provisions for General Design Grant

1. Contracts for Engineering Services

In the event the Grantee contracts for engineering services, the Grantee will require that the engineering firm certify that it is authorized to do business in the State of Alaska and provide proof of licensing and insurance.

2. Permits

It is the responsibility of the Grantee to identify and ensure that all permits required for the construction and operation of this Project by the Federal, State, or Local governments have been obtained unless otherwise stated in Appendix C. These permits may include, but are not limited to, Corps of Engineers' Wetlands Permit, State Historic Preservation Office, State Fire Marshal approval, rights-of-way for the pipelines, and site control, including any necessary Coastal Zone Management coordination through the Office of Project Management and Permitting (DNR).

3. Exclusion of Existing Environmental Hazards

Grant funds for investigation, removal, decommissioning, or remediation of existing environmental contamination or hazards, are not allowed unless specifically specified and approved in Appendix C.

4. Environmental Standards

The Grantee will comply with applicable environmental standards, including without limitation applicable laws for the prevention of pollution, management of hazardous waste, and evaluation of environmental impacts.

5. Tariffs & Rates for Use of Grant-Funded Assets

Rates for power provided as a result of generation or transmission facilities built with grant funds may be subject to review and approval by the Regulatory Commission of Alaska (RCA), or if the rates are not subject to RCA review and approval, they may be subject to review and approval by the Authority to ensure reasonable and appropriate public benefit from the ownership and operation of the Project.

6. Grant-funded Assets Not Included with PCE

The Grantee agrees that it will not include the value of facilities, equipment, services, or other benefits received under this grant as expenses under the Power Cost Equalization Program or as expenses on which wholesale or retail rates or any other energy tariffs are based.

Appendix C Grantee Proposal/Scope of work

Yakutat Power is located in Yakutat, Alaska. The City and Borough of Yakutat has a population of 631 and is located at the mouth of Yakutat Bay along the Gulf of Alaska, 225 miles northwest of Juneau and 220 miles southeast of Cordova. Yakutat receives monthly barge service during the winter and more frequent service during summer. Yakutat is equipped with 2 jet-certified runways and receives jet service daily.

The Grant funding under this phase of the project will provide for Final Design, Permitting, Equipment Evaluation and Resource Evaluation of the Forest Product fuel source for its eventual replacement of diesel fuel.

Final Design will include mechanical and electrical integration of the forest product system into the Community of Yakutat's electric generation infrastructure, as well as design of the fuel storage and handling system. The Community of Yakutat has received initial funding from a separate funding source to relocate and upgrade its existing power generation system. The forest product fuel project design will be coordinated with the ongoing power plant upgrade design.

Permitting will include NEPA Project Level environmental review of the proposed forest product fuel system and harvesting the resource. The City and Borough of Yakutat will work closely with stakeholders and the USFS to identify and mitigate potential impacts to the environment associated with harvesting the biomass resource.

In conjunction with the project level environmental review, the City and Borough of Yakutat through Yakutat Power will work with the Borough Planners, USFS, Yakutat Tlingit Tribe, Yak-Tat Kwaan Inc., and local stakeholders to define and refine the fuel resource available for this project; including identifying realistic costs associated with harvesting, transporting, processing, storing, and handling the biomass product.

Timeline and Milestones:

The timeframe to complete the final design, permitting, and resource evaluation is 12 to 14 months from the grant award date.

Required Milestone	Reimbursable Tasks	Timeline
1. Grant Agreement In Place	• Submit Concept Design and System Integration Plan with the Yakutat Power generation infrastructure. • Begin wood biomass resource evaluation and equipment evaluation • Submit Updated Project Budget and Schedule • Identify all Necessary Permits and ROW/Site Control issues	Months 1-4

2. Review Project Design and System Integration	• Submit 65% Design Documents • Draft agreements for any ROW/Site Control issues and apply for required Permitting • Submit necessary Power Sales Agreements and MOUs for Securing Wood Supply	Month 5-9
3. Finalize Design and Permitting	• Submit 95% Design • Submit Final Environmental Analysis • Submit Operational Business Plan • Submit Updated Budget and Proposed Construction Schedule	Month 10-14

By reference, the Application of 10/08/2008 is incorporated as amended into this grant agreement.

Appendix D Project Management & Reporting Requirements

1. Project Management

The Grantee will notify the Authority immediately of any significant organizational changes during the term of the grant, including changes in key personnel or tax status, any unforeseen problem or project delay that may cause a change to the work plan or budget or that may otherwise affect the Grantee's ability to perform its commitments under this Grant Agreement. Any unreported or unapproved changes to the work plan or budget evident in reports may result in an amendment being required, costs disallowed, suspension or termination of the grant as described in Appendix A.

2. Contact Persons

For the Grantee	For The Authority
Grant Manager Scott Newlun, General Manager P.O. Box 129 Yakutat, Alaska 99689 yakpower@ptialaska.net (907)784-3242	**Grant Manager** Butch White, Grants Administrator 813 W. Northern Lights Blvd. Anchorage, Alaska 99503 bwhite@aidea.org (907) 771-3052
Project Manager Scott Newlun, General Manager P.O. Box 129 Yakutat, Alaska 99689 yakpower@ptialaska.net (907)784-3242	**Project Manager** Lenny Landis 813 W. Northern Lights Blvd. Anchorage, Alaska 99503 llandis@aidea.org (907) 771-3068

3. Monthly Progress and Financial Reports

The Grantee will provide monthly status reports by email (or other method allowed by the Authority, if email is not available) to the Authority's Project Manager. These reports are due starting the first full month after the award of the grant. This report must update the Authority on the project's progress, regulatory and compliance issues, possible delays, and grant expenditures during the month. These Monthly Progress Reports must summarize, in one or two pages, the progress made on grant tasks during the month and identify any difficulties in completing tasks or meeting goals or deadlines. The Grantee must also include with the report copies of any work products due to the Authority during this period.

Reports are due on the 1st business day of each month. Reports are considered late five (5) days after the due date. No further payments will be made without submission and approval of required reports. Work completed after the twenty-day period when required reports have not been submitted is at the Grantee's risk, and costs incurred may be disallowed. Repeated failure to submit reports in a timely manner could result in suspension or termination of the grant.

All reports and deliverables required in this agreement must have been submitted and approved by the Authority prior to the final payment being released.

4. Documentation and Record Keeping

The Grantee shall maintain the following in their files:

- Grant application,
- Grant agreement and any amendments,
- All written correspondence or copies of emails relating to the Grant,
- Reports, including any consultant work products,
- A separate accounting of grant income and expenditures,
- Supporting documentation for the expenditures charged to the grant (including supporting documentation for all required matching contributions).

The Authority and any authorized federal representative may inspect, in the manner and at any reasonable time either considers appropriate, the Grantee's facilities, records, and activities funded by this Grant Agreement.

Appendix E Project Budget & Reimbursement Provisions

1. *Allowable Costs*

Allowable costs under this grant include all reasonable and ordinary costs for direct labor & benefits, travel, equipment, supplies, contractual services, construction services, and other direct costs identified and approved in the Project budget that are necessary for and incurred as a direct result of the Project and consistent with the requirements noted in B.3 Eligible Costs.

A cost is reasonable and ordinary if, in its nature and amount, it does not exceed that which would be incurred by a prudent person under the circumstances prevailing at the time the decision was made to incur the costs.

Allowable costs are only those costs that are directly related to activities authorized by the Grant Agreement and necessary for the Project. The categories of costs and additional limits or restrictions are listed below:

a. Direct Labor & Benefits

Include salaries, wages, and employee benefits of the Grantee's employees for that portion of those costs attributable to the time actually devoted by each employee to, and necessary for the Project. Direct labor costs do not include bonuses, stock options, other payments above base compensation and employee benefits, severance payments or other termination allowances paid to the Grantee's employees.

b. Travel, Meals, or Per Diem

Include reasonable travel expenses necessary for the Project. These include necessary transportation and meal expenses or per diem of Grantee employees for which expenses the employees are reimbursed under the Grantee's standard written operating practice for travel and per diem or the current State of Alaska Administrative Manual for employee travel.

c. Equipment

Include costs of acquiring, transporting, leasing, installing, operating, and maintaining equipment necessary for the Project, including sales and use taxes.

Subject to prior approval of the Authority's Project Manager, costs or expenses necessary to repair or replace equipment damage or losses incurred in performance of work under the grant may be allowed. However, damage or losses that result from the Grantee's employees, officer's, or contractor's gross negligence, willful misconduct, or criminal conduct will not be allowed.

d. Supplies

Include costs of material, office expenses, communications, computers, and supplies purchased or leased by the Grantee necessary for the Project.

e. Contractual services

Include the Grantee's cost of contract services necessary for the Project. Services may include costs of contract feasibility studies, project management services, engineering and design, environmental studies, field studies, and surveys for the project as well as costs incurred to comply with ecological, environmental, and health and safety laws.

f. Construction Services

For construction projects this includes the Grantee's cost for construction contracts, labor, equipment, materials, insurance, bonding, and transportation necessary for the Project. Work performed by the Grantee's employees during construction may be budgeted under direct labor and benefits. Contracted project management or engineering may be budgeted under contractual services and major equipment purchases made by the Grantee may be budgeted under equipment.

g. Other Direct Costs

In addition to the above the following expenses necessary for the Project may be allowed.

- Net insurance premiums paid for insurance required for the grant Project;
- Costs of permits and licenses for the grant Project;
- Non-litigation legal costs for the Project directly relating to the activities; in this paragraph, "non-litigation legal costs" includes expenses for the Grantee's legal staff and outside legal counsel performing non-litigation legal services;
- Office lease/rental payments;
- Other direct costs for the Project directly relating to the activities and identified in the grant documents; and/or
- Land or other real property or reasonable and ordinary costs related to interests in land including easements, right-of-ways, or other defined interests.

2. Specific Expenditures not allowed

Ineligible expenditures include costs for overhead, lobbying, entertainment , alcohol, litigation, payments for civil or criminal restitution, judgments, interest on judgments, penalties, fines, costs not necessary for and directly related to the grant Project, or any costs incurred before the beginning date of the grant as indicated on the signature page.

Overhead costs described in this section include:

- salaries, wages, applicable employee benefits, and business-related expenses of the Grantee's employees performing functions not directly related to the grant Project;
- office and other expenses not directly related to the grant Project; and
- costs and expenses of administration, accounting, human resources, training, property and income taxes, entertainment, self-insurance, and warehousing.

3. Match

The Grantee is required to provide $17,652 in matching cash funds to complete the Project.

4. Cost Share Match Requirements

Cost sharing or matching is that portion of the Project costs not borne by the Authority. The Authority will accept all contributions, including cash and in-kind, as part of the Grantees' cost sharing or matching when such contributions meet the following criteria:

- Are provided for in the Project budget;
- Are verifiable from the Grantee's records;
- Are not included as contributions for another state or federally assisted project or program; (The same funds can't be counted as match for more than one program.)
- Are necessary and reasonable for proper and efficient accomplishment of the Project or program objectives;
- Are allowable costs;
- Are not paid by the State or federal government under another award, except for authorized by the State or federal statute to be used for cost sharing or matching;
- Must be incurred within the grant eligible time period.

5. Valuing In-Kind Support as Match

If the Grantee chooses to use in-kind support as some or all of its match, the values of those contributions must be approved by the Authority at the time the budget is approved. The values will be determined as follows:

- The value of real property will be the current fair market value as determined by an independent third party or a valuation that is mutually agreed to by the Authority and the Grantee and approved in the grant budget.

- The value assessed to Grantee equipment or supplies will not exceed the fair market value of the equipment or supplies at the time the grant is approved or amended.

- Equipment usage will be valued based on approved usage rates that are determined in accordance with the usual accounting policies of the recipient or the rates for equipment that would be charged if procured through a competitive process. Rates paid will not exceed the fair market value of the equipment if purchased.

- Rates for donated personal services will be based on rates paid for similar work and skill level in the recipient's organization. If the required skills are not found in the recipient organization, rates will be based on rates paid for similar work in the labor market. Fringe benefits that are reasonable, allowable, and allocable may be included in the valuation.

- Transportation and lodging provided by the Grantee for non-local labor will not exceed the commercial rates that may be available within the community or region.

6. *Grant Disbursements*

The Grantee must request disbursement of grant funds in the form and format required by the Authority with appropriate back-up documentation and certifications. (See Attachment 1)

The back-up documentation must demonstrate the total costs incurred are allowable, and reflect the amount being billed. Documentation must include:

- A summary of direct labor costs supported by timesheets or other valid time record to document proof of payment
- Travel and per diem reimbursement documentation
- Contractor or vendor pay requests
- Invoices

Payment of grant funds will be subject to the Grantee complying with its matching contribution requirements of the Grant.

7. Withholding of Grant Funds

If, upon review of the monthly billings, the Authority discovers errors or omissions in the billings it will notify the Grantee within thirty (30) days of receipt of the billing. Payment for the portion of billings for which there is an error or omission may be withheld pending clarification by Grantee.

Grant funds may be withheld for the following reasons:

- The Grantee fails to provide adequate back-up documentation.
- The Authority determines that a specific expense is not allowed under the grant.
- The Grantee's matching contribution requirements are not met.

Up to 10% of the Authority's contribution of grant funds may be retained by the Authority until the Project is completed and all required final documentation and reports are received and accepted by the Authority.

8. Advance Disbursements

In most instances, payments to a Grantee will be made on a cost reimbursable basis. If the Authority determines that cost reimbursement will significantly inhibit the Grantee's ability to perform the Project and determines that an advance is in the public interest, the Authority may recommend an advance to the Grantee of an amount not to exceed a projected thirty (30) day cash need, or twenty percent (20%) of the grant amount, whichever amount is less.

Before the Authority will issue an advance, the Grantee must provide in writing, and the Authority must approve a "Request for Advance Payment" form which includes:

a. justification of the need for the advance,
b. documentation of anticipated line item costs associated with the advance.

All advances will be recovered with the Grantee's next Financial / Progress Report form. Should earned payments during the terms of this Grant Agreement be insufficient to recover the full amount of the advance, the Grantee will repay the unrecovered amount to the Authority when requested to do so by the Authority, or at termination of the Grant Agreement.

9. *Unexpended Grant Funds and Interest Earned*

Any grant funds not expended under this agreement and any interest accruing on the grant funds belong to the Authority and shall be returned to the Authority.

10. *Budget Adjustments and Changes*

When a Grantee faces increased unbudgeted costs, the grantee should contact the Authority's Project Manager. Budget adjustments **cannot** increase the grant award amount. Cost overruns that may require reduced scope of work will require AEA approval and an amendment to the grant. If a budget adjustment or other changes indicate to the Authority's Project Manager that the project can't be completed as currently planned and budgeted for, the Project Manager will not approve the release of additional grant funds until the grantee provides sufficient information on how the grantee intends to complete the revised project.

Budget Adjustments

The Grantee shall identify budget changes on its Financial Reports submitted to the Authority.

At least quarterly, the Authority will compare actual costs to budgeted distributions based on the financial report / request for reimbursement form. Costs charged to grant funds must reflect adjustments made as a result of the activity actually performed. The budget estimates or other distribution percentages must be revised at least quarterly, if necessary, to reflect changed circumstances.

Attachment 1 Financial Report/Request for Reimbursement Form

Grantee: Yakutat Power, ' ıc **Project:** Yakutat Biomass Feasibility

Period: ______ to ____________ **Grant Number:** 2195424

BUDGET SUMMARY	A TOTAL GRANT BUDGET	B PRIOR EXPENDITURES	C EXPENDITURES THIS PERIOD	D = B + C TOTAL EXPENDITURES	E = A - D GRANT BALANCE
BY TASK OR MILESTONE					
Design, NEPA permitting & Resource Evaluation	$ 267,252				
Pilot Project Testing	$ 0				
CAT Integration (GO/NO-GO)	$ 0				
Commercialization (GO/NO-GO)	$ 0				
TOTAL	**$ 267,252**				
BY BUDGET CATEGORIES					
Direct Labor and Benefits	$ 17,652				
Travel					
Equipment					
Engineering/Contractual	$ 249,600				
Contractual					
Construction					
Materials/Freight					
Other					
TOTAL	**$ 267,252**				
BY FUND SOURCES					
Grant Funds	$ 249,600				
Grantee Match – Cash	$ 17,652				
Grantee Match – In-Kind					
Other Contributions					
TOTAL	**$ 267,252**				

CERTIFICATION

Form requires two original signatures. The person certifying must be different from the person preparing the report. One signature should be the authorized representative of the Grantee organization or highest ranking officer; the other should be the person who prepared the report.

I certify to the best of my knowledge and belief the information above is correct and funds were spent in accordance with grant agreement terms and conditions.

Certified By: ______________________ Prepared By: ______________________

Title: ______________ Date: ________ Title: ______________ Date: ________

Attachment 2 Progress Report Form

Grantee: Yakutat Power, .

Project Name: Yakutat Biomass Feasibility

Grant # 2195424

Period of Report: ___________ to ________________

Project Activities Completed:

Existing or Potential Problems:

Activities Targeted for Next Reporting Period:

Attachment 3 Notice of Project Closeout

NOTICE OF PROJECT CLOSEOUT
ALASKA ENERGY AUTHORITY

Project Name: Yakutat Biomass Feasibility

Grantee: Yakutat Power,

Grant Number: 2195424

Agreement Execution Date:

The Alaska Energy Authority certifies and acknowledges that the Project referenced above has been completed, and that all tasks have been satisfactorily carried out in accordance with the terms and conditions of Agreement Number: ________________.

________________________________ ________________________
Project Manager Date
Alaska Energy Authority

The ____ certifies that the Project named above is complete in accordance with the terms and conditions of Alaska Energy Authority Agreement Number: ________________.

________________________________ ________________________
Authorized Signature Title

________________________________ ________________________
Printed Name Date

Available online at www.sciencedirect.com
SCIENCE DIRECT
Biomass and Bioenergy 30 (2006) 715–727
BIOMASS & BIOENERGY
www.elsevier.com/locate/biombioe

The development of short-rotation willow in the northeastern United States for bioenergy and bioproducts, agroforestry and phytoremediation

T.A. Volk[a,*], L.P. Abrahamson[a,b], C.A. Nowak[a], L.B. Smart[b], P.J. Tharakan[c], E.H. White[a]

[a]Faculty of Forest and Natural Resources Management, SUNY-ESF, 241 Illick Hall, Syracuse, NY 13210, USA
[b]Faculty of Environmental and Forest Biology, State University of New York College of Environmental Science and Forestry, 1 Forestry Drive, Syracuse, NY 13210, USA
[c]Energy and Environment Division, International Resources Group (IRG), 1211 Connecticut Avenue, NW, Suite 700, Washington, DC, USA

Accepted 24 January 2006
Available online 23 June 2006

Abstract

Research on willow (*Salix* spp.) as a locally produced, renewable feedstock for bioenergy and bioproducts began in New York in the mid-1980s in response to growing concerns about environmental impacts associated with fossil fuels and declining rural economies. Simultaneous and integrated activities—including research, large-scale demonstrations, outreach and education, and market development—were initiated in the mid-1990s to facilitate the commercialization of willow biomass crops. Despite technological viability and associated environmental and local economic benefits, the high price of willow biomass relative to coal has been a barrier to wide-scale deployment of this system. The cost of willow biomass is currently \$3.00 GJ^{-1} (\$57.30 odt^{-1}) compared to \$1.40–1.90 GJ^{-1} for coal. Yield improvements from traditional breeding efforts and increases in harvesting efficiency that are currently being realized promise to reduce the price differential. Recent policy changes at the federal level, including the provision to harvest bioenergy crops from Conservation Reserve Program (CRP) land and a closed-loop biomass tax credit, and state-level initiatives such as Renewable Portfolio Standards (RPS) will help to further reduce the difference and foster markets for willow biomass. Years of work on willow biomass crop research and demonstration projects have increased our understanding of the biology, ecophysiology and management of willow biomass crops. Using an adaptive management model, this information has led to the deployment of willow for other applications such as phytoremediation, living snowfences, and riparian buffers across the northeastern US.

Keywords: *Salix*; Adaptive management; Incentives; Economics

1. Introduction

Willow (*Salix* spp.) cultivation and use has a long history, going back at least to the Roman Empire in the second century BC, where species of willow such as *S. caprea*, *S. alba* and others were regarded as particularly useful. The Romans used willow for the production of baskets, fences, medicine, and as framing for shields. Across North America, Native Americans understood the biology and benefits associated with willow and used local species for medicinal purposes and as construction material for a wide array of items including sweat lodges, furniture, baskets, rope, whistles, arrows and nets [1]. Coppicing was a common practice among Native Americans, and in some regions willow cuttings were used to stabilize streambanks that were prone to erosion [2]. European immigrants began cultivating willow in the United States in the 1840s in western New York (NY) and Pennsylvania. By the late 1800s willow cultivation for basketry and furniture had spread from the shores of Maryland to the western borders of Wisconsin and Illinois. New York dominated willow cultivation in the US at this time, with 60% of the total reported area and about 45% of the income generated from willow products [3]. However, at the end of the 1800s,

*Corresponding author. Tel.: +1 315 470 6774; fax: +1 315 470 6934.
E-mail addresses: tavolk@esf.edu, tavolk@mailbox.syr.edu (T.A. Volk).

0961-9534/\$ - see front matter © 2006 Published by Elsevier Ltd.
doi:10.1016/j.biombioe.2006.03.001

demand for willow was declining due to competition from cheaper and lower quality material and competition from basket production overseas. By the 1930s only isolated pockets of willow cultivation remained.

The cultivation of willow was revitalized in upstate NY in the mid-1980s at the State University of New York College of Environmental Science and Forestry (SUNY-ESF). The focus was research on cultivation of willow biomass crops as a locally produced, renewable feedstock for bioenergy and bioproducts. Since that time, and with an increased understanding of willow biology and production systems, research and demonstration of willow applications have grown to include agroforestry and phytoremediation.

This paper will summarize the development of willow biomass crops in the northeastern United States and highlight some of the results from almost 20 years of research. The current economic status of willow biomass crops and the impact of recent developments in breeding, harvesting technology, current and future markets for willow biomass, and recent policies at the federal and state level and their impact of the economics of the system will be highlighted. An increased understanding about the biology, ecophysiology and management of willow biomass crops has led to willow being used in other applications such as phytoremediation, living snowfences, and riparian buffers. The status of these efforts in the northeastern United States will be summarized.

2. Development of willow biomass crops in the northeastern United States

As initial research on willow biomass crops in North America and Sweden began to yield encouraging results, and concern about environmental issues related to the use of fossil fuels and declining rural economies grew, interest developed in the concept of a rural-based enterprise centered on willow biomass as a renewable source of energy and woody lignocellulosic feedstock for bioproducts. In the mid-1990s, over 20 organizations formed the Salix Consortium, whose goal was to facilitate the commercialization of willow biomass crops in the northeastern and mid-western regions of the United States. The Consortium included electric utilities, universities, state and federal government agencies, and private companies with expertise in natural resources management and bioenergy. To reach the Consortium's goals a series of simultaneous activities, including research, regional clone-site trials, a large-scale demonstration program, and outreach and education efforts, were initiated (Fig. 1). These activities were aimed at optimizing the production system to produce the highest biomass yields at the lowest cost, educating potential producers so that they could make informed decisions about becoming involved in the production of the crop, educating other key target audiences, and expanding markets for bioproducts and bioenergy.

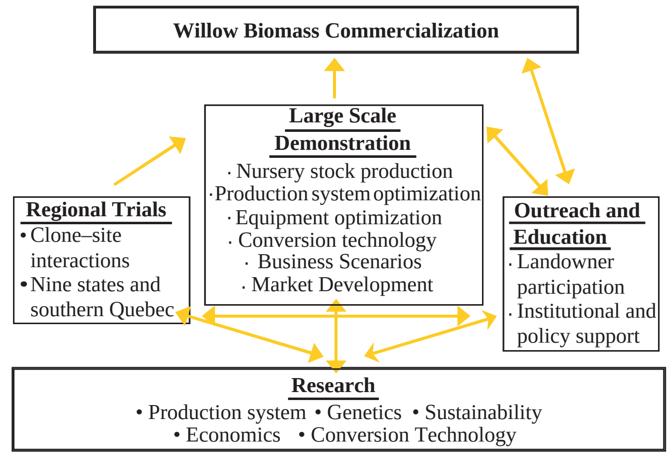


Fig. 1. Components of the Salix Consortium's program that were developed and implemented simultaneously in the 1990s to reach the goal of commercialization.

Collaboration among the members of the Salix Consortium resulted in the establishment of over 280 ha of willow biomass crops between 1998 and 2000 in western and central NY. Valuable experience and information were gained on different aspects of large-scale deployment of willow, including nursery stock production, site and clone selection, management and tending of the crop, pests and diseases, harvesting, and transportation logistics. Smaller clone-site trials, ranging in size from 0.5 to 1.0 ha, were established in 10 states and southern Quebec (Fig. 2). At each site between six and 32 different clones of willow were screened for their suitability to different soils and climate conditions. These trials indicated that shrub willow could be developed across a wide geographical area. Results revealed that several of the clones tested are plastic in nature, meaning that they grow well across a range of sites, while other clones were more site-specific [4].

Yields of fertilized and irrigated willow grown in three-year rotations have exceeded 27 odt ha^{-1} y^{-1} in North America [5] and 30 odt ha^{-1} y^{-1} in Europe [6]. Considering economic limitations, irrigation will probably not be used for most large-scale production operations. However, this work sets a benchmark for the potential of willow shrubs grown in this type of system. First-rotation, non-irrigated research-scale trials in central NY have produced yields of 8.4–11.6 odt ha^{-1} y^{-1} [5,7]. Second-rotation yields of the five best producing clones increased by 18–62% compared to the first rotation [8]. The first commercial-scale harvests of willow biomass crops in North America began in the winter of 2001/2002. First-rotation commercial-scale harvests of the most consistent clones resulted in average yields of 7.5 odt ha^{-1} y^{-1} (Volk, unpublished data). Improvements in different parts of the production system, ranging from improved weed control, breeding new varieties, matching planting density with crown architecture, and optimizing nutrient management, will help reach the production potential of this crop.

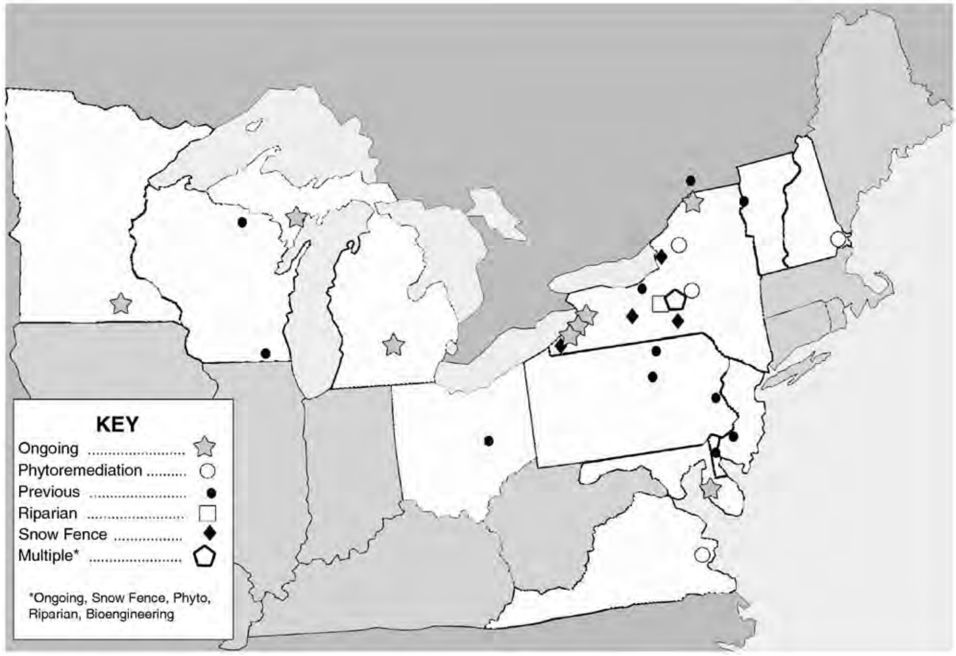


Fig. 2. Location of ongoing and previous willow trials in the northeastern and mid-western United States for biomass production, phytoremediation, living snowfences and riparian buffers.

Research, demonstration and scale-up efforts have been important in refining the production system for willow biomass crops, improving the knowledge base about the biology and ecology of shrub willows, correcting misconceptions about willow biomass crops among the public, policy makers and non-governmental organizations, and quantifying some of the associated environmental and rural development benefits.

Extensive work in Sweden [9], the United Kingdom [10], and Canada [11] contributed significantly to the efforts to develop willow production systems in North America. The basic characteristics of the willow biomass production system involve genetically improved plant material grown on open or fallow agricultural land. Production involves intensive site preparation to control weeds, double-row mechanical planting of 15,300 plants ha^{-1}, nitrogen inputs at the beginning of each rotation, and multiple 3–4 year rotations [12,13].

3. Selected research results on the sustainability of willow

Quantifying environmental and rural development benefits associated with willow biomass crops has been a focused area of research over the past decade. Issues related to soil conservation, biodiversity, CO_2 and energy balances, and socioeconomic impacts of the system have been studied with different levels of intensity. Results from this research have been important in making the case for the sustainability of willow biomass crops [14], which has bolstered public support and encouraged policy decisions at the state and federal level that place value on these benefits.

Concerns expressed by landowners, natural resources and agriculture professionals and other collaborators about erosion on susceptible soils during the establishment phase of willow biomass crops led to research on alternative methods of site preparation. Results indicate that cover crops, like winter rye (*Secale cereale*), and changes in the timing of tillage practices can effectively be incorporated during the establishment of willow without compromising, and in some cases increasing, aboveground biomass production. The approach to managing cover crops during the establishment of willow requires balancing three critical factors, aboveground biomass production, weed control, and residue cover. The most effective management system identified to date that balanced these three critical factors was to establish a rye cover crop in the fall after plowing and disking, kill it with a post-emergence herbicide in the spring, and control new weed growth with pre-emergence herbicides [15]. These results have led to modifications in the establishment of willow biomass crops that allows them to be grown on sloping farmland across the region. The system can be refined further so that soil conservation benefits are realized and associated expenses are minimized. Recent developments in mechanically controlling cover crops in agricultural systems, such as rolling, roll-chopping, undercutting or partial rototilling could be developed as options for using cover crops during the establishment phase of willow. Further research is required to determine the most effective combinations of cover crop species to use, methods and timing of cover crop control, amounts of residue to leave on the soil, and application rates for various pre-emergence herbicides when residues are left on the soil after planting on a range of soil conditions.

A common misconception about willow biomass crops is that they are monocultures, which when deployed across the landscape will create "biological deserts". Mixtures of different species and hybrids of willow are deployed in each field by planting blocks of different varieties across a field or random mixtures of varieties within each row. Years of research on above- and belowground biodiversity in these systems has been essential in correcting misconceptions about diversity in willow crops. Willow crops provide good foraging and nesting habitat for a diverse assemblage of bird species. Seventy-nine bird species were observed in willow plantings, 39 of which were seen regularly [16]. At least 21 species were confirmed breeding in plantings, while another six species were probable nesters due to the persistent territory they established and maintained. Bird diversity in woody crops is greater than in agricultural land and is comparable to natural habitats including shrub land, successional habitats (e.g. abandoned fields, second-growth forest, and regenerating clear-cuts), and intact eastern deciduous forest. These data, together with other information demonstrating that willow biomass crops enhance landscape diversity, have been important in gaining recognition for the diverse environmental benefits associated with willow biomass crops.

Soil microarthropods have been used as an indicator of biodiversity belowground, because they are essential in the decomposition of organic matter and nutrient cycling. Healthy and diverse populations of soil microarthropods are one indicator of a healthy soil. The diversity and density of soil microarthropods under willow immediately after planting is similar to agricultural fields that are tilled annually, but lower than undisturbed fallow fields. However, four years after planting, the density and diversity of soil microarthropods under willow are similar to levels in nearby undisturbed, fallow fields [17]. Because of the perennial nature of the crop, it is anticipated that these levels will be maintained or increased.

Life cycle analysis studies have demonstrated that the production and conversion of willow biomass can produce electrical energy with no net addition of CO_2 to the atmosphere [18]. This means that the amount of CO_2 that is released during the production, harvest, transportation and conversion of the biomass is equal to the amount taken up by the growing crop. Therefore, the production and conversion of willow biomass can produce useable electrical energy with no net addition of CO_2 to the atmosphere. Portions of the willow production system produce other greenhouse gases, so the production of electricity from woody crops has a small global warming potential (GWP) (39–52 kg CO_2 equivalent $MW\,h^{-1}$ of electricity) depending on the conversion technology. This GWP is the same order of magnitude as wind and building integrated photovoltaic systems [19]. While progress can be made to reduce these emissions, especially through better use of N fertilizers, they are far below emissions from coal (over 1000 kg CO_2 equivalent $MW\,h^{-1}$) or natural gas (600 kg CO_2 equivalent $MW\,h^{-1}$) [20]. Quantifying these benefits helps to illustrate the potential of these systems to address concerns with climate change.

The net energy ratio for the production and conversion of short-rotation woody crops (SRWC) is 1:11 for co-firing and 1:16 for a gasification system [18,20]. This means that for every unit of non-renewable fossil fuel energy used to grow, harvest and deliver SRWC, between 11 and 16 units of useable energy are produced. In essence, willow crops are large solar collectors that capture the sun's energy and store it as woody biomass. In contrast, the net energy ratio for ethanol produced from corn is 1:1.3 [21], and 1:0.4 for a natural gas system [20]. Production of willow biomass crops, and other systems with similar positive net energy balances, can be used to address concerns about energy security now and in the future.

Willow biomass crops have the potential to revitalize rural economies by diversifying farm crops, creating an alternative source of income for landowners, and circulating energy dollars through the local economy. While this is an important benefit of this system, it is more difficult to characterize and quantify. Willow biomass crops will be produced in close proximity to end-users because they require a short supply chain due to transportation costs and short storage time. This provides an important link and business relationship between the end-user and local community businesses. Because these feedstocks are available locally, the money that is paid to obtain their energy is spent locally, thereby stimulating the local economy and providing income for local businesses. Modeling efforts have indicated that about 75 direct and indirect jobs will be created and over $\$520,000\,y^{-1}$ in state and local government revenue would be generated for every 4000 ha of willow that is planted and managed as a dedicated feedstock for bioenergy [22].

4. Market development for willow biomass

The development of woody biomass as a feedstock for bioenergy and bioproducts involves the use of multiple sources of material that together creates a year round supply. This is useful for end-users because they are not dependant on a single source of material and the fluctuations that can occur within a single source. With multiple sources, there are varying amounts of supplies available depending on locations and the time of year. The three main sources of woody biomass are: (1) wood residues from wood manufacturing industries; (2) low-value material in forests that is currently being under-utilized; and (3) SRWC, like willow biomass crops. Development and deployment of willow biomass crops will occur as one of multiple streams of woody biomass rather than a sole source of material.

The challenge in large-scale deployment of willow biomass crops is to simultaneously optimize production, develop farmer interest, increase crop acreage, add a new fuel to the power supply, and a new feedstock to the developing value-added bioproduct markets. The scenario remains challenging because there is currently not enough willow biomass established to initiate large-scale use of the material, while at the same time there are currently no long-term commitments assuring producers of a stable market in the future. The time frame from planting to first harvest is typically four years, so there is a larger time gap that needs to be bridged compared to new annual crops that are introduced into the market place. Similar challenges have faced the deployment of willow in other countries as well [23].

The utilities initially involved with the Salix Consortium were actively engaged in the process and had begun to discuss supply agreements with producers of willow biomass crops. However, the sale of power plants was made a requirement of restructuring the energy industry in NY, which dramatically reduced the level of interest and participation among these partners. New owners of the plants have become interested in the concept to a limited degree, but are more sensitive to short-term economic issues since each plant now must operate profitably as a cost center.

There are two coal-fired power plants in NY that have been retrofit to co-fire biomass. The 104 MW Greenidge pulverized coal power plant (originally owned by New York State Electric and Gas, but currently owned by AES) in central NY has been co-firing wood residues at levels up to 10% by heat input for almost a decade. Test firing of willow biomass at Greenidge was performed in the late 1990s and valuable lessons were learned about processing and handling the material. The second location is a 100 MW boiler at the Dunkirk Steam Station (originally owned by Niagara Mohawk Power Corporation (NMPC), but currently owned by NRG Inc.) in western NY. In November 2002, a week-long test of the co-firing system at the Dunkirk Steam Station, including intensive monitoring of emissions, was successfully completed. Over 15 tons of willow were successfully processed and converted to electricity. Over the course of the week a total of 265 tons of woody biomass were processed and co-fired. During the week, 372 MW h of green power were produced, which is enough to meet the weekly electricity demand of about 2000 homes. Emission tests indicated that NO_x, SO_x and particulate matter emissions were reduced when biomass was used. These test results should provide the data necessary to allow NRG Inc. to obtain regulatory approval to pursue commercial co-firing, which will create a market for willow biomass crops.

There are several other facilities across NY where co-firing of coal and woody biomass, including willow, could occur. Estimates indicate that woody biomass used in co-firing situations could contribute almost 300 MW of renewable energy [24]. The production of 1 MW of power would require about 300–325 ha of willow biomass crops, if willow were the sole source of woody biomass for co-firing. Even if willow is one of the multiple sources of woody biomass, developing co-firing in NY has the potential to provide a significant market for willow.

In addition to co-firing facilities, willow biomass can be used as part of the fuel mix in power plants, heating facilities and combined heat and power (CHP) operations that use woody biomass as fuel. These may range from small systems that are primarily used to generate heat or larger biomass facilities that produce heat and power or just power. There are ongoing discussions with biomass end-users to include willow biomass as a part of their fuel mix. Several end-users have expressed interest because it provides another source of feedstock, making them less vulnerable to price and supply fluctuations associated with other sources of woody biomass.

Alternative technologies that will increase the overall conversion efficiency of these systems and improve their environmental benefits are currently in various stages of research and development, including gasification and pyrolysis. These are markets that will develop in the near future. One gasifier feasibility study has been initiated in central NY, and several others are being planned. The size of these gasifiers ranges from 300 kW to 5 MW depending on the application and local demand for heat and power. Other studies have explored the use of willow as a part of the fuel mix for an advanced, high-temperature air-blown gasifier for farm-based power production [25].

In the near future, multiple products will be made from each ton of biomass using the concept of a biorefinery. The biorefinery is based on present day oil refineries, where a barrel of oil is used to simultaneously create multiple products. The model for biomass-based biorefineries is evident today in facilities such as corn to ethanol plants, where liquid fuels, animal feed, CO_2 and other products are produced, or pulp and paper mills, where paper products and heat and power are produced. In the future, biorefineries will fully utilize a ton of biomass to produce a wider array of products, including biobased fuels, specialized and platform chemicals, biodegradable plastics, materials and heat and power, as alternatives to products currently derived from non-renewable fossil fuels. The first generation of wood-based biorefineries is most likely to occur in association with wood-fired power plants or pulp mills. At these locations valuable chemicals can be extracted before the wood chips are used to produce energy or pulp. Lab-scale tests indicate that an extraction which removes about 10% of the energy from willow and sugar maple (*Acer saccharum*) wood chips can add up to $45 of value to a dry ton of woody biomass (Amidon T, personal communication). The development of these value-added bioproducts will spur demand for woody biomass, including willow, in the future. Willow biomass crops can be developed as part of a mix of woody biomass feedstocks because these systems provide large amounts of biomass on a relatively small land base compared to traditional forestry operations.

5. Improving the economics of willow biomass crops

Despite the numerous environmental and rural development benefits associated with willow and other SRWC, and projections of their deployment in the future, their use as a feedstock for bioproducts and bioenergy has not yet been widely adopted in the US. The primary reason is their high cost. Current costs to produce and deliver SRWC to an end-user are \$49.66–57.30 odt^{-1} (\$2.60$-$3.00 GJ^{-1}) [26,27]. On an energy unit basis, these prices are greater than commonly used fossil fuels like coal, which for large-scale power producers in the northeast have averaged \$1.40–1.90 GJ^{-1} over the last few years. A commercial willow enterprise will not be viable unless the biomass price, including incentives and subsidies, is comparable to that of fossil fuels, and parties involved in growing, aggregating and converting the fuel are able to realize a reasonable rate of return on their investment. In some ways this challenge of an economically viable system for willow has not changed in 100 years. At the turn of the century the stated solution to the problem of a declining willow industry was "A good grade of willow must be produced at a lower cost" [3].

There are two pathways to make willow cost competitive with fossil fuels. One is to lower the cost of production by reducing operating costs and increasing yields. The other is to value the environmental and rural development benefits associated with the crop. Ongoing research projects are focused on reducing operating costs and increasing yields. The two areas with the greatest potential for immediate impact are improving yields through traditional breeding and reducing costs by improving harvesting efficiency. Recent policy developments in the federal CRP and Conservation Reserve Enhancement Program (CREP), federal renewable energy tax credits, and state RPS are mechanisms that begin to value some of the benefits associated with willow biomass crops. Their implementation will have a significant impact on the delivered price of willow biomass and the potential to deploy willow biomass crops in the northeast.

5.1. Increasing yield through willow breeding

There is potential to increase yields of shrub willows through traditional breeding and hybridization, largely due to the wide range of genetic diversity across the genus and the historical lack of domestication of shrub willow as a crop. Many species of willow are amenable to hybridization, which can lead to dramatic hybrid vigor. Willow can be quickly and easily propagated vegetatively from stem cuttings, which greatly simplifies and speeds the breeding, screening, and selection process. Once superior individuals are identified (even within a family of otherwise inferior siblings), they can be rapidly propagated for deployment in the production system. A 20% increase in the yield of willow biomass crops decreases the delivered cost by 13% [27].

Major efforts to breed *S. viminalis* as a biomass crop have been progressing for more than 15 years in Sweden [28] and the United Kingdom [29]. This research has provided a large body of information on the inheritance of traits important for biomass production [30–32] and a genetic map to support breeding for desired traits [33]. These long-term breeding programs have produced yield increases of 12–67% in Sweden [34,35] and 8–143% in the United Kingdom [36]. However, the Swedish-bred varieties tested in the US have been severely damaged by potato leafhopper (*Empoasca fabae*), a major pest on alfalfa in the mid-west and northeast US. Import of willow germplasm from the UK into the United States is prohibited due to quarantine of watermark disease. A focused, long-term breeding program is likely to produce similar increases in yield within 5–10 years with species adapted for growth in the US.

Starting in 1995, researchers at SUNY-ESF have been developing the genetic resources and technical expertise to perform controlled pollinations [37], establish nursery screening trials, and evaluate large numbers of progeny. Significant effort has been dedicated to building a large and diverse collection of individuals of many *Salix* species, both native and exotic. Currently, the SUNY-ESF collection, planted at the Tully Genetics Field Station in Tully, NY, includes more than 750 diverse genotypes of willow collected from natural stands across the northern US or acquired from other breeding programs, including varieties from Canada, China, Japan, Sweden, Ukraine, and the western US. Approximately 400 of the varieties in the collection have previously been evaluated in trials. More than 300 accessions of *S. eriocephala*, *S. purpurea*, *S. nigra*, *S. lucida*, *S. cordata*, *S. discolor*, and *S. bebbiana*, among others, have been collected in the last nine years (Fig. 3) and ~90 of those have been evaluated in nursery trials. The breeding strategy, initiated in 1998, involves producing a large number of families, selecting the best individuals from a diverse array of genetic backgrounds, then propagating those individuals for rigorous, replicated selection trials [38].

Through controlled breeding, more than 3000 progeny genotypes have been produced and maintained. Over the last five years, molecular genetic techniques, including amplified fragment length polymorphism (AFLP), microsatellites, and gene sequencing have been used to determine the genetic diversity within the collection, develop clone-specific fingerprints, and examine the relationship between the genetic similarities of parents and the vigor of their progeny [39]. Application of molecular techniques improves the likelihood of selecting individuals for breeding that will produce improved offspring.

In 1998–2000, 68 families of *S. eriocephala*, 13 families of *S. purpurea*, and 23 families involving other species (104 families total) were produced through controlled breeding and planted in nursery screening trials. More than 300 *S. eriocephala* varieties were then randomly selected from 34 of the 68 families, propagated, and grown in replicated

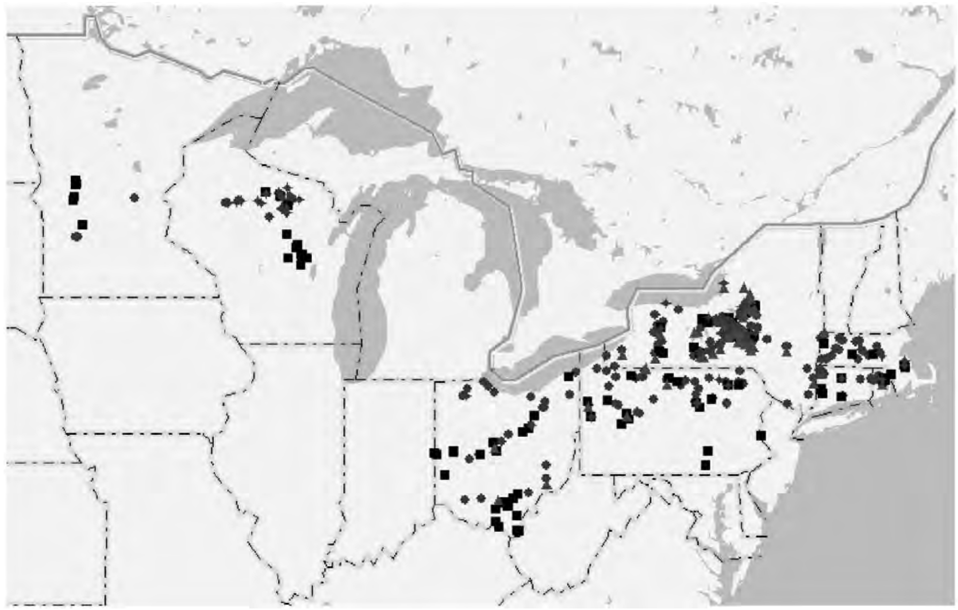


Fig. 3. Locations of shrub willows collected from natural stands in the northeast and mid-west US, propagated, and added to the SUNY-ESF nursery collection from 1995 through 2005. • *Salix eriocephala*; ■ *S. nigra*; ▲ *S. purpurea*; ◆ other *Salix* species.

trials on two sites in central NY. The initial measurements from these trials indicate that traits important for biomass yield are readily passed on from superior parents to their progeny and that a majority of progeny perform better than their parents, displaying hybrid vigor [40]. Progeny of a number of *S. purpurea* families and many inter-specific hybrids displayed vigorous growth, with many of the best individuals having heights close to two standard deviations from the family mean. We have selected individuals in the top 20% of the most vigorous families, propagated them from stem cuttings, and planted them in replicated selection trials for more stringent assessment. Measurements of first-year growth after coppice indicate that some varieties produce up to 140% of the stem area (Smart and Volk, unpublished data) relative to a standard operational variety of *S. dasyclados* (SV1) currently used in large-scale field demonstrations. More than 20 of these new varieties are currently being scaled up for regional clone-site trials, larger yield trials, and eventual deployment in commercial plantings. A new cycle of breeding was initiated in January 2005 that could yield new, improved varieties within 6–8 years.

5.2. Improving harvester efficiency

Improving the efficiency of harvesting and transportation of willow biomass, which accounts for 39–60% of the cost of willow [41,27], can have a significant impact on its delivered price. Increasing harvesting efficiency by 25% can reduce the delivered cost of willow by approximately $0.50 GJ^{-1}. Harvesting systems for willow have been developed over the past 10–15 years in Europe, causing harvesting costs to drop considerably. One of these systems, the Bender, was selected for testing in the US [42], but was unsuccessful due to several factors including higher crop yields and larger diameter material that is being produced in the northeast.

A recent review of cut and chip harvesters, which annually harvest about 2000 ha of willow biomass crops in Europe, indicates that the more successful systems have both higher throughput rates and more power [43]. The most widely used machine, the Claas Jaguar 695, harvests 60 green ton ha^{-1} with 261 kW. However, the Claas cutting head was deemed to be too weak and suffered numerous breakages during the trials with larger willow crops. Large-scale willow demonstration trials in the US have produced yields ranging from 36 to 72 green ton ha^{-1} at the end of the first rotation (Volk, unpublished data). Yields in subsequent rotations are expected to increase by 20–30% [8]. The development of improved varieties of willow through traditional breeding will further increase these yields [38]. In addition, some of the most productive varieties of willow have specific gravities that are 15% higher than most other varieties. Based on experience in Europe, these yields and the higher wood densities will require a harvester with greater than 298 kW [43] and a cutting head, feeding mechanisms and chipping devices that are robust enough to handle the large volume of material. Steps to develop such a system using a Case New Holland FX forage harvester and a specially designed willow cutting head from Coppice Resources Ltd. in the United Kingdom are under way, with full-scale field trials planned for the winter of 2006/2007.

5.3. Recent policy changes that influence the economics of willow biomass crops

5.3.1. Conservation reserve program (CRP)

Land that meets a certain score using an environmental benefits index can be retired from agricultural production and planted with a permanent vegetative cover of grasses or trees that will create wildlife habitat and improve soil and water quality under an agreement with the United States Department of Agriculture (USDA) as part of the CRP. In return, landowners are eligible for annual rent payments for the life of the contract as well as cost sharing funds to offset up to 50% of qualified establishment costs of a vegetation cover [44]. The durations of the contracts are between 10 and 15 years.

Until 2002, harvesting or grazing of land under CRP contract was not allowed, except under emergency conditions such as droughts or similar weather-related emergencies. However, the 2002 Farm Bill modified these restrictions by including a managed haying and grazing option. Managed haying and grazing can occur no more frequently than one out of three years after the cover is fully established on the site [44]. These activities can only take place with approval from the local FSA office and in accordance with the conservation plans drawn up as part of the CRP process. Collaborative efforts with the USDA Farm Service Agency and USDA Natural Resources Conservation Service (NRCS) over the past six years in NY have resulted in the development of state-level guidelines that will make the establishment and harvest of willow biomass crops an acceptable conservation practice under this provision. This will reduce the initial establishment costs for the landowner and provide an annual source of revenue, both of which were barriers that had been expressed by potential producers in the past. The enactment of these policies should encourage the deployment of willow biomass crops across the state.

The implementation of the CREP will further lower the delivered prices for willow biomass grown under this program. CREP is a joint, state and federal land retirement conservation program targeted to improve water quality, erosion control and wildlife habitat related to agricultural use in specific geographic areas. To date 26 states have CREP programs targeting specific areas. In New York State the program includes 12 watersheds. It is a voluntary program that uses financial incentives to encourage landowners to enroll in contracts of 10–15 years in duration to remove lands from agricultural production. Incentive payments for eligible landowners include one time payment of $\$247-371\,\mathrm{ha}^{-1}$, up to 90% of establishment costs, and annual payments at 145% of the CRP rate [45]. Since landowners can enroll in CREP at any time, it will overcome one of the other limitations of the CRP, the restriction that landowners can only sign up during narrow windows designated by the USDA.

5.3.2. Renewable portfolio standards (RPS)

New York has joined 18 other states, seven of which are in the northeast, and the District of Columbia in developing an RPS to increase the proportion of non-fossil fuel electricity purchases in the state. New York's RPS, which when fully implemented in 2013, will require that 25% of the electricity retailed in the state be generated from renewable resources. This is an increase of about 6% from the current baseline of 19%, which is predominantly hydroelectric power. A wide range of sources of biomass have been deemed renewable under the RPS, including energy crops like willow. There are numerous biomass conversion options that have been approved as well [24]. It is anticipated that biomass will make up almost a quarter of the new renewable power generated in the state, about 2300 MW by 2013 [24]. Although the specifics surrounding the implementation of this policy, including how renewable credits will be monitored and traded, are still being developed, the intention is for the RPS to take force during 2006.

5.3.3. Impact of policy changes on willow economics

Without any incentives or supports, the delivered cost of willow biomass has not been competitive with the average costs of solid fossil fuels like coal over the last few years. The delivered price for willow biomass based on current yields is $\$3.00\,\mathrm{GJ}^{-1}$ ($\$57.30\,\mathrm{odt}^{-1}$) [27] compared to the average delivered cost of coal of $\$1.50-2.00\,\mathrm{GJ}^{-1}$ over the last few years. This price includes costs associated with the production, management, harvesting and transportation of willow. The model includes an organization that acts as a biomass broker between the other two players in the system, growers and the end-users. A reasonable internal rate of return is assumed for each player in the model when the delivered price is calculated. Under this baseline scenario, power plants cannot afford to utilize the willow biomass and a commercial willow enterprise cannot exist.

Growing willow on CRP land, with the landowners receiving cost share and annual rental payments, significantly reduces the cost of producing willow feedstock to $\$1.90\,\mathrm{GJ}^{-1}$ [27]. This represents a 33% reduction in the delivered price of the feedstock, relative to the base case scenario. These delivered prices are within the range of current coal costs, especially considering that the commodity spot prices of Appalachian coal have doubled since 2002 [46] making the large-scale deployment and use of willow more likely. However, since the crop is new and both growers and end-users do not have experience with it, this estimate of willow costs is often not enough to stimulate both ends of the market to initiate the development of a commercial enterprise. When the regulations for the RPS in NY are finalized, they may provide enough impetus to make this scenario work. Federal tax credits for power produced using open- and closed-loop biomass were extended in the Energy Policy Act of 2005. The inflation indexed credit is 1.8 cents $\mathrm{kW\,h}^{-1}$ produced using closed-loop biomass in specified co-firing plants or in biomass-fired facilities using other conversion processes. Applying this tax credit to a co-firing situation lowers the cost of willow biomass to about $1.65 GJ^{-1}$ [27], making it competitive with coal. As is the case with CRP, a lack of understanding and experience with willow biomass has restricted entry into the market. In addition, in deregulated power production environments, like NY, power producers are not always able to take full advantage of this tax credit due to their operating structure and profitability.

6. Alternative applications for willow

Shrub willows have numerous inherent characteristics that make them a good choice as a dedicated biomass crop. They have rapid juvenile growth rates, vigorous coppicing ability that is maintained even after multiple harvests, ease of establishment from unrooted cuttings, tolerance of high planting densities, high degree of genetic diversity, and potential for rapid genetic improvement. The biomass production system that is being developed and formalized [13] is based on these characteristics. In addition, willow's perennial nature, extensive and diffuse root systems, high transpiration rates, and tolerance of waterlogged conditions make them potentially beneficial for a wide range of other applications. Years of research and development on willow biomass production systems in the US and Europe has resulted in an increased level of understanding about willow biology. This information is being used to adapt the current willow production system for other applications in the northeastern US including phytoremediation [47], living snowfences [48], and riparian buffers [49]. However, site and socioeconomic conditions for willow plantings associated with these new applications are often different from the agricultural-like settings associated with biomass production. New applications use the knowledge developed from existing willow production systems to frame the design, and then custom tailor it to achieve the greatest success rate under the specific conditions using an adaptive management model [50].

6.1. Developing willow phytoremediation systems

Shrub willows are being used to remediate and contain sites contaminated with various industrial wastes through a process referred to as phytoremediation [51,52]. Willows have been shown to uptake heavy metals and organics from soils (phytoextraction [47]), facilitate the breakdown of organics to non-toxic compounds (rhizodegradation [53]), and control water dynamics, including contaminated groundwater flow and water penetration into soils via evapotranspiration (phytovolatilization and hydraulic control [54]). Willows are useful in phytoremediation due to their perennial nature, fast above- and belowground growth, ability to survive in relatively hostile, wet sites, and high capacity to transpire water. A broad gene pool (there are over 450 species of willow across the world [55] with many more natural and human-developed species hybrids) provides opportunities to develop and screen willow optimized to grow on a wide range of sites and produce specific phytoremediation effects.

Five phytoremediation trials with willow and hybrid poplar are currently under way in the northeastern US in conjunction with SUNY-ESF (Table 1 and Fig. 2). Most trials aim to use willow to control site water problems, either through management of water entering the contaminated site (Solvay trial) or by controlling contaminated groundwater chemistry and flow (Rochester, Fort Drum, and Yorktown trials). All of the trials were established with only a preliminary understanding of how to apply the willow production system for phytoremediation. An adaptive management model [56] has been used to develop tailored systems to reach the specific goals at each location.

Basic questions about the design, establishment and tending of the willow systems at each site existed from the start. Since the conditions at each site are unique, a series of questions need to be addressed at each location. Which varieties to use on sites that have different, and in some cases, quite harsh conditions? What site preparation techniques from large-scale production systems were applicable or needed to be developed? What planting density was optimum to reach the goals of each project?

Table 1
Recently established willow phytoremediation trials in the northeastern United States

Trial location	Establishment year	Phytoremediation method	Site contaminants	Number of clones	Planting density[a] (plants ha^{-1})
Utica, NY	1999	Rhizodegradation	PAHs[b]	8	108,000
Rochester, NH	2000	Hydraulic control	PAHs	8	36,000
Fort Drum, NY	2001	Hydraulic control, rhizodegradation, phytovolatilization	PAHs, herbicides	20	161,000
Yorktown, VA	2004	Hydraulic control	PAHs	8	36,000
Solvay, NY	2004	Hydraulic control	Chloride and other salts	40	15,400

[a]High planting densities, particularly at Utica and Fort Drum, were used to expedite the full occupancy of the site by the planted willow, thereby accelerating any attendant phytoremediation effects caused by the plantations.
[b]PAHs are polycyclic aromatic hydrocarbons.

What pests were of concern? Two of the trials were set up as small-scale, controlled, manipulative, replicated, experiments (Utica and Solvay), where basic information is being produced on water dynamics and rates of contaminant degradation. With the Solvay trial, the high pH and salt concentrations of the soil necessitated the screening of a large number of willow varieties in greenhouse trials before field experiments were established. The three other trials are operational-scale case studies where the willow plantings are expected to contribute to site clean-up through various phytoremediation processes. A fail-safe approach was used to establish these trials. Site preparation was intensive, and unique problems were solved in specific ways at each site. Planting densities were high, and a set of known, plastic (wide ecological amplitude) varieties were used, so that if one or more variety failed (up to 50%), the system would likely still function in relation to phytoremediation processes. All of the operational trials have monitoring schemes to collect data on willow survival, growth and their impact on a site's contamination levels and/or hydrology. Monitoring results have been turned into action, including replacement of poor varieties with new ones or expansion of the proven varieties and adoption of new cultural techniques associated with site preparation and tending. Existing knowledge of the willow production system [13] has been adapted, component by component, to fit each site. In one of the older trials (Fort Drum), a general application of the existing willow biomass production system—clone selection, site preparation, planting, weeding, fertilization, pest management and coppicing—has been transformed over three years into a new system specifically tailored to the conditions and specific phytoremediation clean-up goals on the site. Tailored elements of the system include the featured use of clones usually not well suited for other willow plantation values, very dense plantings to expedite site occupancy (see Table 1), use of manufactured, raised planting beds to mediate excess soil water, and fencing to exclude deer.

6.2. *Developing living willow snowfences*

In areas where snowfall is prevalent, snow blowing across open fields can create dangerous road conditions for the public, require heavy applications of salt and sand, restrict access to emergency services during and after severe winter storms, increase the number of accidents and injuries, and create expensive and challenging situations for road crews to ameliorate. Snow and ice removal costs in the US exceed $2 billion each year, while indirect costs related to corrosion and environmental impacts have been estimated to add another $5 billion per year. Factoring in costs associated with accidents and injuries would further increase this figure [57].

Blowing snow can be controlled using structural or living snowfences, both of which have different benefits and limitations. Plastic or wooden snowfences can reduce blowing and drifting snow immediately, but they have limitations, including capital costs, maintenance and replacements costs, inadequate effectiveness in years of heavy snowfall, and unappealing aesthetics. Living snowfences, which are designed plantings of trees, shrubs and/or grasses [58], can be used to address some of those problems. A 6 m tall living snowfence, with the same density as a regular wooden snowfence, can store almost 16 times more snow and will remain functional throughout the winter [59]. However, living snowfences are often created using slow-growing species that require 6–20 years to become effective [57,58] and require two or more widely spaced rows for effective control. This requires more land than if structural snowfences are used, which is a significant limitation in the northeastern United States, since landowners are less willing to commit strips of land that are several meters wide and roadside rights-of-way are usually narrow. Use of a single row of fast-growing willow shrubs, either alone or as part of a mixed planting design, is one way to address some of the limitations of living snowfences, while capturing their multiple benefits.

The most important characteristics for effective living snowfences are high density of stems and branches during the winter, good height growth, relatively uniform density along the length of the plant and upright form. Shrub willows inherently possess several of these characteristics and others can be manipulated by selecting the right varieties and using different management practices. The density of willow snowfences can be varied by changing the spacing between plants, by coppicing to alter the number of stems on the plants and degree of side branching, and by varying the number of rows of willow planted. Rate of establishment can be modified by changing the size of planting stock, correctly matching varieties to site conditions, which can often be quite harsh, and altering site preparation and snowfence management techniques.

Research on willow for biomass production has produced information on some of these characteristics including aboveground biomass production, stem angles, height growth, and number of stems produced per plant [15,60]. These measurements have been made in high density biomass plantings and experience has shown that some varieties will respond quite differently when planted in single rows in open fields. Using an adaptive management model across a number of different experiments and demonstration sites has resulted in improved designs and a more select list of varieties that will be effective in willow snowfences. In most cases a single row of willow planted at 60 cm intervals is adequate and, if established properly, will result in an effective snowfence in 2–3 years. Some varieties of willow that have a very upright growth habit and limited amount of side branching will require a closer spacing of about 45 cm in order to produce the density necessary to be effective. In areas with limited distances between the roadway and location of the snowfence, multiple rows of closely planted willow may be necessary.

6.2.1. Willow snowfence demonstrations

A living snowfence composed of a single row of willow (*S. purpurea* "*Streamco*") was established in Cortland County, NY in 1993. Effects of the living snowfence were evident as early as the second winter after planting (Dickerson J, personal communication). Density measurements and snow capture patterns collected during the winter of 2000 indicated that density was 65–70%, and the snowfence was effectively trapping the snow blowing across the field (Volk T, unpublished data). The impact of the willow snowfence was apparent to NYS Department of Transportation (DOT) staff, who spent less time plowing this section of the road, and to the landowner, who pulled far fewer cars out of the roadside ditch in front of his farm.

Since 2000, willow snowfence demonstrations ranging in length from 30 to 300 m have been established in five different counties in NY. The siting, design, installation and maintenance of these sites have been a collaborative effort among various agencies including SUNY-ESF, USDA NRCS, state and county DOTs, and Soil and Water Conservation Districts. All the demonstrations are single or double rows of willow established at locations where blowing and drifting snow problems are severe. While the establishment of many of the willow snowfences was successful, there have been cases where they were not. The experience from these trials over the past few years has helped to refine the design and installation and increase the effectiveness of these living snowfences.

6.3. Developing willow riparian buffers

Increasing awareness of the impacts associated with non-point source (NPS) pollution from agriculture and interest in diversifying farming systems is creating opportunities to make use of willow biomass crops in riparian buffers. Water quality is impaired in 60–70% of the streams across the United States [61]. Across the northeast, there are over 88,000 km of riparian areas that do not have any tree or shrub vegetation [62], which makes these waterways especially vulnerable to erosion and NPS pollution.

Riparian buffers have been identified as an effective barrier to soil and nutrient movement from agricultural fields into watercourses. Buffer strips of perennial vegetation along riparian zones reduce overland flow, decrease the amount of sediment and nutrients entering streams, retain chemicals in their rhizosphere for eventual degradation or uptake, improve soil properties such as infiltration rates and stabilize streambanks [63]. Buffer strips improve stream water quality and productivity, and enhance landscape diversity and wildlife habitat. Riparian buffers that include natural stands of trees have been shown to be more effective than grass strips in reducing nitrate (NO_3^-) export, especially during months when other vegetation is dormant [64].

Several characteristics of willow shrubs make them ideal for use in riparian buffers, especially when they are part of a design that uses multiple types of vegetation. The ability of willow to grow vigorously after coppice makes harvesting during the dormant season a potentially viable option. Harvesting on a 3–5-year rotation may improve the long-term effectiveness of riparian buffers, because nutrients are removed from the site so that the buffer does not become saturated and the plants are maintained in a juvenile growth stage with high nutrient demands. The rapid development of an extensive fine root system at a variety of depths is an important attribute for effective riparian buffers. Fine roots (<2 mm in diameter) make up 70–90% of belowground biomass of 2-year-old willow biomass crops [15]. Rapid and extensive fine root development results in the systems becoming functional as nutrient sinks, as sources of carbon for microbial process, and as soil stabilizers soon after they are planted. The abundance and diversity of microorganisms supported in the rhizospheres of woody crops is an important part of the filtering capacity of riparian buffers. Some of these organisms can degrade herbicides, insecticides, and other toxic compounds. Increasing the amount and distribution of roots in the buffers by planting different sizes of cuttings is one approach to enhancing the population of microorganisms, increasing the environmental benefits of the system.

While the characteristics of willow indicate that they should be effective in riparian buffers, the impact of newly established riparian buffers with willow or other woody species is not well quantified. In 2002 and 2003 six willow-grass and six grass-only buffers were established along two streams in central NY. Soil and shallow groundwater in these buffers and adjacent unbuffered cropland is being intensively monitored for NH_4^+, NO_3^-, and P concentrations. Initial results indicate groundwater concentrations of reactive P and NO_3^- are significantly lower in both the grass and willow-grass buffers compared to cropland (Young E, personal communication). Further monitoring and experiments to understand site and soil factors influencing these results and the role of willow is under way.

7. Summary

Decades of research and experience with willow biomass crops in the US and Europe have resulted in the development of a system that is currently at a precommercial stage as an alternative crop. In the near term, co-firing willow biomass with coal can be an economically viable option for power generation if federal and state incentives are applied that value environmental and rural development benefits associated with production and use of biomass feedstock. In the future, other conversion technologies, including a biorefinery model, will provide new markets. Ongoing research will optimize the production system and increase yields, which will further lower delivered costs for willow biomass.

The development and deployment of willow biomass crops in the US and Europe have resulted in an increased level of understanding about willow biology and ecology.

This information is being applied to adapt the current willow production system for phytoremediation, living snowfences, and riparian buffers using an adaptive management model. Using this iterative process, these applications will be optimized in the years to come. In the near future, willow biomass crops will become increasingly prominent in the mid-western and northeastern United States in association with a variety of land management systems. Farmers will use willows as an alternative crop—to produce feedstock for fuel and bioproducts applications—and as vegetation filter strips in riparian areas. Land managers, landscape architects, and engineers will incorporate willow into environmental management systems. The ongoing study of the biological diversity of willow and all aspects of willow culture will, in the future, continue to inform society about other promising applications of willow, including as a feedstock for the production of hydrogen fuel.

Acknowledgments

This work was supported by the New York State Energy and Research Development Authority (NYSERDA), the US Department of Agriculture Cooperative State Research Education and Extension Service (USDA CSREES) and the US Department of Energy through the Biomass Power for Rural Development Program and the Biomass Feedstock Program.

References

[1] Moerman DE. Native American ethnobotany. Portland, OR: Timber Press; 1998.

[2] Shipek F. Kumeyaay plant husbandry: fire, water, and erosion management systems. In: Blackburn TC, Anderson K, editors. Before the wilderness: environmental management by native Californians. Menlo Park, CA: Ballena Press; 1993. p. 379–88.

[3] Hubbard WF. The basket willow. Bulletin No. 46, USDA Bureau of Forestry; 1904.

[4] Kiernan BD, Volk TA, Tharakan PJ, Nowak CA, Phillipon SP, Abrahamson LP, et al. Clone-site testing and selections for scale-up plantings. Final report for the US Department of Energy (DE-FC36-96GO10132), Short-rotation woody crops program at SUNY-ESF, Syracuse, NY; 2003.

[5] Adegbidi HG, Volk TA, White EH, Briggs RD, Abrahamson LP, Bickelhaupt DH. Biomass and nutrient export by willow clones in experimental bioenergy plantations in New York. Biomass and Bioenergy 2001;20(6):389–98.

[6] Christersson L, Sennerby-Forsse L, Zsuffa L. The role and significance of woody biomass plantations in Swedish agriculture. Forestry Chronicle 1993;69(6):687–93.

[7] Adegbidi HG, Biggs RD, Volk TA, White EH, Abrahamson LP. Effect of organic amendments and slow-release nitrogen fertilizer on willow biomass production and soil chemical characteristics. Biomass and Bioenergy 2003;25(4):389–98.

[8] Volk TA, Kiernan BD, Kopp R, Abrahamson LP. First- and second-rotation yields of willow clones at two sites in New York State. Abstract submitted to fifth biomass conference of the Americas, September 17–21, 2001, Orlando, FL; 2001. The abstract is available at ⟨http://bioproducts-bioenergy.gov/pdfs/bcota/abstracts/22/z146.pdf⟩ last accessed January 21, 2006.

[9] Verwijst T. Willows: an underestimated resource for environment and society. Forestry Chronicle 2001;77:281–5.

[10] Armstrong A. Establishment of short rotation coppice. Forestry Commission Practice Note, Edinburgh, UK: 1999.

[11] Kenney WA, Sennerby-Forsse L, Layton P. A review of biomass quality research relevant to the use of poplar and willow for energy conversion. Biomass 1990;21:163–88.

[12] Volk TA, Abrahamson LP, White EH, Kopp RF, Nowak CA. Producing short-rotation willow crops in the Northeastern United States. In: Proceedings of the second short-rotation woody crops operations working group conference; 1999. p. 7–16.

[13] Abrahamson LP, Volk TA, Kopp RF, White EH, Ballard JL. Willow biomass producer's handbook. Syracuse, NY: SUNY-ESF; 2002.

[14] Volk TA, Verwijst T, Tharakan PJ, Abrahamson LP, White EH. Growing energy: assessing the sustainability of willow short-rotation in woody crops. Frontiers in Ecology and the Environment 2004;2(8): 411–8.

[15] Volk TA. Alternative methods of site preparation and coppice management during the establishment of short-rotation woody crops. PhD thesis, SUNY College of Environmental Science and Forestry, Syracuse, NY; 2002.

[16] Dhondt AA, Wrege PH. Avian biodiversity studies in short-rotation woody crops. Final report to the US Department of Energy (DE-FC36-96GO10132), Cornell University Laboratory of Ornithology, Ithaca, NY; 2003.

[17] Minor M, Volk TA, Norton RA. Effects of site preparation techniques on communities of soil mites (*Acari: Oribatida*, *Acari*: *Gamasina*) under short-rotation forestry plantings in New York. USA. Applied Soil Ecology 2004;25:181–92.

[18] Heller MC, Keoleian GA, Volk TA. Life cycle assessment of a willow biomass cropping system. Biomass and Bioenergy 2003;25(2):147–65.

[19] Heller MC, Keoleian GA, Mann MK, Volk TA. Life cycle energy and environmental benefits of generating electricity from willow biomass. Renewable Energy 2004;29(7):1023–42.

[20] Mann MK, Spath PL. Life cycle comparison of electricity from biomass and coal. In: Industry and innovation in the 21st century: Proceedings of the 1999 ACEEE summer study on energy efficiency in industry. American Council for an Energy-Efficient Economy NICH Report No. 27315; 1999. p. 559–69.

[21] Shapouri H, Duffield JA, Wang M. The energy balance of corn ethanol: an update. Agricultural Economic Report No. 814, USDA, Economic Research Service Office of the Chief Economist, Office of Energy Policy and New Uses, Washington, DC; 2002.

[22] Proakis GJ, Vasselli JJ, Neuhauser EH, Volk TA. Accelerating the commercialization of biomass energy generation within New York State. In: Proceedings of the fourth biomass conference of the Americas. Oxford, UK: Elsevier Science Ltd.; 1999. p. 1711–6.

[23] Hilton BS. Establishment, management and harvesting of short rotation coppice at the commercial scale for ARBRE. Aspects of Applied Biology 2001;65:109–16.

[24] State of New York Public Service Commission. Case 03-E-0188—Proceeding on motion of the commission regarding a retail renewable portfolio standard. Order approving implementation plan, adopting clarifications, and modifying environmental disclosure program, Albany, NY; April 14, 2005.

[25] Martin JR, Pian CCC, Volk TA, Abrahamson LP, White EH, Jarnefeld J. Recent results of willow biomass gasification feasibility study. First international energy conversion engineering conference, Providence, RI; August 16–19, 2004.

[26] Walsh ME, Becker D, Graham RL. The conservation reserve program as a means to subsidize bioenergy crop prices. Proceedings of bioenergy 96—the seventh national bioenergy conference, Nashville, TN; September 15–20, 1996.

[27] Tharakan PJ, Volk TA, Lindsey CA, Abrahamson LP, White EH. Evaluating the impact of three incentive programs on cofiring willow biomass with coal in New York State. Energy Policy 2005;33(3): 337–47.

[28] Gullberg U. Towards making willows a pilot species for coppicing production. Forestry Chronicle 1993;69:721–6.
[29] Lindegaard KN, Barker JHA. Breeding willows for biomass. Aspects of Applied Biology 1997;49:155–62.
[30] Rönnberg-Wästljung AC, Gullberg U, Nilsson C. Genetic parameters of growth characteristics in *Salix viminalis* grown in Sweden. Canadian Journal of Forest Research 1994;24:1960–9.
[31] Rönnberg-Wästljung AC, Gullberg U. Genetic relationships between growth characters in *Salix viminalis* grown in Sweden. Theoretical and Applied Genetics 1996;93:15–21.
[32] Rönnberg-Wästljung AC. Genetic structure of growth and phenological traits in *Salix viminalis*. Canadian Journal of Forest Research 2001;31:276–82.
[33] Hanley S, Barker JHA, Ooijen JWV, Aldam C, Harris SL, Åhman I, et al. A genetic linkage map of willow (*Salix viminalis*) based on AFLP and microsatellite markers. Theoretical and Applied Genetics 2002;105:1087–96.
[34] Larsson S. Genetic improvement of willow for short-rotation coppice. Biomass and Bioenergy 1998;15:23–6.
[35] Larsson S. Commercial varieties from the Swedish willow breeding programme. Aspects of Applied Biology 2001;65:193–8.
[36] Lindegaard KN, Parfitt RI, Donaldson G, Hunter T, et al. Comparative trials of elite Swedish and UK biomass willow varieties. Aspects of Applied Biology 2001;65:183–92.
[37] Kopp RF, Maynard CA, Rocha De Niella P, Smart LB, Abrahamson LP. Collection and storage of pollen from *Salix* using organic solvents. American Journal of Botany 2002;89:248–52.
[38] Kopp RF, Smart LB, Maynard CA, Isebrands JG, Tuskan GA, Abrahamson LP. The development of improved willow clones for eastern North America. Forestry Chronicle 2001;77:287–92.
[39] Kopp RF, Smart LB, Maynard CA, Isebrands JG, Tuskan GA, Abrahamson LP. Predicting within-family variability in juvenile height growth of *Salix* based upon similarity among parental AFLP fingerprints. Theoretical and Applied Genetics 2002;105:106–12.
[40] Phillips IS. Quantitative genetics of traits predictive of biomass yield in first- and second-generation *Salix eriocephala*. MS thesis, SUNY College of Environmental Science and Forestry, Syracuse, NY; 2002.
[41] Mitchell CP, Stevens EA, Watters MP. Short-rotation forestry—operations, productivity and costs based on experience gained in the UK. Forest Ecology and Management 1999;121:123–36.
[42] Pellerin RA, Aneshansley DJ, Phelps A, Abrahamson LP, Volk TA. Evaluation of tree harvesters and delivery systems for short-rotation willow crop, ASAE precision forestry session. ASAE Paper No. 995055, Toronto, Canada; 1999.
[43] Hartsough B, Spinelli R. Productivities and costs of short-rotation woody crops harvesting technologies: projections for American plantations. Draft Final Report to Oak Ridge National Laboratory; 2000.
[44] Farm Service Agency. Conservation reserve program haying and grazing acreage. USDA FSA Fact Sheet; 2004.
[45] Farm Service Agency. Conservation reserve enhancement program: New York State. USDA FSA Fact Sheet; October 2003.
[46] Energy Information Agency. Coal news and markets. ⟨http://www.eia.doe.gov/cneaf/coal/page/coalnews/coalmar.html⟩ [last checked August 5, 2005].
[47] Riddell-Black D, Pulford ID, Stewart C. Clonal variation in heavy metal uptake by willow. Aspects of Applied Biology 1997;49:327–34.
[48] Dickerson JA, Barber A. Developing living snowfence practice in the Northeast. In: Buck LE, Lassoie JP, editors. Proceedings of the fifth conference on agroforestry in North America. Ithaca, NY: Cornell University; 1999. p. 122–3.
[49] Riddell-Black D, Alker G, Mainstone CP, Smith SR, Butler D. Economically viable buffer zones—the case for short rotation forest plantations. In: Haycock NE, Burt TP, Goulding KWT, Pinay G, editors. Buffer zones: their processes and potential in water protection. Hertfordshire, UK: Quest Environmental; 1997. p. 228–35.
[50] Nowak CA, Volk TA, Ballard B, Abrahamson LP, Filhart RC, Kopp RF, et al. The role and process of monitoring willow biomass plantations. In: Proceedings of the fourth biomass conference of the Americas, Oakland, CA; 1999. p. 25–30.
[51] Mirck J, Isebrands JG, Verwijst T, Ledin S. Development of short-rotation willow coppice systems for environmental purposes in Sweden. Biomass and Bioenergy 2005;28:219–28.
[52] Licht LA, Isebrands JG. Linking phytoremediated pollutant removal to biomass economic opportunities. Biomass and Bioenergy 2005;28:203–18.
[53] Ebbs S, Bushey J, Poston S, Kosma D, Samiotakis M, Dzombak D. Transport and metabolism of free cyanide and iron cyanide complexes by willow. Plant Cell and Environment 2003;26:1467–78.
[54] Corseuil HX, Moreno FN. Phytoremediation potential of willow trees for aquifers contaminated with ethanol-blended gasoline. Water Resources 2001;12:3013–7.
[55] Argus GW. Infrageneric classification of *Salix* (Salicaceae) in the new world. Systematic Botany Monographs No. 52; 1997.
[56] Baskerville G. Adaptive management: wood availability and habitat availability. Forestry Chronicle 1985;61:171–5.
[57] Taber RD. Controlling blowing and drifting snow with snow fences and road design. Final report prepared for national cooperative highway research program. NCHRP Project 20-7(147); 2003.
[58] Gullickson D, Josiah SJ, Flynn P. Catching the snow with living snow fences. University of Minnesota Extension Service MI7311-S; 1999.
[59] Brandle JR, Nickerson B. Windbreaks for snow management, University of Nebraska Cooperative Extension Bulletin 96-1770-X; 1996.
[60] Tharakan PJ, Volk TA, Nowak CA, Abrahamson LP. Morphological traits of 30 willow clones and their relationship to biomass production. Canadian Journal of Forest Research 2005;35(2):421–31.
[61] Environmental Protection Agency. National water quality inventory: 1992 report to Congress. EPA 841-R-94-00; 1994.
[62] Garrett HE, Buck LE, Gold MA, Hardesty LH, Kurtz WB, et al. Agroforestry: an integrated land-use management system for production and farmland conservation. Resource conservation act (RCA) appraisal of US agroforestry. USDA SCS; 1994.
[63] Schultz RC, Colletti JP, Isenhart TM, Simpkins WW, Mize CW, Thompson ML. Design and placement of a multi-species riparian buffer strip system. Agroforest Systems 1995;29:201–26.
[64] Haycock NE, Pinay G. Groundwater dynamics in grass and poplar vegetated riparian buffer strips during the winter. Journal of Environmental Quality 1993;22:273–8.

ARTICLE IN PRESS

BIOMASS AND BIOENERGY ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Available at www.sciencedirect.com

ScienceDirect

http://www.elsevier.com/locate/biombioe

Energy crops in Ireland: An economic comparison of willow and *Miscanthus* production with conventional farming systems

David Styles[a,*], *Fiona Thorne*[b], *Michael B. Jones*[a]

[a]*Botany, School of Natural Sciences, Trinity College Dublin, Dublin 2, Ireland*
[b]*Rural Economy Research Centre, Teagasc, Malahide Road, Dublin 17, Ireland*

ARTICLE INFO

Article history:
Received 15 May 2006
Accepted 26 October 2007

Keywords:
Miscanthus
Willow
Energy crops
Net present value
Gross margins
Economics

ABSTRACT

Recent full decoupling of EU agricultural subsidy payments from production in Ireland is forecast to result in substantial destocking of grassland over the coming decade. In conjunction with increased energy prices, this presents new opportunities for energy crops. This paper uses extensive literature review and country-specific information on current prices to construct life-cycle cost assessments for production of *Miscanthus* and short-rotation coppice willow (SRCW) in Ireland. Gross margins for different harvest and supply strategies (e.g. chopped or baled harvest for *Miscanthus*; stick or chipped harvest for SRCW) are calculated based on farm-gate biomass prices equivalent to 70, 100 and 130 € t^{-1} dry matter (DM) at maximum 20% moisture content—reduced for some SRCW supply strategies to reflect additional chipping and transport costs, and lower heating values. These are compared with gross margin projections for conventional agricultural systems (dairy, cattle rearing, 'cattle and other', sugar beet, winter wheat, spring barley and set aside) using a net present value approach. Production costs expressed per tonne DM were similar for *Miscanthus* (€37–48) and SRCW (€31–46). Mid-estimate discounted, annualised gross margins ranging between 326 and 383 € ha^{-1} for *Miscanthus*, and between 211 and 270 € ha^{-1} for SRCW, compared favourably with all conventional agricultural systems considered except dairy. These gross margins were based on peak-productivity combustible yields of 14 and 10 t DM ha^{-1} a^{-1} for *Miscanthus* and SRCW. Yield variation will affect gross margins, but low yields were still calculated to realise positive returns. However, the application of high-activity cost estimates for all energy-crop cultivation activities resulted in negative returns for some supply strategies. Recently announced government support for SRCW and *Miscanthus* considerably reduces investment risk for farmers, whilst utilisation of SRCW to treat waste water could substantially increase revenues. Energy crop cultivation has the potential to offer farmers a modestly profitable alternative to declining returns from conventional land uses.

*Corresponding author. Tel.: +353 1 608 3068.
E-mail address: dstyles@tcd.ie (D. Styles).

0961-9534/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biombioe.2007.10.012

1. Introduction

In 2004, Irish greenhouse gas (GHG) emissions were 25% higher than 1990 levels [1], significantly exceeding Ireland's Kyoto Commitment to a maximum GHG emission increase of 13% above 1990 levels over the 2008–2012 commitment period. As a consequence, Ireland will be required to pay hundreds of millions of euro, either in penalties or towards GHG emission reduction schemes in developing countries. Of the 68.5 Mt carbon dioxide equivalents (CO_2 eq.) emitted in Ireland in 2004, 28% were attributable to agriculture [1]. This reflects the large agricultural land area (4.3 M ha) relative to population size (4.24 M people), and the dominance of livestock production within the agricultural sector [2]. Grassland supporting sheep and cattle systems account for 83% of agricultural land area [2] and result in the emission of the potent GHGs methane and nitrous oxide. Approximately 22% of 2004 GHG emissions were attributable to electricity production, and a further 22% to the heating of domestic, commercial and public buildings [3]. Styles and Jones [4] demonstrate the substantial national GHG emission savings possible through the co-firing of energy crop biomass in existing peat and coal power stations, accounting for both displaced livestock production and substituted coal and peat electricity production. Similar savings are possible through the utilisation of energy crop biomass for heating [5].

Recently in the republic of Ireland, the debate regarding the future role of energy crop production has heightened in direct response to a number of issues. Firstly, in response to the reform of the EU Common Agricultural Policy (CAP), Ireland replaced production-indexed farm subsidies with production-'decoupled' single farm payments (SFP) in 2005, based on land area farmed during 2000–2002. Economic modelling of farm-level response to this decoupling of direct payments has indicated that livestock numbers will decline significantly (i.e. 21% reduction in dairy cows; 10% reduction in non-dairy cattle; 26% reduction in sheep numbers from 2002 to 2012 [6]). The land areas dedicated to both cereal production and sugar beet (in response to a reduction in EU sugar-beet price support) are also forecast to decline [7,8]. Secondly, dramatic increases in oil and gas prices have recently made fossil-based electricity and heat production substantially more expensive. These high prices may reflect a new era of higher energy costs perpetuated by limitations in the rate of oil supply and rapidly increasing demand from the growing economies of China and India. Thirdly, the introduction of the EU Emission Trading Scheme (ETS) in 2005, with future CO_2 allowances trading at approximately €15 t^{-1} CO_2 for 2008 [9], will further increase the costs incurred by large-scale fossil-fuel combustion, and provide financial incentives for carbon-neutral fuels, including biomass, under the EU ETS legislation [10,11]. The competitive economics of *Miscanthus* co-firing in peat power stations, and willow wood chip heating in domestic and small-commercial dwellings, are outlined in [12].

One key determinant of whether Ireland will fully respond to the aforementioned drivers for change is the presence of a strong and apparent economic incentive for farmers to become producers of energy crops. Deurwaarder [13] identified uncertainty regarding the cost effectiveness of biofuel production in Europe as one of the major impediments to the development of the sector. There has been no published research on the comparative economics of energy crop production in the republic of Ireland in the recent past. Without some assessment of the economic value of these crops, the future development of bioenergy crops in this region remains uncertain. While similar studies have been undertaken in other countries [14–16], and in N. Ireland [17,18], there is significant scientific merit in establishing work that will specifically determine the potential role of indigenous energy crop production in the republic of Ireland. Hence, this paper explores the current economic outlook for the production of energy crops in Ireland, particularly considering competitiveness with conventional agricultural land uses. The energy crops considered are the fast-growing and high-yielding short-rotation coppice willow (SRCW) and *Miscanthus* × *giganteus* (also referred to as Elephant grass). As of early 2007, these crops became eligible for new government planting and maintenance subsidies (detailed below) [19].

2. Methodology

2.1. Life-cycle cost assessment

Life-cycle cost assessments for 23-year, 7-cut SRCW, and 16 year, 14-cut *Miscanthus* plantations were conducted, based on the farm operation sequences shown in Table 1, and for each of the supply strategies listed in Table 2. Costs for each activity were taken from the literature, and converted to 2006 prices (Table 3) using inflation rates for agricultural inputs up until 2004 [2], and FAPRI-Ireland projections for variable-cost inflation thereafter (Fig. 1). This ensured accurate comparison with FAPRI-Ireland projections for conventional agricultural system gross margins after 2004. Activities outlined in Table 1, and yields outlined in Table 4, are identical to those applied in a previous paper [4], in which life-cycle analysis was used to identify the GHG emission reductions possible through *Miscanthus* and SRCW utilisation.

Fertiliser application rates of 100:20:100 kg ha^{-1} a^{-1} N:P:K were used for *Miscanthus*, following maximum rates suggested by [20]. This covers the crop off-takes of 88, 11 and 95 kg N, P and K per hectare in 13.5 t dry matter (DM) stems as calculated by [21], and is greater than the 80, 10 and 60 kg ha^{-1} a^{-1} replenishment rate used by [22]. Also shown in Table 3 is an estimate of cultivation costs based on new contracts provided by the first Irish agricultural contractor to specialise in *Miscanthus* [23]. They 'guarantee' both successful establishment for a cost of €2470 ha^{-1} to the farmer, and a crop price of approximately €50 t^{-1} at up to 20% moisture content (€63 t^{-1} DM). *Miscanthus* plantations may maintain high productivity for up to 20 years after planting [20,24], but the conservative assumption of a 15-year productive lifetime was applied here (Table 1). Herbicide application on established SRCW plantations is highly dependent on local circumstances, and in many instances may not be necessary due to rapid canopy closure once the crop is established, and the beneficial effect of some ground cover. Here, it was assumed that worst-case scenario herbicide costs of €75 ha^{-1}

Table 1 – Life cycle activities for SRCW and *Miscanthus* cultivation, as applied to LCA in [4], and to life-cycle cost assessment in this paper

Year	SRCW	Year	*Miscanthus*
0	Herbicide application Subsoiling and ploughing	0	Herbicide application Subsoiling and ploughing
1	Herbicide and insecticide (leather jacket control) application Lime application (3 t ha^{-1}) Soil rotovation Planting using a step or cabbage planter at density of 15,000 cuttings per ha	1	Fertiliser application (67, 13 and 67 kg ha^{-1} N, P and K) Lime application (3 t ha^{-1}) Soil rotovation Planting, potato planter at density of 20,000 rhizomes per ha Rolling Herbicide application
2	Coppice Fertiliser application (128, 28 and 178 kg ha^{-1} N, P and K) Herbicide application	2	Fertiliser application (67, 13 and 67 kg ha^{-1} N, P and K) Cut and bale/chop harvest late winter Drying[a] Storage on farm[b]
5	Stick/chip harvest late winter (i.e. winter year 4/5) Drying[a] Storage on farm[b] Fertiliser application (192, 42 and 267 kg ha^{-1} N, P and K) Herbicide application[c]	3–15	Repeat year 2, but apply fertiliser at 100:20:100 kg ha^{-1} N, P and K from year 4 onwards
8	Late winter harvest (i.e. winter year 7/8) Drying[a] Storage on farm[b]	16	Apply herbicide to new growth and plough
9–22	Repeat year 5–8 rotation 5 more times		
23	Remove stools		

[a] Drying depends on harvest method, storage and end use.
[b] Storage dependent on harvest method and end use.
[c] Assume every other rotation.

Table 2 – Harvest and supply strategy abbreviations and descriptions for SRCW and *Miscanthus*

	SRCW				*Miscanthus*		
	S1	S2	C1	C2	C	B	A
Harvest	Stick	Stick	Chip	Chip	Chopped	Baled	Chopped, delayed
Storage	Outdoors, covered	Outdoors, covered	Shed	None	Outdoor, covered	Outdoor, covered	None
Drying	Natural	Natural	Forced, heating	None	Natural	Natural	Delayed harvest
Process	Chip on farm	Bundle	None	None	None	None	None
Supply	Dried chips	Dried sticks	Dried chips	Wet chips	Dried, chopped	Dried bales	Semi-dry, chopped

are incurred every other harvest cycle [25]. Herbicide application is considered necessary only in the establishment year for *Miscanthus*, as leaf-litter ground cover and rapid canopy closure were assumed to suppress weed growth [21].

The 2006 cost estimates shown in Table 3 include low-, mid- and high-cost estimates for each activity, representing the range of values found in the literature. These were used to generate low-, mid- and high-production cost estimates, denoted by the suffices '*a*', '*b*' and '*c*', respectively, applied to supply strategy labels (e.g. S1b refers to mid-cost stick harvest and supply). The most appropriate values were chosen for the 'mid-cost' estimates, based on similarity to Irish circumstances and contemporaneousness. In some instances, it was possible to find only one or two values for specific activities in the literature, or values that included certain fixed costs, such as shed construction and rent, not considered here (see Section 4.1). 'Mid-cost' estimates were thus sometimes at the lower or upper extreme of the quoted literature range, but were considered by these authors to be the most realistic costs. It is clear that there is a wide variation in cost estimates for some activities. Rabbit fencing may be required for SRCW if there are large rabbit populations in the area, and this is considered in the 'high' establishment cost estimate (Table 3). A high degree of certainty may be associated with establishment costs based on data from Rural Generation and the *Miscanthus* contractor [23], who base their

Please cite this article as: Styles D, Thorne F, Jones MB. Energy crops in Ireland: An economic comparison of willow and *Miscanthus* production with conventional farming.... Biomass and Bioenergy (2007), doi:10.1016/j.biombioe.2007.10.012

Table 3 – Costs (adjusted to 2006 prices) associated with each of the activities outlined in Table 1, based on mid-cost estimates from the literature and maximum yields of 12 and 20 t ha^{-1} a^{-1} for SRCW and *Miscanthus*, respectively

Activity	SRCW (€ ha^{-1})				*Miscanthus* (€ ha^{-1})		
	Stick, store, chip	Stick, store	Chip, dry, store	Chip	Chop	Cut and bale	Contractor
Establishment			2736 [25] 1500–3215			2470 [42] 1060–2555	2470
Fertiliser app.			336 [2] 274–494			161 [2] 80–241	161
Herbicide app.			80 [25] 31–80			31 [25] 31–80	31
Harvest	682 [43] 514–1056	682 [43] 514–1056	417 [15] 140–541	417 [15] 140–541	237 [27] 233–237	389 [27] 315–389	237
Dry+store	24 [26] 0–948	24 [26] 0–948	701 [26] 455–948	n/a	110 [27] 28–261	48 [27] 48–141	0
Chipping	243 [32] 112–524	n/a	n/a	n/a	n/a	n/a	0
Removal			517 174–1864			207 154–259	207

The ranges of low to high cost estimates from the literature are also displayed beneath. *Miscanthus* costs based on contractor establishment and immediate off-take are displayed on the right.

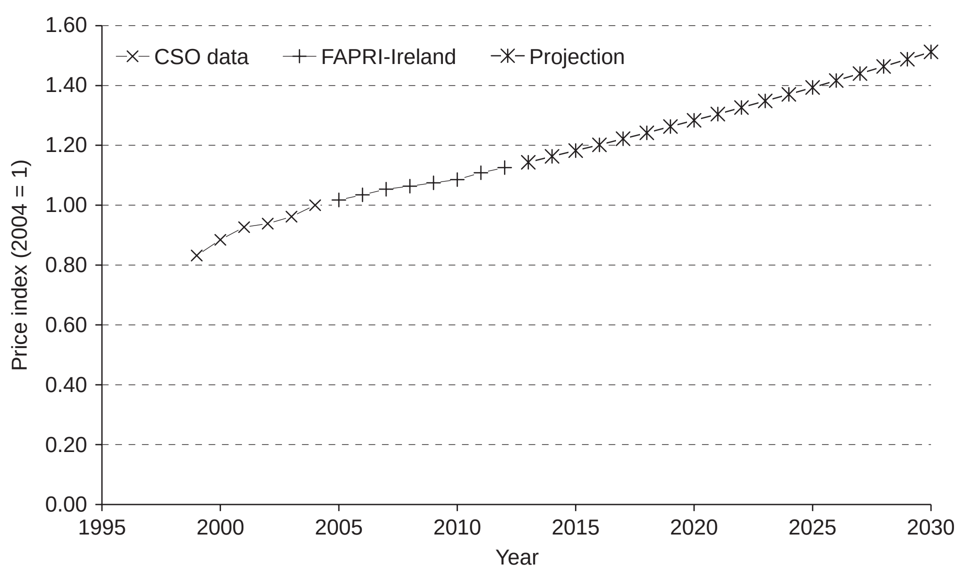


Fig. 1 – CSO, FAPRI-Ireland, and projected price inflation applied to model (*Source*: [2,6]). Projections based on 3-year rolling average extrapolated from FAPRI-Ireland data.

business practice on these costs. In fact, the *Miscanthus* establishment cost quoted by [23] is identical to (and perhaps based upon) the 2006-inflated DEFRA cost estimate. Fertiliser costs, based on average fertiliser prices quoted by [2], are also reliable. In contrast, drying and storage costs varied widely in the literature, depending on the techniques/equipment used and assumptions made in the cost calculations (discussed later), and these were associated with the greatest uncertainty. Fixed shed costs were not included in wood chip storage costs here, and outdoor storage of stick-harvested SRCW and *Miscanthus* under plastic sheeting was assumed [26], for an average of 9.5 months.[1] *Miscanthus* storage costs of €48 and €110 ha^{-1} a^{-1} for baled and chopped material [27], were high compared with SRCW storage costs of €24 ha^{-1} a^{-1} [26], but this may be representative of higher yields and less

[1] Assume at least 6 months required to bring moisture content down to less than 20%, based on [37].

Table 4 – Low, mid and high annualised yield assumptions for SRCW and *Miscanthus*

Yield level	SRCW ($t\,DM\,ha^{-1}\,a^{-1}$)		*Miscanthus* ($t\,DM\,ha^{-1}\,a^{-1}$)	
	Standing	Combust.	Standing	Combust.
Low				
Av. 1st cut (s)	4.0	3.4	9.3	6.5
Subsequent	6.0	5.1	14.0	**9.8**
Plantation av.	5.2	4.4	11.7	8.2
Mid				
Av. 1st cut (s)	8.0	6.8	13.3	9.3
Subsequent	12.0	10.2	20.0	14.0
Plantation av.	10.4	8.8	16.7	11.7
High				
Av. 1st cut (s)	9.3	7.9	17.3	12.1
Subsequent	14.0	11.8	26.0	18.2
Plantation av.	12.2	10.3	21.7	15.2

Yields are divided into those for the first cut (year 4) for SRCW and an average of the first 2 cuts (years 2 and 3) for *Miscanthus*, subsequent maximum annual yields, and plantation lifetime average.
Standing yields refer to above-ground biomass productivity.
Combustible yields refer to net, exportable biomass after harvest and storage losses.

favourable handling/storage properties of *Miscanthus*, so they were applied.

2.2. *Ex ante methods for comparing the economics of energy crops with traditional farming systems*

From the costs listed in Table 2, an economic spreadsheet model, based in Microsoft Excel, was used to evaluate the life-cycle economics of SRCW and *Miscanthus*. A net present value (NPV) approach was adopted, similar to that presented by [28], in which the two perennial energy crops considered were converted to an annual income stream, enabling a comparative economic analysis with competing conventional farming systems. Total costs and returns for the two energy crops over their 16 and 23 year plantation lifetimes were calculated as NPV for the year of plantation using a 5% discount rate, annualised, and expressed per hectare. Where literature values were expressed per t DM they were converted to per hectare costs based on DM yield scenarios set out in Table 3. For *Miscanthus*, leaf senescence, harvest and storage losses were estimated at 30% of DM [29,30], whilst for SRCW, harvest and storage losses were estimated at 15% (though this will vary according to harvest, drying and storage methods [26]). Within each cost level, the model varied fertiliser input, harvest, drying and storage costs in proportion to yield. A number of harvest and supply routes were considered—if energy crops are to continuously supply heat and power generation throughout the year, a range of harvest strategies may be required depending on the time period between harvest and combustion, and the method of combustion [26]. Unless otherwise stated, the main results presented are based on the 'mid-cost' estimates.

In the absence of well-defined markets for energy-biomass in Ireland, with only a pioneer market for wood fuels, the price farmers could expect to receive for energy crop biomass is uncertain, though likely to benefit from recent increases in energy costs. The *Miscanthus* contractor is offering a guaranteed price of approximately €50 t^{-1} of *Miscanthus* at up to 20% moisture content (~€63 t^{-1} DM), and this value is applied to the contractor scenario. Once a demand is established for biomass in Ireland (discussed later), prices may be expected to increase above this value. Here, we have assumed identical prices for *Miscanthus* and wood chips, at 70, 100 and 130 € t^{-1} DM for low, mid and high estimates. These prices are in line with the delivered price of moist wood chips quoted by Rural Generation in Northern Ireland (~€100 t^{-1} DM), and the current wood pellet price of approximately €168 t^{-1} DM in the republic of Ireland [31], considering pellets contain 20 GJ t^{-1} DM energy compared with 18 GJ t^{-1} DM for wood chips at 20% moisture content, and their superior convenience. In the S2 supply strategy, where the farm-gate product is bundled sticks rather than chips, the price of the wood is reduced by €5 t^{-1} DM over the price range considered (i.e. farm-gate prices of €65, €95 and €125 t^{-1} DM). This accounts for the additional cost of (more-efficient) centralised chipping incurred by the consumer (based on the 2006-adjusted prices of €3.52 t^{-1} DM quoted by [26], and €7.68 t^{-1} DM quoted by [32]). Similarly, in the C2 supply strategy, where wet chips are sold immediately after harvest, the price received for them is reduced by the additional transport cost (~€3.24 t^{-1} DM, over 50 km) and according to their lower net heat of combustion.[2] Thus, farm-gate prices of 60, 87 and 115 € t^{-1} DM are applied to C2 supply strategy gross margin calculations. This was done in an effort to normalise farm-gate prices for SRCW, so that a standard product of chipped, dried (max 20% moisture content) wood was being compared among supply strategies.

Energy crop NPVs were compared with gross margins calculated for traditional farming systems in the republic of

[2] LHV of 16.4 GJ t^{-1} DM at 50% MC compared with 18.1 GJ t^{-1} DM at 20% MC [35].

Please cite this article as: Styles D, Thorne F, Jones MB. Energy crops in Ireland: An economic comparison of willow and *Miscanthus* production with conventional farming.... Biomass and Bioenergy (2007), doi:10.1016/j.biombioe.2007.10.012

Ireland; namely specialist dairy farms, specialist beef rearing farms, specialist other beef farms, and sugar beet, spring barley, winter wheat and set aside, as defined by the Teagasc National Farm Survey (NFS). The most up-to-date version of this survey [33] presents 2004 values, but gross margins have been extrapolated up to 2012 in the FAPRI-Ireland model [7,34] based on predictions of the response to the new, decoupled subsidy scheme (Fig. 2). Unfortunately, farm-level FAPRI-projections for sheep farming could not be obtained, and this land use is therefore omitted from the comparison despite its probable high potential for substitution in Ireland. In 2005, there was a large decrease in gross margins associated with each agricultural system, reflecting the decoupling of subsidy payments from production (Fig. 2). The area-based SFP is activated simply by 'farming' the 2000–2002 reference land area in accordance with 'good environmental practises', and so would also be received by farmers growing energy crops. Therefore, this subsidy is not considered in the calculations here. However, the energy-crop-specific EU subsidy of €45 $ha^{-1} a^{-1}$ is considered in the energy crop NPV, as it is activated only by growing energy crops. The CAP also enables farmers to sustain set-aside payments (though not the €45 $ha^{-1} a^{-1}$ subsidy) on set-aside land used for energy crops, so financial comparison of energy cropping with this land use excludes the energy crop subsidy and is based on the maintenance costs for set-aside land [7]. Gross margins in the NFS include labour costs, but not land rental or fixed farm costs. These costs are therefore not considered in the economic analyses of energy crops applied here, following the examples of [14,16,17]. The use of contractor prices for specialised operations such as planting and harvesting ensures that specialised machinery costs are indirectly accounted for.

In early 2007, the Irish Department for Agriculture and Food announced planting subsidies for SRCW and *Miscanthus*, to cover up to half of the establishment costs [19]. Planting on up to 1400 hectares is to be funded in 2007, and will be accompanied by an €80 $ha^{-1} a^{-1}$ energy-crop premium top-up (bringing the total energy-crop premium to €125 $ha^{-1} a^{-1}$, except on set aside). The combined impact of these supports on discounted annual gross margins is included in NPV model runs for *Miscanthus* and SRCW, and the results presented alongside biomass-price sensitivity.

3. Results

3.1. *Production costs for different supply routes*

Fig. 3a displays the total, discounted annual production costs for each hectare of SRCW and *Miscanthus*, up to the farm gate, over plantation lifetimes of 23 and 16 years, respectively. Fig. 3b displays the same costs expressed per t DM product. In both instances, total production costs for each supply route are broken down into major source categories. Discounted, annualised production costs for *Miscanthus* range from €430 to €559 ha^{-1}, or, expressed per unit product, from €37 to €48 t^{-1} DM. These compare with annualised SRCW production costs ranging from €275 to €407 ha^{-1}, or €31 to €46 t^{-1} DM. For *Miscanthus*, the B (baled) harvest strategy was slightly more expensive than the C (chopped) harvest strategy (discounted costs of €48 compared with €43 t^{-1} DM), whilst the A (contractor) supply strategy (delayed, chopped harvest and immediate supply) was the least expensive at €37 t^{-1} DM. For SRCW production, the C1 (chip and dry) supply strategy was the most expensive, though only slightly more costly than the S1 (stick harvest and chip) supply strategy (discounted cost of €46 t^{-1} DM), and the C2 (wet-chip supply) strategy was the least expensive (discounted cost of €32 t^{-1} DM).

For SRCW supply strategies, establishment accounted for the largest portion of production costs (€13 t^{-1} DM), whilst annual harvesting accounted for the largest portion of

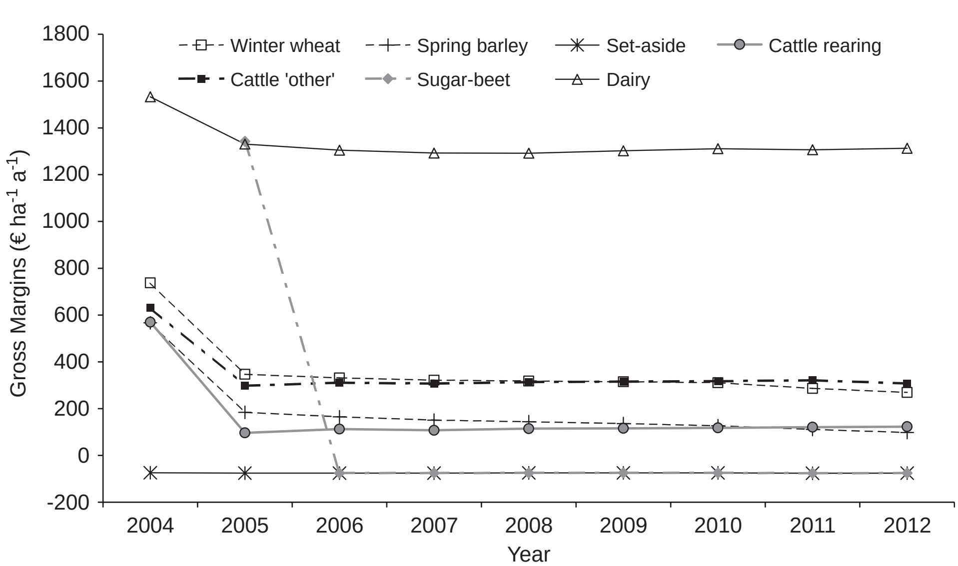


Fig. 2 – FAPRI-Ireland farm-level forecast gross margins for conventional systems, and the range of discounted annualised gross margins for energy crops for reference.

Please cite this article as: Styles D, Thorne F, Jones MB. Energy crops in Ireland: An economic comparison of willow and *Miscanthus* production with conventional farming.... Biomass and Bioenergy (2007), doi:10.1016/j.biombioe.2007.10.012

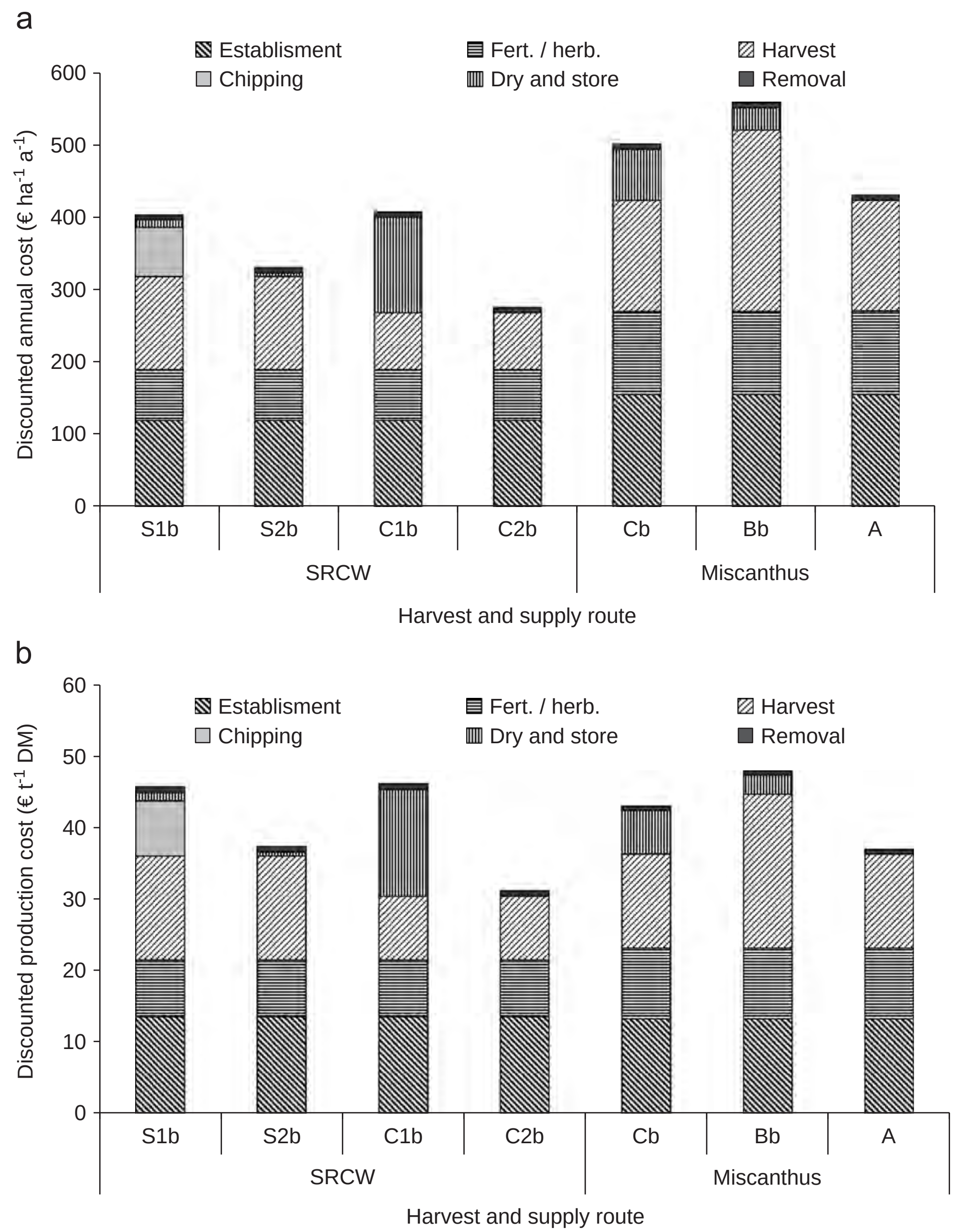


Fig. 3 – 2006 production costs, expressed per hectare (a) and per tonne of combustible dry matter (b) for SRCW and *Miscanthus* broken down into main source categories.

Miscanthus production costs. Drying and storage incurred the largest cost in the case of the SRCW C1 supply strategy (€15 t^{-1} DM), though incurred low costs for the other supply strategies. Fertiliser and herbicide application costs were significant, accounting for approximately one fifth of SRCW production costs (€8 t^{-1} DM) and approximately one quarter of *Miscanthus* production costs (€10 t^{-1} DM). After discounting and division over the crop lifetime, the cost of crop removal made a small contribution to overall costs.

3.2. *Energy crop gross margins and sensitivity analyses*

Table 5 displays annualised discounted profit margins for SRCW and *Miscanthus*, and variation of these margins in response to changed costs, yields and discount rates. Values are centred around mid-costs (Table 3), mid-yields (Table 4), a 5% discount rate, and a biomass price of €100 t^{-1} DM (adjusted to 95 and 87 € t^{-1} DM for SRCW S2 and C2 strategies). These values vary according to low and high estimates for costs, presented in Table 3, yields presented in Table 4, and alternative discount rates of 3% and 8%. Based on the mid-cost and mid-price estimates for energy crop production and sale, discounted, annualised gross margins from SRCW range from €211 $ha^{-1}\,a^{-1}$ for the C1 supply strategy to €270 $ha^{-1}\,a^{-1}$ for the C2 supply strategy (Table 5). For *Miscanthus*, gross margins are €383 and €326 $ha^{-1}\,a^{-1}$ for chopped and baled supply strategies, respectively (Table 5), and €172 $ha^{-1}\,a^{-1}$ in the instance of €63 t^{-1} DM Quinn's price.

Please cite this article as: Styles D, Thorne F, Jones MB. Energy crops in Ireland: An economic comparison of willow and *Miscanthus* production with conventional farming.... Biomass and Bioenergy (2007), doi:10.1016/j.biombioe.2007.10.012

Table 5 – Results of sensitivity analyses, comparing discounted, annualised profit margins (2006 prices) at different cost levels, yields and discount rates

	SRCW (€ ha^{-1} a^{-1})				*Miscanthus* (€ ha^{-1} a^{-1})	
	S1	S2	C1	C2	C	B
Cost						
Low	373	364	385	397	586	519
Mid	245	261	211	270	383	326
High	−139	−71	59	166	103	−13
Yield						
Low	32	44	19	49	270	230
Mid	245	261	211	270	383	326
High	296	314	257	324	609	535
Discount rate						
3%	294	314	251	325	472	405
5%	245	261	211	270	383	326
8%	128	139	102	146	279	232

Mid yield and cost estimates, 5% discount rate, and €100 t^{-1} DM price is applied unless otherwise stated.

Applying the low cost estimates results in substantially higher discounted annual gross margins, of up to €397 and €586 ha^{-1} a^{-1} for SRCW (C2a) and *Miscanthus* (Ca), respectively. Conversely, applying the high cost estimates diminishes discounted annual gross margins, down to −€139 and −€13 ha^{-1} a^{-1} for SRCW (S1c) and *Miscanthus* (Bc), respectively. Positive gross margins were maintained assuming combustible yield reductions of 50% and 30% for SRCW and *Miscanthus*, but were reduced by up to 91% (SRCW-C1) and 30% (*Miscanthus*-C), respectively (Table 5). The assumption of yield increases of 17% and 30% for SRCW and *Miscanthus* resulted in gross margin increases of up to 22% (SRCW-C1) and 64% (*Miscanthus*-B), respectively (Table 5). Discounted *Miscanthus* gross margins exceeded €600 ha^{-1} a^{-1} under the high-yield scenario. Gross margins proved less sensitive to variation in discount rates than to variation in costs and yields. Reducing the discount rate applied from 5% to 3% increased discounted annual per hectare gross margins to between €251 (39% increase) and €325 (20% increase) for SRCW, and to €405 (24% increase) and €472 (18% increase) for *Miscanthus*. Increasing the discount rate applied from 5% to 8% reduced discounted annual per hectare gross margins to between €102 (43% decrease) and €146 (46% decrease) for SRCW, and to €232 (29% decrease) and €279 (27% decrease) for *Miscanthus* (Table 5).

Discounted annual gross margins were highly sensitive to variation in the energy crop biomass price from 70 to 130 € t^{-1} DM (Table 6). At a €70 t^{-1} DM price, SRCW gross margins were reduced to between 33 and 110 € ha^{-1} a^{-1}, and *Miscanthus* gross margins to 109 and 167 € ha^{-1} a^{-1}. At a €130 t^{-1} DM price, SRCW gross margins were increased to between 388 and 436 € ha^{-1} a^{-1}, and *Miscanthus* gross margins to 651 and 708 € ha^{-1} a^{-1}. Incorporating the new 50% establishment grant (up to €1450 ha^{-1}) and €80 ha^{-1} a^{-1} energy-crop premium top-up would result in substantial increases for energy-crop gross margins. The impact is especially great for low farm-gate biomass prices, where gross-margins are increased by between 105% and 352% for SRCW, and by between 87% and 132% for *Miscanthus*. At mid- and high-biomass prices, these subsidies would have a proportionately smaller, but significant, overall effect on discounted annual gross margins. For example, they would increase mid-price gross margins for SRCW by between 43% and 55%, and for *Miscanthus* by 38% and 44%, enabling healthy mid-price discounted gross margins of up to 386 and 527 € ha^{-1} a^{-1} for SRCW and *Miscanthus*, respectively (Table 6).

3.3. *Waste-water treatment*

There is an increasing realisation of the potential to utilise SRCW for biofiltration treatment of wastes and contaminated land, owing to the dense root network and high transpiration rate of willow. Bjorsson [36], and Rosenqvist and Dawson [18], estimated the waste-water treatment capacity of SRCW and attributed values to this, in the contexts of Sweden and Northern Ireland respectively. Figures from [18] were applied here, with the assumption that circumstances should be similar between the North and Republic of Ireland. Their figures comprised an estimated annual cost of €1306 ha^{-1} for capital investment in irrigation ponds, pumps, pipes, pumping costs, labour, etc., and a 100% reduction in fertiliser costs. The potential net annual income from waste-water treatment, assuming full payment of the conventional treatment cost, was estimated at between €1159 and €2947 ha^{-1} depending on conventional treatment method. Here, the mid-point value of €2053 ha^{-1} a^{-1} was used as an estimate of farm revenue from WW treatment, resulting in a net income of €747 ha^{-1} a^{-1}, before discounting. Table 6 displays discounted, annualised gross margins for the range of energy-crop biomass price scenarios, for mid-yield estimates, when WW treatment returns are applied. Assuming a biomass price of €100 t^{-1} DM, WW treatment could raise gross margins substantially to between €774 and €833 per hectare per year for SRCW.

Please cite this article as: Styles D, Thorne F, Jones MB. Energy crops in Ireland: An economic comparison of willow and *Miscanthus* production with conventional farming.... Biomass and Bioenergy (2007), doi:10.1016/j.biombioe.2007.10.012

Table 6 – The impact of varying farm-gate energy crop biomass prices (70, 100 and 130 € t^{-1} DM), use of SRCW for waste-water treatment, and recently announced 50% establishment subsidy with €80 ha^{-1} a^{-1} top-up payment, on discounted, annualised gross margins for different energy crop strategies

Price (€ t^{-1} DM)	SRCW (€ ha^{-1} a^{-1})				*Miscanthus* (€ ha^{-1} a^{-1})	
	S1	S2	C1	C2	C	B
Biomass						
70	68	84	33	110	167	109
100	245	261	211	270	383	326
130	423	439	388	436	708	651
Biomass+WW treatment						
70	631	647	596	673		
100	808	824	774	833		
130	986	1002	951	999		
Subsidy (50% est.+€80 a^{-1})						
70	184	200	149	226	311	254
100	362	377	327	386	527	470
130	539	555	504	552	853	795

3.4. *Comparison with conventional agricultural crops*

Fig. 2 displays the data from the farm-level FAPRI projections for selected conventional agricultural systems, extrapolated from 2004 data, and running until 2012. Most of the conventional agricultural systems exhibit a sharp decline in gross margins between 2004 and 2005, after which they remain relatively stable through to 2012, reflecting the decoupling of subsidy payments from production (and thus exclusion from gross margin calculations) in 2005. Sugar-beet gross margins decline steeply from a high 2005 value of €1342 ha^{-1} a^{-1} to the equivalent of set-side payments in 2006, reflecting the recent announcement that the only sugar processing factory in Ireland is to close. On the other hand, high initial dairy gross margins remain fairly steady at over €1300 ha^{-1} a^{-1} through to 2012.

Fig. 4 compares annualised, discounted (mid-estimate) gross margins for the different conventional agricultural land uses and energy cropping strategies, calculated over the 16 and 23 year timescales of *Miscanthus* and SRCW cultivation, respectively. Both the *Miscanthus* C and B supply strategies prove highly competitive with all but the dairy (€965 ha^{-1} a^{-1}) land uses, whilst the *Miscanthus* A strategy fails to match the gross margins for 'cattle and other' (€229 ha^{-1} a^{-1}) or winter wheat (€214 ha^{-1} a^{-1}) land use classifications, but is competitive with spring barley (€87 ha^{-1} a^{-1}), sugar beet (−€56 ha^{-1} a^{-1}), set aside (−€56 ha^{-1} a^{-1}) and cattle rearing (€88 ha^{-1} a^{-1}). All but the C1 SRCW strategies proved competitive with all the land use classifications except dairy (€867 ha^{-1} a^{-1}). Removing the €45 ha^{-1} a^{-1} subsidy has a small impact on energy crop returns, reducing discounted gross margins for *Miscanthus* by approximately €35 ha^{-1} a^{-1}, and for SRCW by approximately €31 ha^{-1} a^{-1}. Therefore, all energy crop production and supply strategies return gross margins considerably higher than set aside (Fig. 4). The annualised, discounted gross margin resulting from including WW treatment in combination with the mid-range SRCW-S1 strategy (€808 ha^{-1} a^{-1}) proved highly competitive with all land uses, and was only 10% below the average dairy gross margin. Similarly, including the recently-announced energy-crop establishment grant and subsidies significantly elevated energy-crop gross margins compared with most conventional land uses (Fig. 4). This was especially true for the SRCW C2, wet-chip supply strategy, reflecting the lower overheads for this strategy (Fig. 3). For simplicity, these comparisons were made for mid-estimate energy-crop gross margins only. Varying the yield, biomass price and activity-cost estimates (Tables 5 and 6) would substantially alter these comparisons.

4. Discussion

4.1. *Energy crop production costs*

The least certain cost estimates are those for storage and drying. These largely depend on the techniques used, but the range of values in the literature also reflects different methods of calculation. If the shed storage cost of €2.77 t^{-1} DM $month^{-1}$ calculated in [26] was applied in this study, wood chip production would increase in cost by approximately €284 ha^{-1} a^{-1} (assuming 9.5 months average storage). Such fixed costs are not directly considered in the FAPRI-Ireland model projections, or energy crop cost calculations in this study, although machinery costs are indirectly accounted for through contractor costs for planting, maintenance and harvest operations. Flexible harvest timing for SRCW offers the possibility to plan harvesting around storage availability, and [14] ignored fixed costs associated with SRCW production on the assumption that only 10–15% of any farm's land would be converted to SRCW cropping, ensuring that existing facilities would be adequate. For stick-harvested SRCW, and *Miscanthus*, 6 months of outside storage may reduce moisture content to less than 15% [30,37]. In this study, a final moisture content of 20% or less was assumed after

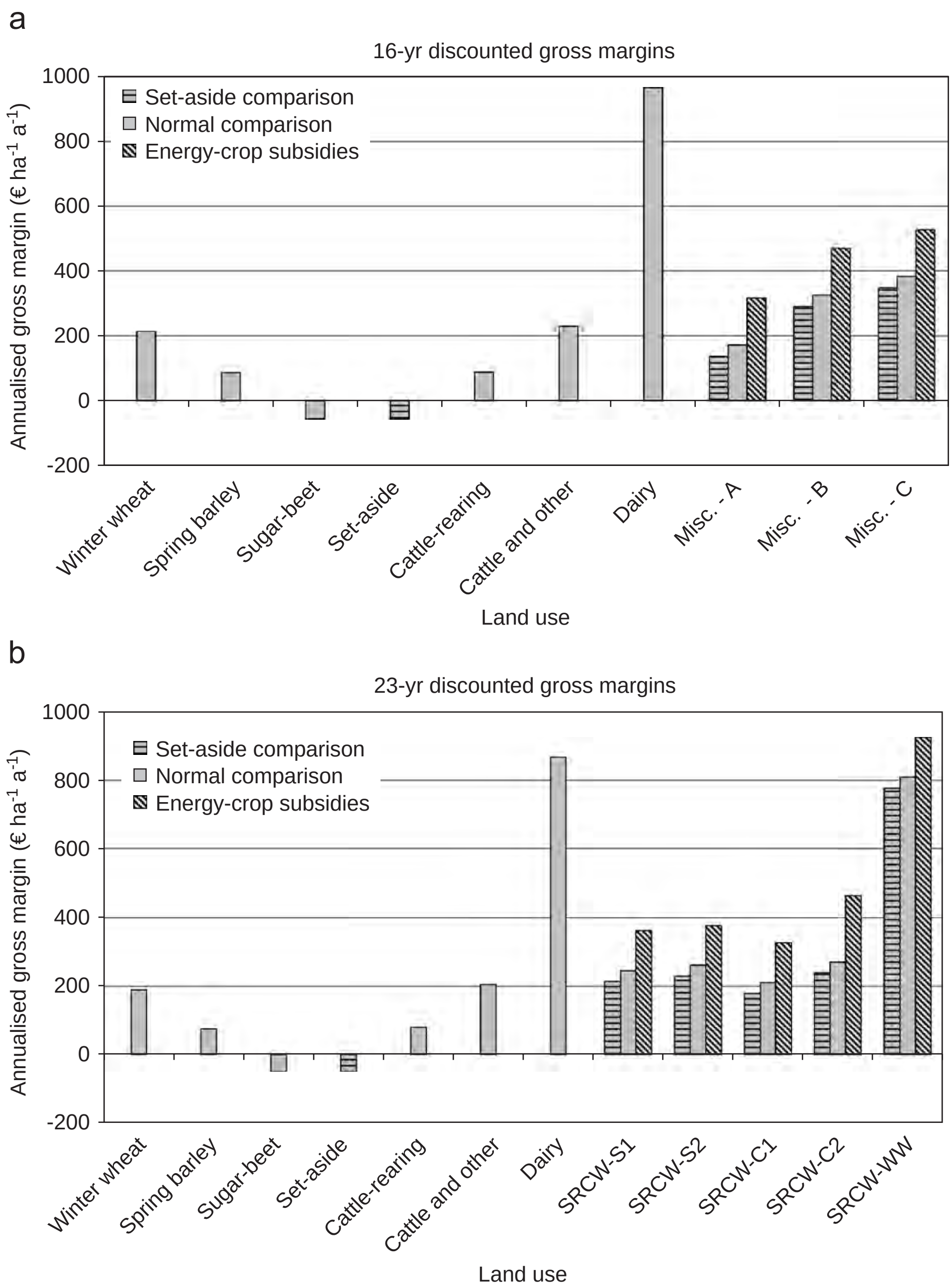


Fig. 4 – Discounted, annualised gross margins for conventional agricultural systems and energy crop plantations over the 16 (a) and 23 (b) year plantation lifetimes of *Miscanthus* and SRCW. Comparisons with set aside (minus €45 ha^{-1} a^{-1} energy crop subsidy), without, and with, additional subsidies, respectively.

outdoor storage under plastic sheeting, at relatively low costs (Table 3). Harvesting SRCW as chips requires the forced drying of wood chips prior to storage, unless moist chips are to be used immediately (e.g. in gasification boilers or large combustion plants) or cheaply dried by the consumer (e.g. using waste process-heat). Forced ventilation drying of wood chips with heated air is expensive, and was calculated to cost between €14 and €29 t^{-1} DM by [38]. Rabbit fencing was not accounted for in the 'mid-cost' estimates, though this cost will only be incurred if there are significant rabbit populations in the area, and will ultimately be highly dependent on the size of the plot. Increasing establishment costs by €500 ha^{-1} to account for rabbit fencing would result in discounted, annualised gross margins decreasing by approximately €22 ha^{-1} a^{-1} (<10%).

Higher costs of production per hectare for *Miscanthus* compared with SRCW reflect the higher fertiliser requirements, annual (compared with 3-yearly) harvesting requirement, and shorter plantation time over which establishment costs are divided for *Miscanthus*. However, these higher costs are compensated for by higher yields, and discounted production costs per tonne of DM (Fig. 2) are similar for SRCW (€32–€47) and *Miscanthus* (€36–€47). In fact, non-discounted, price-inflated costs per tonne of DM are higher for SRCW (€56–€83 t^{-1} DM) than for *Miscanthus* (€52–€67 t^{-1} DM), reflecting the longer discount and price-inflation period used in SRCW calculations (23 compared with 16 years). Sensitivity analyses indicated that the cost of SRCW production was more susceptible to variation in yield and discount rate than *Miscanthus*, reflecting the higher portion of costs (fertiliser application, annual harvest and storage) linked directly with yield, and the shorter crop lifetime, in the instance of *Miscanthus*. The cost of dried wood chip production quoted by [39] (€50 t^{-1} DM) lies between the discounted and non-discounted price-inflated costs of dried wood chip production calculated here.

4.2. Supply strategies

It is apparent that the harvest and supply strategy has a critical impact on production costs, and on additional transport, handling and preparation costs that may be borne by either the producer or consumer. Combined harvest and chipping is cheaper than stick harvest (€417 compared with €682 ha^{-1}), and saves substantial post-harvest chipping costs of €226 ha^{-1} (decentralised), or €106 (centralised), for the *farmer*. If SRCW is to be used as a feed stock for peat power stations, adequate size-reduction may be achieved through chunking, rather than chipping, with decentralised costs of €86 ha^{-1} (based on [26]). Unless chips are immediately used, they incur substantial drying costs of €701 ha^{-1} [26] and will require shed storage space, compared with cheap outdoor stick storage. The lower density of *Miscanthus* enables natural drying of both baled[3] and chopped material [30]. Higher costs for baled harvest compared with chopped harvest (€389 vs €287 ha^{-1}) are partially offset by lower storage costs for baled material (€48 vs 110 ha^{-1}), and may also result in higher combustible yields through collection of senesced leaf material (though this would also increase nutrient uptake and deteriorate combustion properties). Transport of the baled material may also be cheaper, though this should be considered against any necessary disaggregation and chopping costs incurred prior to combustion. Non-adjusted transport and handling costs calculated by [27] of 6.8 and 8.9 € t^{-1} over 20 km for baled and chopped *Miscanthus*, respectively, are considerably higher than biomass transport costs of €4.1 t^{-1} for 50 km calculated for Ireland by [5]. Such costs are difficult to accurately quantify in the absence of national case-studies.

Here, variable costs incurred by the consumer according to the supply strategy are reflected in variable biomass prices: i.e. the chipping costs for supply of stick bundles, and the additional transport costs and reduced LHV of wet wood chips, are translated into reduced biomass prices received for these products. This standardises the product output to an equivalent of chipped, dried (maximum 20% MC) wood chips for SRCW, but has the effect of reducing the impact of supply-strategy on gross margins for farmers. If additional processing costs were borne by the consumer, farmers could realise substantially higher profits. For example, applying the standard farm-gate price of €100 t^{-1} DM to wet wood chip in the NPV model (instead of the adjusted €87 t^{-1} DM), results in the C2 production strategy realising discounted gross margins of €347 (rather than €270) $ha^{-1}\,a^{-1}$. Ultimately, there will be a need for coordination along the supply–consumer chain, and this may optimise cost-sharing between producers and consumers. For example, some large consumers may be able to cost-effectively dry wood chip utilising waste heat (with associated energy-balance benefits compared with forced drying). The lowest-cost supply strategy depends on a number of factors, including moisture content at harvest, the time between harvest and combustion, the method of energy conversion, the possibility to utilise waste heat in drying [26]. Further work is needed to explore the logistics and feasibility of possible energy-cop supply to consumer chains within Ireland, with the aim of optimising the energy balance and economics. The farm-gate biomass prices applied in this paper, for chipped/chopped biomass at 20% moisture content, are used as the input to energy-crop electricity and heat production in a related paper [12].

4.3. Prices and market establishment

The farm-gate price range of 70, 100 and 130 € t^{-1} DM applied here for indicative purposes is based around current actual prices in Ireland's fledgling wood-fuel market. In N. Ireland, Rural Generation is delivering wood chips for around €100 t^{-1} DM [39], and wood pellets are sold for prices of €168 t^{-1} DM in bulk, and up to €333 t^{-1} DM by the bag [31]. Pellets will command significantly higher prices than wood chips due to their higher energy content (20.0 GJ t^{-1} DM compared with 18.1 GJ t^{-1} DM) and superior handling and combustion properties. Irish wood chip prices are high compared with some wood chip price estimates used elsewhere, such as the €40 and €59 t^{-1} DM[4] used by [16] to calculate the economics of willow production in Poland. However, those same authors refer to a wide range of wood chip prices in Europe, citing examples ranging from €47 t^{-1} DM[4] in Germany to €94 t^{-1} DM[4] in Denmark. *Miscanthus* prices are more speculative, as no market exists for *Miscanthus* yet in Ireland. It is assumed that ultimately energy producers may be willing to pay the same price for *Miscanthus* as for wood chip once a market is established, but initially farmers can only expect the farm-gate price of €63 t^{-1} DM offered by the contractors (although presumably this is less than the end consumer is willing to pay). Whilst farmers could maximise farm-gate prices through direct supply to final consumers, intermediaries may prove necessary to hedge some of the risk involved and guarantee contracts for both farmers and consumers. Additionally, as indicated by [17], initial small-scale 'pioneer grower' costs could prove to be higher than cost estimates used here as techniques are adapted to, though this effect could be reduced if contractors are used. It is therefore possible that initial returns for pioneer farmers may be closer to those based on the lower price estimate of €70 t^{-1} DM.

There are signs that momentum is building in the Irish biomass-fuel market, with positive implications for future

[3] Assuming moisture reduction prior to late winter harvest.

[4] Converted from 2003 price expressed per MWh fuel to 2006 price expressed per t DM, based on 5 MWh (18 GJ) t^{-1} DM lower heating value and inflation values in Fig. 1.

Please cite this article as: Styles D, Thorne F, Jones MB. Energy crops in Ireland: An economic comparison of willow and *Miscanthus* production with conventional farming.... Biomass and Bioenergy (2007), doi:10.1016/j.biombioe.2007.10.012

energy-crop biomass prices. In recent years, a small number of wood chip suppliers have begun operating in Ireland, and the relatively new Edenderry peat power-station[5] has recently been taken over by Ireland's peat supply board (Board nà Mona) with the intention of experimentation with alternative biomass fuels. After adding transport costs and tax to the farm-gate prices used in this study, *Miscanthus* and SRCW were calculated to be borderline competitive as fuel for electricity generation compared with peat through co-firing, and highly competitive as a source of heat generation in domestic boilers (even at a farm-gate price of €130 t^{-1} DM) [12]. Upward pressure on energy prices through fossil fuel and CO_2 emission costs may result in large-scale energy producers willing to pay more for biomass fuels in the future, towards the speculative upper price level of €130 t^{-1} DM used here. Rosenqvist and Dawson [17] report that market development in Sweden resulted in a decline in wood chip prices to around €57 t^{-1} DM (~2003) as a consequence of abundant supply from vast forests and large areas of efficient SRCW cultivation. The availability of competing wood sources in Ireland is far lower than in Sweden, with less than 10% of Ireland's national land area forested, compared with 70% under agricultural uses. Utilisation of alternative biomass supplies, such as meat and bonemeal and forestry thinnings, is likely in Ireland, though whether this dampens or primes the market for energy-crop biomass will depend on the scale of future demand for biomass.

The recently announced establishment and annual subsidy top-up payments for *Miscanthus* and SRCW cultivation in Ireland [19] significantly improve NPV calculations for energy-crop plantations, and extend the benefit of energy crops compared with most of the conventional agricultural systems referred to in this study. These payments offer good insurance against gross revenues being diminished by high costs and low yields, and generate a high probability that energy-crop gross margins will be favourable compared with alternative land uses. However, the greatest impact is likely to be the reduced risk and shorter payback period associated with the 50% establishment grant (two-thirds paid in the establishment year, one third in the subsequent year). Worth up to €1450 ha^{-1}, this grant substantially reduces the high initial outlay (2736 and 2470 € ha^{-1} for SRCW and *Miscanthus*, respectively) required from farmers to cultivate these energy crops, and thus reduces the risk-based inertia and payback commitment period.

4.4. *Competitiveness with conventional crops*

The decoupling of subsidy payments from production in January 2005 substantially decreased gross margins attributable to conventional agricultural production, although dairy gross margins remain relatively high. The proposed reform of the EU common market organisation for sugar, and the decision by Irish Sugar to cease processing sugar in 2006, reduces the market based gross margin for sugar beet to levels equivalent to that of set-side land. In combination with the modest EU biofuel subsidy of €45 $ha^{-1}\,a^{-1}$, and recently announced Irish-specific subsidies (for a restricted number of farmers), these factors present a strong opportunity for energy crops, such as *Miscanthus* and SRCW, to compete financially with existing agricultural land uses. When all possible land uses are compared as a stream of future net revenue over the plantation lifetimes of *Miscanthus* and SRCW using the NPV method, annualised returns for these crops prove to be highly competitive with a number of the major current agricultural land uses. In particular, future gross margins predicted for sugar beet, spring barley and cattle rearing are low, and uncompetitive with any of the energy cropping strategies considered here. The most profitable energy-cropping strategies (i.e. SRCW-C2 and *Miscanthus* C) are competitive with all the other land uses considered, except dairy. Well-managed, and planted on good-quality soils, the high DM yields attainable from these energy crops offer relatively high earning potential for farmers compared with current options. Planting on set-aside land is financially an attractive option, but would disrupt current crop rotation systems and may cause some logistical difficulties. Opportunities for multiple uses, such as WW and sewage sludge treatment, further enhance the financial attractiveness of SRCW, and could substantially increase farm revenues.

In addition to biomass price assumptions discussed earlier, calculated returns from energy crops were based on mid-yield and mid-cost estimates, and a discount rate of 5%. Low yields could render SRCW uncompetitive with average gross margins for productive agricultural land uses, although *Miscanthus* remains competitive due to lower yield-related costs (Table 5). If these low yields are caused by poor growing conditions, presumably conventional agricultural productivity would also be impaired, and comparative gross margins would be lower. This may prove to be an advantage for SRCW, which does comparatively well in wet conditions [40]. The greatest potential threat to energy crop gross margins is variation in cultivation costs. The high-cost estimates used in the sensitivity analyses applied here result in negative returns for some energy crop harvest and supply strategies (Table 5). These are highly pessimistic estimates, however, incorporating the highest costs found in the literature for all activities, and include high fixed costs not included in the compared conventional land use gross margins. With respect to the impact of biomass pricing, even at the lower biomass price of €70 t^{-1} DM, returns would be competitive with cattle rearing and spring barley, not to mention set aside and sugar beet. Generally, the annual harvest and higher proportion of yield-related costs make *Miscanthus* less susceptible to variations in the parameters applied to the economic model.

4.5. *Barriers and opportunities*

The main barriers to realising potential energy crop profits are market uncertainty combined with the risk of large upfront establishment costs. Farmers are reluctant to invest into such

[5] A modern circulating fluidised bed boiler design capable of co-firing high proportions of biomass alongside peat with no major modifications. Two similar power stations have recently commenced electricity generation, bringing total peat power station capacity to 375 MW_e.

long-term financial commitments as SRCW and *Miscanthus* plantations before a developed market for biomass emerges. Conversely, potential consumers (householders, building managers, electricity generators) are reluctant to invest in the technology necessary for energy crop utilisation before guaranteed biomass supplies become established. These supplies may initially be dominated by non-energy-crop biomass. There are positive signs of change, in the form of the recently announced *Miscanthus* and SRCW establishment subsidies, and significant consumer subsidies for wood heat (up to €4200 to householders investing in wood boilers and stoves). However, the ongoing challenge will be to coordinate planning of supply strategies between potential consumers and farmers, and to integrate policy between relevant government departments. As indicated elsewhere (e.g. [26]), it is clear that overall supply-chain costs could be reduced through coordinated, logistical planning of supply and utilisation networks.

The higher yields, higher potential profits, shorter period to first harvest, greater similarity with existing cropping practices, and the potential to apply existing farm machinery and techniques, may favour *Miscanthus* over SRCW from a farmer perspective. However, SRCW may be grown on wetter, less agriculturally productive (less profitable) soils, and offers the opportunity to generate extra revenue through WW treatment. Wood chip is also a more suitable fuel than *Miscanthus* for small-scale heating boilers (*Miscanthus* would need to be pelleted, with associated logistical and financial complications). Initial *Miscanthus* utilisation is most likely to occur via co-firing in peat power stations, but broader utilisation could be achieved through research and development into utilisation in smaller boilers (e.g. assessing the feasibility of pelleting), or following gasification or lignocellulosic digestion to produce gaseous/liquid fuels. Further research and development could identify optimum utilisation strategies, in terms of supply chains and inter-sectoral sustainable development policy. For example, if it was decided to use *Miscanthus* as the sole feed stock to achieve the policy target of 30% biomass co-firing in peat power stations, then 34,000 ha of land would need to be planted with *Miscanthus*, with a 3-year delay until peak yields are attained. The extent, and level, of government financial support for farmers will need to be carefully considered and targeted. The recently announced subsidies, directed towards 1400 ha in the first year, may be regarded as an informative pilot scheme.

Ultimately, the comparisons here were based on many assumptions, and used average values. Gross margins within Ireland vary widely according to variations in climate and soil type [41], and management practices on individual farms. Thus, the decision as to whether energy crops are an attractive alternative will vary among farms, and according to the views of individual farmers. However, data presented here indicate that SRCW and *Miscanthus* are promising substitutes to conventional land uses in an emerging era of area-based agricultural subsidy payments and higher energy prices. Future extension of the EU ETS may add further financial incentives for farmers to cultivate *Miscanthus* and SRCW, which have relatively low cultivation emissions and could enhance soil C sequestration [4].

5. Conclusions

On a per hectare basis, *Miscanthus* cultivation is more expensive than SRCW cultivation, owing to higher fertiliser requirements, annual harvest and a shorter lifetime over which establishment costs are absorbed. However, *Miscanthus* is anticipated to produce higher DM yields than SRCW, resulting in similar production costs per tonne DM. Conservative peak combustible yield estimates (after harvest and storage losses) of 14 and 10 t^{-1} DM ha^{-1} a^{-1} were applied to *Miscanthus* and SRCW economic analyses. Crop storage and drying are associated with the greatest uncertainty, and the choice of supply strategy results in variation of these and post-production transport, handling and combustion costs. For SRCW, producing wet wood chip for immediate sale is the most profitable supply strategy, even after prices were adjusted to reflect additional transport costs and reduced LHV compared with dried wood chip. These costs, borne by the consumer, may be mitigated if wood chip is used close to where it is produced, and if process heat can be used for drying (requires coordinated supply chain). Consequently, farmers may not need to reduce the farm-gate prices for wet wood chip supply, enabling higher revenues to be realised. Stick-harvest and outdoor drying may be the most realistic strategy, both from a whole-chain cost and energy-use perspective. For *Miscanthus*, chopped harvest is the cheaper supply strategy when compared with baling, but it may be associated with higher handling costs beyond the farm gate.

Profitability was highly dependent on production costs, and annualised gross margins became negative for some supply strategies when the highest cost estimates were applied. However, profitability was maintained, albeit diminished, when low yields were assumed, owing to the assumed proportionality of many costs to harvestable yield. Variations in the discount rate had a modest, but not critical, impact on discounted gross margins. Gross margins were critically dependent on the farm-gate price of biomass, though remained positive at the low end of the 70, 100 and 130 € t^{-1} DM range applied to both *Miscanthus* and SRCW. The mid price of €100 t^{-1} DM is indicative of current circumstances in Ireland for wood chip, but is more speculative for *Miscanthus*, for which no real market yet exists. Predicted gross margins based on the market establishment efforts of one company are modest, and probably low compared with longer-term potential considering likely future demand for 'C-neutral' biomass fuels.

Compared with gross margins accruing from conventional agricultural land uses, many of which exhibited a marked decline in 2005 after subsidies were decoupled from production, energy crop gross margins predicted here are highly competitive. In particular, average cattle rearing, sugar beet and spring barley systems are forecast to return low or negative gross margins against which discounted energy crop returns of €211–383 ha^{-1} a^{-1} are highly attractive. In addition, although not activating the EU biofuel production subsidy, energy crops grown on set-aside land do activate the set-aside subsidy, and generate a strong financial incentive for cultivation compared with the alternative cost burden of set-aside maintenance. The recently announced government subsidy scheme for *Miscanthus* and SRCW improves the likely returns from these crops, and, more importantly, considerably reduces the investment risk. However, the establishment of an energy-crop biomass market will require significantly higher establishment rates than envisaged under this new scheme.

In conclusion, the main barriers to energy crop production are the high upfront establishment costs in combination with long payback periods, lack of an established biomass market in Ireland associated with future price uncertainties, and a lack of policy coordination among sectors. Dissemination to farmers of energy crop knowledge and opportunities, and an extension of recently announced establishment subsidies in the context of coordinated policy, could promote a new market for energy-crop biomass in Ireland. Research and development work will be needed to identify optimum supply and utilisation strategies from a national perspective. Potential farmer and consumer financial benefits, combined with significant potential GHG emission reductions, should encourage government support for these crops.

Acknowledgements

The authors are grateful to the Irish Environmental Protection Agency for funding provided under the ERTDI 2000-2006 program. In addition, the authors are grateful to Dr. Thia Hennesy from the FAPRI-Ireland farm-level team for providing access to data on the outlook for conventional farming systems.

REFERENCES

[1] McGettigan M, Duffy P, Connolly N, O'Brien P. National inventory report 2006: greenhouse gas emissions 1990–2004 reported to the United Nations framework on climate change. Wexford: Environmental Protection Agency; 2006.
[2] Central Statistics Office website: 〈http://www.cso.ie/〉, last accessed May 2007.
[3] Howley M, O'Leary F, O'Gallachoir B. Energy in Ireland 1990–2004: Trends, issues, forecasts and indicators. Dublin: SEI; 2006.
[4] Styles D, Jones MB. Energy crops in Ireland: quantifying the potential life-cycle greenhouse gas reductions of energy-crop electricity. Biomass and Bioenergy 2007;31:759–72.
[5] Sustainable Energy Ireland. Co-firing with biomass (report prepared by Elekrowatt-Ekono). Dublin: SEI; 2004.
[6] Binfield J, Donnellan T, Hanrahan K, Westhoff P. The Luxembourg CAP reform agreement: implications for EU and Irish Agriculture. Dublin: Teagasc; 2003.
[7] Thorne FS. The impact of the 'Mid Term Review' on Irish tillage farms. In: Proceedings of the national tillage conference 2003. Carlow: Teagasc; 2003. p. 15–38.
[8] Thorne FS. Reform of the common market organisation for sugar: distributional impacts for Irish sugar beet producers. Agricultural Research Forum, Tullamore Court Hotel; 2006.
[9] Point carbon website: 〈http://www.pointcarbon.com/Home/Market%20prices/Historic%20prices/article7342-390.html〉, accessed May, 2007.
[10] EC. Directive 2003/87/EC of the European parliament and of the council of 13 October 2003.
[11] EC. Directive 2004/101/EC of the European parliament and of the council of 27 October 2004.
[12] Styles D, Jones MB. Current and future competitiveness of electricity and heat from energy crops: a case study from Ireland. Energy Policy 2007;35:4355–67.
[13] Deurwaarder EP. Overview and analysis of national reports on the EU Biofuels Directive: prospects and barriers for 2005. The Netherlands: ECN; 2005.
[14] Heaton RJ, Randerson PF, Slater FM. The economics of growing short rotation coppice in the upland area of mid-Wales and an economic comparison with sheep production. Biomass and Bioenergy 1999;17:59–71.
[15] Goor F, Jossart JM, Ledent JF. ECOP: an economic model to assess willow short rotation coppice global profitability in a case of small scale gasification pathway in Belgium. Environmental Modelling & Software 2000;15:279–92.
[16] Ericsson K, Rosenqvist H, Ganko E, Pisarek M, Nilsson L. An agro-economic analysis of willow cultivation in Poland. Biomass and Bioenergy 2006;30:16–27.
[17] Rosenqvist H, Dawson M. Economics of willow growing in Northern Ireland. Biomass and Bioenergy 2005;28:7–14.
[18] Rosenqvist H, Dawson M. Economics of using wastewater irrigation of willow in Northern Ireland. Biomass and Bioenergy 2005;29:83–92.
[19] Department of Agriculture and Food. Minister Coughlan announces details of new bioenergy initiatives. 〈http://www.agriculture.gov.ie/index.jsp?file=pressrel/2007/18-2007.xml〉, accessed February 2007.
[20] Heaton EA, Clifton-Brown J, Voigt TB, Jones MB, Long SP. *Miscanthus* for renewable energy generation: European Union experience and projections for Illinois. Mitigation and Adoption Strategies for Global Change 2004;9:433–51.
[21] DEFRA (UK) Best practice guidelines for applicants to DEFRA's energy crops scheme. London: DEFRA; 2001.
[22] Bullard M. Economics of *Miscanthus* production. In: Jones M, Walsh B, editors. Miscanthus for energy and fibre. London: James and James; 2001 [Chapter 8].
[23] Quinns of Baltinglass. Personal communication by telephone, 30.01.2006.
[24] Lewandowski I, Heinz A. Delayed harvest of *Miscanthus*-influences on biomass quantity and quality and environmental impacts of energy production. European Journal of Agronomy 2003;19:45–63.
[25] Rural generation. Description and costs for willow planting on grass ley. 〈http://www.ruralgeneration.comwww.ruralgeneration.com〉, accessed January 2006.
[26] Gigler JK, Meerdink G, Hendrix EMT. Willow supply-strategies to energy plants. Biomass and Bioenergy 1999;17:185–98.
[27] Venturi P, Gigler JK, Huisman W. Economical and technical comparison between herbaceous (*Miscanthus* × *giganteus*) and woody energy crops (*Salix viminalis*). Renewable Energy 1999;16:1023–6.
[28] Rosenqvist H, Aronsson P, Hasselgren K, Perttu K. Economics of using municipal wastewater irrigation of willow copice crops. Biomass and Bioenergy 1997; 12:1–8.
[29] Clifton-Brown JC, Neilson B, Lewandowski I, Jones MB. The modelled productivity of *Miscanthus* × *giganteus* (GREEF et DEU) in Ireland. Industrial Crops and Products 2000;12:97–109.
[30] Lewandowski I, Clifton-Brown J, Scurlock JMO, Huisman W. *Miscanthus*: European experience with a novel energy crop. Biomass and Bioenergy 2000;19:209–27.
[31] Kerry Biofuels website: 〈http://www.kbf.ie/fuel/plts_lse_brites.htm〉, accessed March 2007.
[32] van Loo S, Koppejan J. Handbook of biomass combustion and co-firing. Enschede: Twente University Press; 2003.
[33] Connolly L, Kinsella A, Quinlan G, Moran B. National farm survey 2004. Dublin: Teagasc; 2005.

[34] Breen J, Hennessy T. The impact of the MTR and the WTO reform on Irish farms. In: Outlook 2003, Medium term analysis for the agri-food sector. Dublin: Teagasc; 2003. p. 78–92 (Conference proceedings).

[35] Matthews RW. Modelling of energy and carbon budgets of wood fuel coppice systems. Biomass and Bioenergy 2001;21:1–19.

[36] Borjesson P. Environmental effects of energy crop cultivation in Sweden-I: identification and quantification. Biomass and Bioenergy 1999;16:137–54.

[37] Gigler JK, van Loon WKP, Sonneveld C. Experiment and modelling of parameters influencing natural wind drying of willow chunks. Biomass and Bioenergy 2004;26:507–14.

[38] Gigler JK, van Loon WKP, Vissers MM, Bot GPA. Forced convective drying of willow chips. Biomass and Bioenergy 2000;19:259–70.

[39] Rural Generation. Personal communication by telephone, 13.02.06.

[40] Londo M, Vleeshouwers L, Dekker J, de Graaf H. Energy farming in Dutch dessication abatement areas: yields and benefits compared to grass cultivation. Biomass and Bioenergy 2001;20:337–50.

[41] Clifton-Brown JC, Stampfl PF, Jones MB. Miscathus biomass production for energy in Europe and its potential contribution to decreasing fossil fuel carbon emissions. Global Change Biology 2004;10:509–18.

[42] DEFRA. Establishment costs for energy crops in England. 〈http://www.defra.gov.uk/farm/acu/pdf/cambridge-estab-costs.pdf〉, last accessed March 2006.

[43] van den Broek R, Teeuwisse S, Healion K, Kent T, van Wijk A, Faaij A, Turkenburg W. Potentials for electricity production from wood in Ireland. Biomass and Bioenergy 2001;26:991–1013.

Nature's Revenue Streams

Five Ecological Value Case Studies

Prepared by:

Aqua-Tex Scientific Consulting Ltd. (1993)

Cori L. Barraclough, M.Sc., R.P. Bio.
Daniel A. Hegg, B.Comm.
and contributors

Sponsored by:

The Canada Mortgage and Housing Corporation
The Federation of Canadian Municipalities

Through a grant to the Corporation of the District of Saanich

December 2008

Acknowledgements

This study was funded by the Canada Mortgage and Housing Corporation and the Federation of Canadian Municipalities (Green Municipal Fund) through a grant to the Corporation of the District of Saanich. Mr. Jas Michalski (FCM) and Ms. Cate Soroczan (CMHC) were instrumental in managing and supporting this project, for which we are indebted. Mr. Colin Doyle and Mr. Dwayne Halldorson (Saanich Engineering) have provided administrative support as well as key information from the municipal perspective. Mr. Gerald Fleming (Saanich Parks) provided essential trail usage information.

Contributors to this report included Mr. Michael Robinson, RICS whom we thank for sharing his expertise in land development economics and valuation. Mr. Wm. Patrick Lucey, R.P. Bio. provided detailed information on the history and implementation of each project. Mr. Rick Lloyd, PEng provided background municipal engineering information for the case studies. Ms. Lehna Malmkvist, R.P. Bio. provided background on South Valley Estates.

We thank Homewood Constructors (South Valley Estates), Cadillac Homes (Willowbrook), Genco Construction Ltd. and Fairwest Construction Ltd. (Baxter Pond), Mr. Ray and Mrs. Judy Galey of Galey Bros. Farms (Blenkinsop) and Mr. Joe Van Belleghem (VITP) for providing information and data about their projects, without which this study could not have happened.

Finally, we extend our thanks to Mr. Chris Corps, RICS, for his efforts on driving forward the agenda of Green Value and helping us all to view the world through a different economic lens.

Table of Contents

List of Figures

Executive Summary

The valuation of ecosystem services has been the subject of considerable study by high profile agencies such as the United Nations (Millennium Ecosystem Assessment) and the World Business Council. These agencies have stressed the need to monetize ecosystem services in order that ecosystems be recognized, and thus protected, by business and management decision-making processes. So-called "green infrastructure" is a key component of urban ecosystems, and building infrastructure to mimic nature's processes in one method of replacing lost ecosystem services within the urban environment. While the ecological value of green infrastructure is readily apparent in the form of green trees, healthy streams and abundant wildlife, its economic significance is less obvious. This study examines five projects that have applied nature's principles in the design of stormwater management facilities and compared their overall value to that of the traditional "pipe and drain" approaches. Focussed largely on stormwater, but with broader attributes, the question raised was whether the projects have tangible economic value, savings or other benefits either to the developer, the occupant, the community, or the municipality.

Figure 1: Leeds Creek (May 2008)

The five case studies examined are all located within the Colquitz River watershed in Saanich, British Columbia. They are: 1) the relocation and restoration of Blenkinsop Creek on the Galey Farm 2) Swan Creek restoration and wetland construction within the Willowbrook Subdivision 3) stream restoration within the South Valley Subdivision 4) Wetland construction adjacent the Rogers Farm Subdivision and 5) permeable paving and swale/wetland construction at the Vancouver Island Technology Park. Aqua-Tex Scientific Consulting Ltd. and their associates completed these projects within the space of a few years between 2000 and 2002. These projects included farmland, residential and institutional development projects that implemented innovative stormwater management practices, and creek and wetland restoration initiatives, as incremental parts of the watershed's gradual restoration.

Many ecological benefits had been noted for each of the projects; however there had been little quantification of the full financial benefit. Following review, the claimed benefits were confirmed in almost every instance by interviewing participants, but in the case of South Valley the information was difficult to substantiate and quantify as it was mostly unobtainable or insufficient to provide adequate estimates. As a result, the South Valley case study does not have a value discussion, but remains in this study as it highlights many barriers with respect to the application of green infrastructure.

Overall, the primary conclusions were:

- There are capital cost savings or avoidance in almost all instances (*i.e.*, an ecological approach is less expensive in terms of initial capital cost, or can avoid larger capital costs that would typically accrue in a traditional approach to stormwater management);
- There is an expected operation and maintenance (O&M) savings that will accrue to the municipality due to the nature of the ecological infrastructure (upon comparison to O&M costs of traditional infrastructure). Continued monitoring in the future will confirm whether O&M costs will remain low in the long term, as the case studies are all relatively recent;
- There is increased value to a developer when applying an ecological approach to a development. However, this is largely received through increased lot yields (*i.e.*, density bonusing), faster development application approvals, faster lot or building sales or rentals, and other related benefits.
- Although many studies have shown that there is an increased market value (rent or sale price) in relation to the distance to green space (or greenways), we found this almost impossible to quantify with any certainty. Lack of sufficient quality data and other external impacts (distance to highway / arterial roads) made identifying any value differential inconclusive; the benefit may exist, but we could neither prove nor disprove it.
- The ecological solutions have operational cost savings, but we identified an instance where the initiatives had not worked (due to poor maintenance) and as a result will increase management costs. This solution may be replaced with a more traditional solution;
- Municipalities can secure savings and extra value from the implementation of ecological solutions; and
- To ensure the success of the ecological solutions reviewed, ongoing management and training of operations staff is desirable or costs may rise.

Economic value and cost-benefit is usually assessed for a single party and it is the developer's profit that usually triggers development. Developers see profit from their perspective, but other values can also arise from projects of this nature. Communities and councillors have different value perspectives, as might neighbours, planners and so on. This may not always be well addressed in the typical assessment of market value, but the overall "Public Interest Value" can be substantial. Multiple people obtain value from projects of this nature and this is not always understood or appraised. In short, multiple stakeholders benefit from projects of this nature. Lastly we note that there will be benefits in reviewing the way that projects of this nature are approved and tracked if the value is to be proven.

Introduction

This project is part of a larger study to "…*assess, monitor, and quantify results from previous alternative stormwater projects and utilize these results to design and test a set of management tools that will assist in promoting ecologically engineered alternative stormwater management and smart urban development*" (Barraclough & Lucey, 2005).

The Federation of Canadian Municipalities, the District of Saanich and the Canada Mortgage & Housing Corporation have sponsored this study, with
Aqua-Tex Scientific Consulting Ltd. acting as the prime consultant and project manager.

Using five case studies, the following report sought to compare the costs associated with traditional stormwater infrastructure solutions to the costs of ecologically engineered alternative stormwater management. Furthermore, this study sought to identify and quantify additional use and non-use benefits that can be derived when ecological infrastructure is applied to manage stormwater. The five case studies examined were:

- The Blenkinsop Creek Restoration;
- The Willowbrook and Glanford Station Developments;
- The South Valley Estates Development;
- The Rogers Subdivision Development, and;
- The Vancouver Island Technology Park (VITP) Development.

In analysing the projects, we have primarily attempted to reconcile their attributes using value equivalents, but have also applied a "Triple Bottom Line" methodology (*i.e.*, assessing the costs and benefits with reference to ecological, social and financial criteria). Triple Bottom Line (TBL) is a widely referenced concept[i] in which attributes are evaluated under the three headings or "accounts" (*i.e.*, economic, social equity, ecology). At the outset of this study, we attempted to stay as closely as possible to valuation standards and guidelines developed by the International Valuation Standards Committee.[ii] However, given the lack of data that met these criteria, supplementary information from published literature and proxy data were required in order to try and fully capture as many of the benefits as possible. Commentary is given on how valuation standards may be augmented to adapt to evaluating sustainable principles. A data collection checklist is also provided to enable future projects of a similar nature to better track and assess their full value.

Scope & Methodology

Scope

This report is to provide an analysis of the value (costs and benefits) of alternative solutions to traditional stormwater management practices within urban environments. The contract specified:

"An economic review and cost benefit analysis of five alternative systems vs. conventional techniques will be documented in case study fashion. These case studies will examine their marketability and profitability in comparison to standard practices by the housing industry. Elements to be considered in the analysis will include: construction cost, operation and maintenance cost, market value and municipal infrastructure cost, ecological benefit, and social benefit (i.e., use a Triple Bottom Line method). Where possible the case studies will note regulatory barriers, incentives, and potential liability issues" (Barraclough & Lucey, 2005).

The five case studies were chosen in conjunction with Aqua-Tex Scientific Consulting to assess the overall benefit of ecologically engineered alternative stormwater management to traditional stormwater design and treatment (piped infrastructure). All the projects were located within the Colquitz watershed in the District of Saanich, BC.

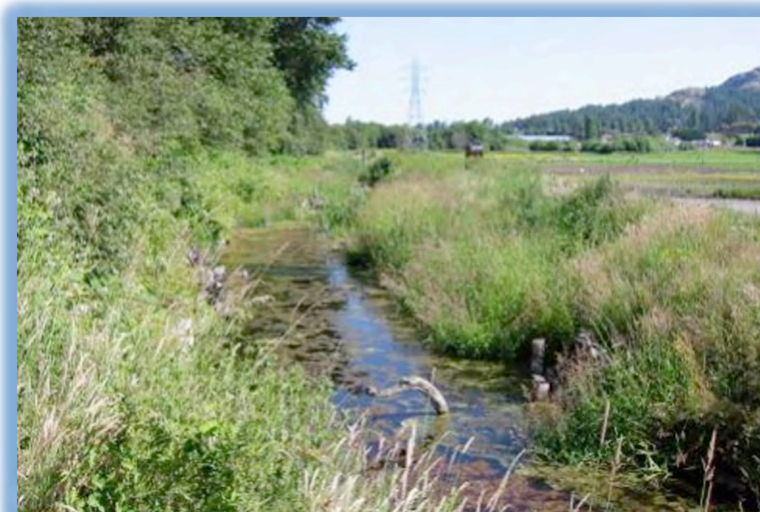


Figure 2: Galeys' Farm Creek Restoration

It was intended that the report assess the differences from each beneficiary's perspective (*i.e.*, taking into account the different benefits for a planner, politician, developer, lender, and so on). We have thus, following discussion with others involved in the case studies, tried to assess and summarize the key benefits and detriments affecting their role in the urban development process. These are summarised both within the each of the case studies and salient aspects are summarised in the conclusions.

Our analysis was not restricted to the information provided to us, nor solely to the participants in each of the case studies. We researched at a preliminary level, literature and best practices that might affect or inform this report, and have provided commentary and reference to these other documents. The scope included providing comments on our findings and we have thus provided observations and recommendations. These include municipal barriers, political, legal and practical impacts affecting a more natural approach to stormwater treatment while concentrating on the relationship of ecological solutions to value (*i.e.*, how financial and non-financial value and efficiency might be improved).

The scope included comparing traditional methods of construction with those chosen for each of the case studies. For example, we attempted to evaluate the use of stormwater drainage as a comparison for creek restoration. It exceeds the project's scope and budget to have detailed designs drawn up and costed for each project; however we approached engineering experts and sought their advice on the likely components for traditional alternatives, using estimates drawn from comparable examples. We then cross-tested opinions against other experts' opinions in an attempt to validate any single individual's opinion, and sought input from non-expert participants[iii].

Figure 3: Grasscrete permeable paving at South Valley

The scope, and thus our analysis, had reference to not only identify the original capital costs of each project, but the maintenance and operational costs as well. This is because the long-term operations, management, finance, and risk associated with each project is normally part of the business case for approving a major capital project. In normal construction, the long-term operations of a building can substantially exceed the original capital costs of construction. Thus, attention to the long-term aspects of a project is just as important as the original construction.

Review/audit difficulty is a challenge when evaluating and reviewing projects that break new ground. When each project was started, the full extent of its benefits was unknown, and each was undertaken for ecological reasons, not solely for financial ones. Therefore, a proper business case was not constructed at the outset of each project and the parameters that needed to be tracked for future review of the benefits were unknown. As a result, neither the financial nor other outcomes were sufficiently tracked or detailed enough to conduct a conclusive review and valuation according to international valuation standards.[iv] To the extent possible, key information was crosschecked, reconciled and the data validated, but this does not provide assurance that all the data are accurate or as reliable as we would prefer. As a result, we were satisfied that, although proper business cases had not been used, each project represented an appropriate investment of taxpayer, private and non-profit investment.

Methodology

The scope of the project encouraged the application of a Triple Bottom Line methodology. Triple Bottom Line is a concept originally put forward by John Elkington in his book "Cannibals with Forks" in which the business case for an activity comprises more than purely an economic exercise and should in-fact measure social, and environmental and economic impacts of an activity as well. As such, the triple bottom line (TBL) methodology is a flexible tool that can be used for corporate *planning* and reporting to help further the goals of corporate social responsibility and sustainable development. Defined by Elkington, the triple bottom line construct “at its narrowest … is used as a framework for measuring and reporting corporate performance against economic, social and environmental parameters. At its broadest, the term is used to capture the whole set of values, issues and processes that companies must address in order to minimize any harm resulting from their activities and to create economic, social and environmental value” (Elkington, 1998).


Figure 4: Ducks in Blenkinsop Creek (Post Project)

The TBL concept is essentially a clever term “for highlighting the non-market and non-financial areas of performance and responsibility: environmental, social and economic,” but its application can be difficult:

“A triple bottom line is not a quest for a new bottom-line metric but rather an approach to management and performance assessment that stresses the importance and interdependence of economic, environmental and social performance. However, the relevant dimensions of corporate performance are not always neatly divided into these three categories, with some companies already talking about a fourth pillar in corporate governance and ethics. Triple bottom line is therefore best seen as a metaphor that encapsulates the task of managing, measuring and publicly reporting multi-dimensional corporate performance” (Suggett & Goodsir, 2002, pg 12).

Since Elkington's original hypothesis, there has been an increasing realization that there are more than three bottom lines, including the political and cultural bottom lines, therefore enabling one to measure or cope with local aboriginal cultures, or in Canada, First Nation historical interests. While this was included in the review, preliminary discussions and initial review of texts relating to the sites suggested there was limited cultural history to be considered, albeit Galeys’ Farm was adjacent to a former rail alignment that had been preserved and had cultural value.

Methods

The methods used in this study require explanation as they provide insight into how the analysis was undertaken and the limitations of the conclusions.
In attempting to analyse the differences in value and cost/benefit of natural solutions we have used direct monetary methods or proxies to assess value.

The two main direct monetary valuation methods applied were: the direct comparison or investment methods, and the cost method:

- The direct comparison method looks at examples of similar projects or aspects, where the values are known, to conclude a value. For example, if one house on a street sells for $x, then a similar house next door that's comparable, is probably worth a similar amount of money;
- The cost method uses costs to conclude the value of something. For example if it costs $x to build a creek, then the theory is that the total cost is what the project is "worth" to the owner (*i.e.*, the cost of the project, which they would not have undertaken if the cost was too high).

Figure 5: Recycled Curbing at VITP

In practice, the methods used in evaluating the five projects had to be adapted to use proxies for estimates of costs, revenues, and social benefits because many of the case studies were found to lack sufficient information recorded in a usable/accessible way, therefore limiting our capacity to identify the actual project expenses and revenues.

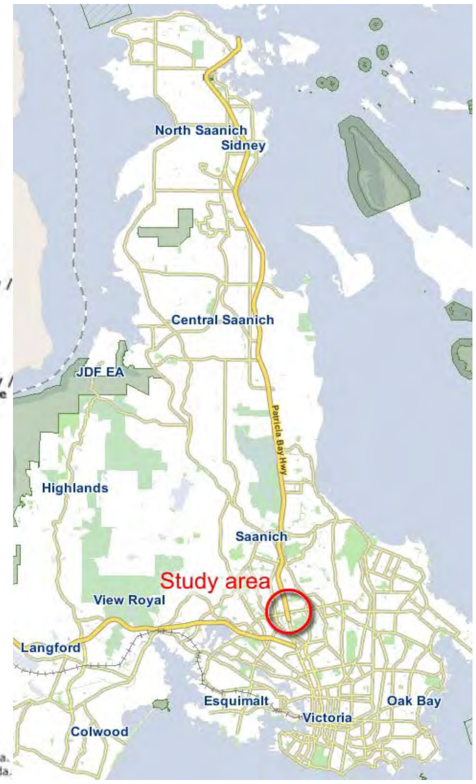
For example, in the Blenkinsop Creek Restoration, much of the benefits of the project could not be tracked by comparing yearly crop yields pre- and post-project, because of the nature of crop rotation and plantation schedules, method of land management, and the change in global/local produce markets. Furthermore, as some benefits were related to the project itself, other external and unrelated factors affected the farm viability. By comparison, more direct methods could be applied to assess how much time was saved in an average year (*i.e.*, multiply by the hourly gross wages and translate this to a financial benefit based on cost).

As such, the benefits derived from each project were evaluated and the components assessed. The benefits were discussed in non-financial terms and we then assessed values or value equivalents to each aspect, where possible. We then developed (or considered) a business case discussing how each project might have been undertaken if they had not been done with sustainable methods (*i.e.*, comparing what was done with more traditional methods, for example using storm sewers instead of swales). This was assessed with input from current and former Saanich staff, consultants, and Aqua-Tex staff. We then undertook a comparison cost/revenue analysis for each aspect of the costs and benefits for the "traditional" method of development. Differences between the "ecological" approach and "traditional" approach were then compared and stabilised to the extent possible. Values that could not accurately be identified were estimated using proxies identified in the valuation literature. To ensure that our approach is as conservative as possible, we have split our value analysis into three different tables (traditional, sustainable, and estimated additional benefits) for each project. The traditional and sustainable tables strictly compare the hard costs and benefits between “traditional” and “sustainable” projects that could be tangibly proved with hard data; the third table, “estimated additional benefits” includes the estimated values of benefits that we derived from the literature in order to provide a more holistic analysis. The present value analysis for each heading is separate and discrete for clarity. The present values from the three tables are combined and are totalled as a net benefit.

Once the projects had been identified and chosen with Aqua-Tex, we jointly inspected them discussing what the extent of the potential business case for each project might be, the complexity involved, and probability of producing a good analysis. One project was rejected and replaced as a result. We then completed on-site videotaped discussions with Aqua-Tex explaining the project. The tapes were reviewed and distilled to create the overall project summaries and areas for further research were noted. The next step was to internally discuss the approach to a business case for each component of each project. The immediate difficulties identified were the lack of sufficient or reliable data, differences of approach or opinion, and the lack of available of evidence. Furthermore, we found there was some uncertainty over costs, with interviewees' memories proving inconsistent. This led to a review of data in an attempt to validate the information provided by various sources. We have used our best estimate from the information available and where the data appears unreliable have we noted our reservations.

Figure 6. Willowbrook Subdivision with wetlands in the foreground and Swan Creek on the right.

Location Plans



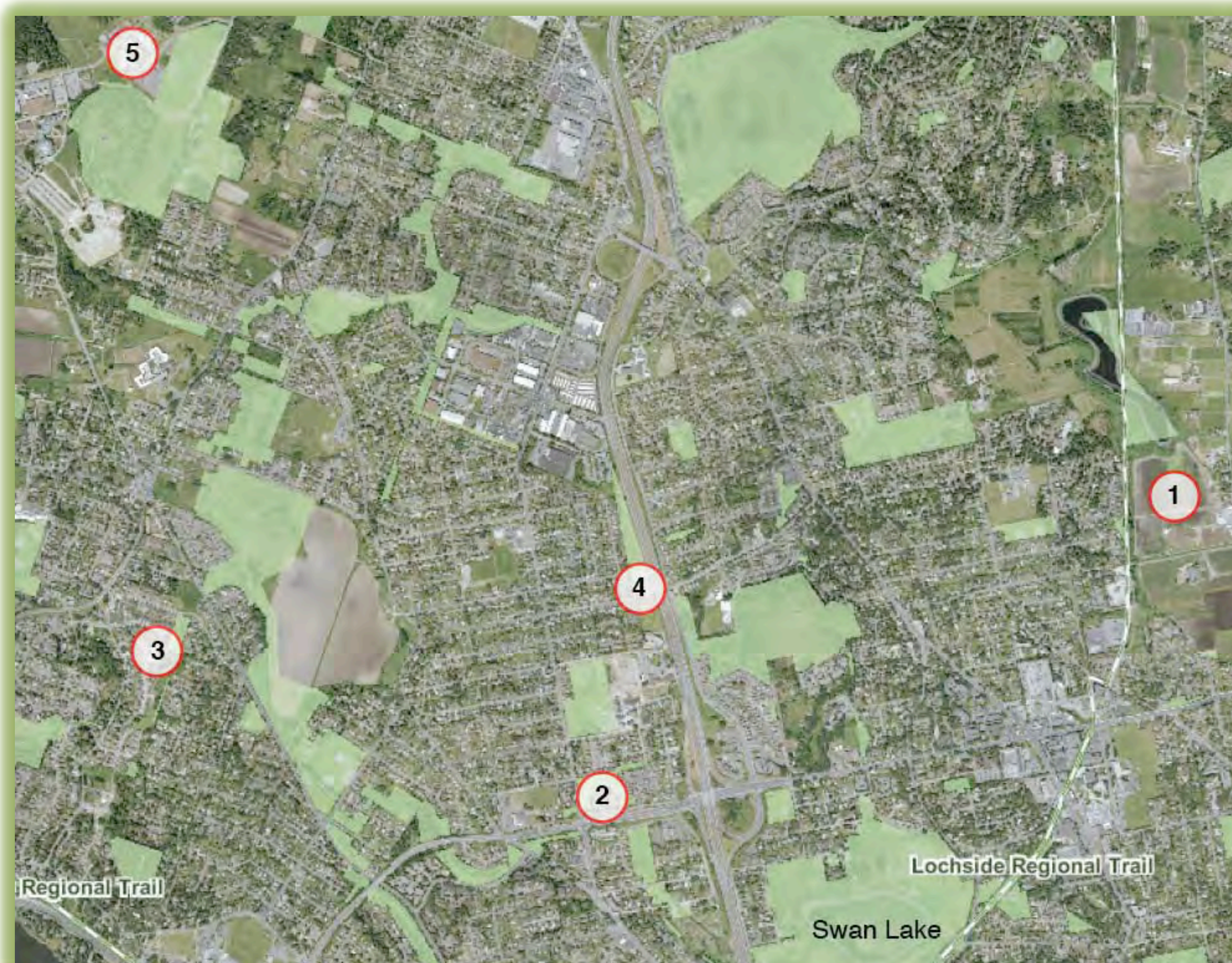


Figure 7: Locations of the Projects Examined in the Study

1: Blenkinsop Creek Restoration 2: Willowbrook Subdivision 3: South Valley Subdivision
4: Rogers Subdivision 5: Vancouver Island Technology Park (VITP)

Blenkinsop Creek Restoration

Project Description

Figure 8: The original drainage ditch on the Galey Farm prior to relocation and restoration.

This project was undertaken on Galeys' Farm located in the Blenkinsop Valley, Saanich BC (location 1 in Figure 7). The site is situated between a former railway and Blenkinsop Road, with a local minor road servicing the Valley. Land in the Valley largely consists of urban agriculture, with most of the agricultural lands located within the Valley being classified as Agricultural Land Reserve (ALR)[v]. The site is downstream from Blenkinsop Lake (to the north), the headwaters of Blenkinsop Creek, and within the Colquitz watershed, which discharges southwards into Swan Lake downstream from Galeys' Farm. In summary, the project comprised of the removal of a drainage ditch (Blenkinsop Creek) and realignment of the ditch to the west side of the property where it was rehabilitated to an ecologically functioning creek. The main objective of the project was to restore ecological function to a 650 m length of the creek, and to demonstrate the application of Proper Functioning Condition (PFC) assessment[vi] method as design criteria.

Prior to the commencement of the project, a long-established drainage ditch divided Galeys' field. The ditch ran approximately north-south, in parallel to the original path of the creek, which had long been degraded by farming practices (Figure 8). The field's division into two parts meant each parcel, in effect, had to be farmed individually. The size and shape of the fields prior to the project reduced the operational efficiency of the farm due to the large turning radius required for farm vehicles which was greater than the width of portions of the fields when divided by the ditch.

Upon the commencement of nearby development (West of the field) and the installation of the Galloping Goose Trail (the adjacent rail alignment was turned into part of the walking/riding trail system), vandalism to both farm property and crops increased. Since there was no direct trail or access to Blenkinsop Road from the Galloping Goose, large numbers of cyclists, hikers, and passers-by would wander onto the farm roadways and fields in order to access Blenkinsop Road, failing to give way to farm machinery and vehicles. In the process, both crops and farm equipment were regularly damaged, at an estimated cost of $100,000 a year[vii].

In the late 1960's, a dam had been erected downstream of the Galey Farm at the request of local farmers to help retain water for summer irrigation and manage winter flood volumes, thus reducing periodic flooding risk to the homes and infrastructure downstream. As a result of changing weather patterns, the frequency and duration of flooding of farmers' fields in the Blenkinsop Valley has increased in recent decades. With continued climate change, increased severity and frequency of storm events is expected to further impair the efficiency of the farm. The result of these aspects and increasing interest in this watershed, combined with farming difficulties, prompted the suggestion of a creek restoration project in the late 1990's. By realigning the ditch and re-forming the creek in a more efficient location, it was felt that farming efficiency would be improved and other watershed benefits could be obtained.

At this time, farming in the region had become gradually less viable, owing to competition from overseas markets and aspects such as farm and field size. With many farmers ageing and seeking retirement, pressure to improve farm efficiency had also resulted in the Galeys seeking to diversify into agritourism. Success with small ventures such as corn mazes and similar attractions suggested that the creek restoration could create additional interest. Through the Municipal Freshwater Planning Process and funding and partnership opportunities, the Galey Bros. Farm location was identified as a potential restoration module within the SwanCreek/Blenkinsop Creek subwatershed. Aqua-Tex developed the project concept and organized funding partnerships (Malmkvist, 2002). Planning was completed and the project was undertaken and completed in 2002.

Figure 9: Galeys' field prior to realignment of the creek

(Aqua-Tex photo)

Site Plan

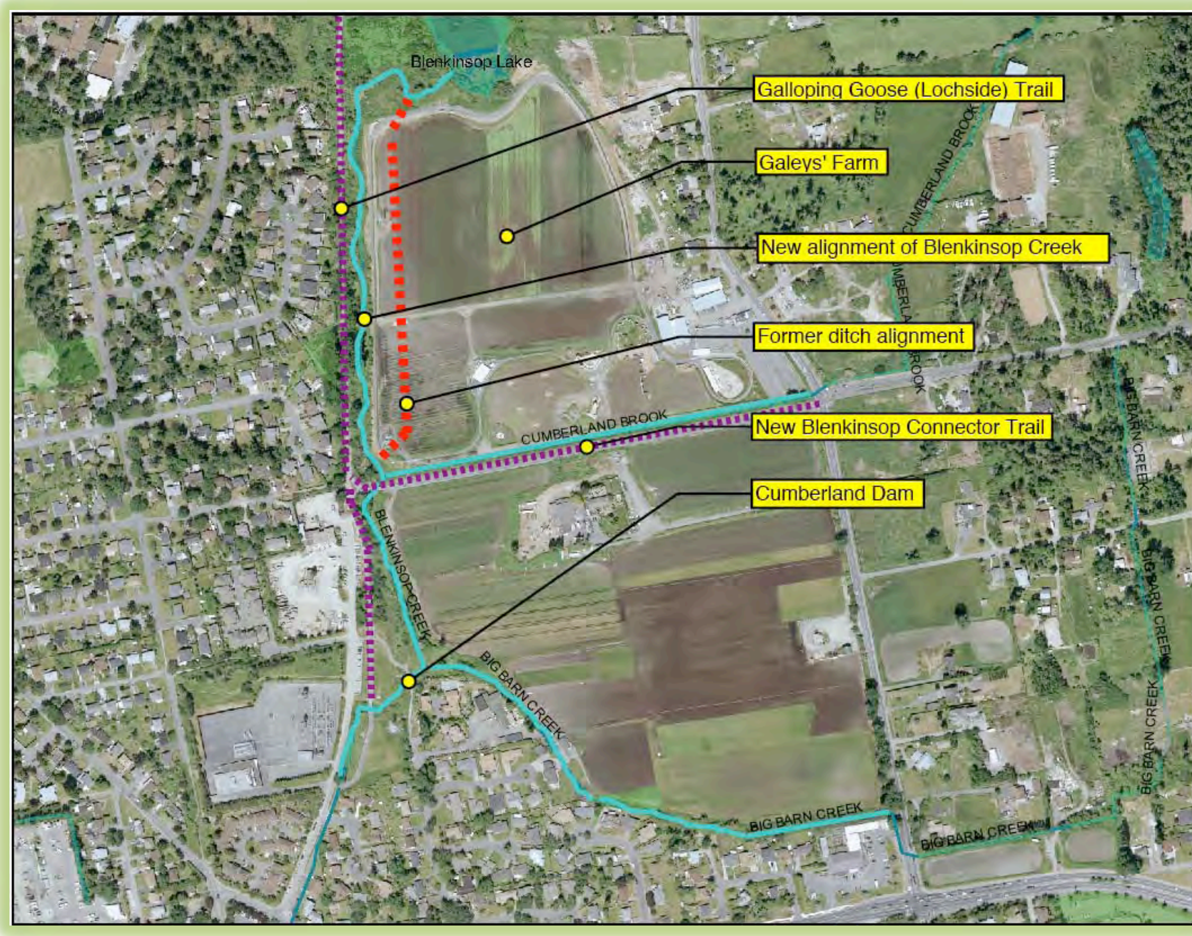


Figure 10: Galeys' Farm Site Plan

Analysis

Project Cost

Discussion and review of the project with Aqua-Tex confirmed the project cost had been audited by a qualified accounting practice. A copy of the audit report for the creek restoration project was obtained from the Swan Lake Christmas Hill Nature Sanctuary, the non-profit society that provided administrative services for the project. We reviewed the report with them and while there is a question whether all the contributed time and effort was included, the audited statement appears to be the best possible indicator of the project's cost.

The audited statement indicated a slightly lower project cost than was assessed by Aqua-Tex and we determined the difference was likely due to costs and contributions not claimed or accounted for in the accounting audit. The Aqua-Tex assessment of project cost is taken at face value at $375,000, which provides the metric against which the individual project benefits can be judged. Although it was a related benefit of the creek restoration (it was an agreement between Saanich and the Galeys post-project), it should be noted that this value does not include the costs of the trail that was installed along the road easement. The trail cost was approximately $500,000.

We attempted to assess a comparable project cost of a similar-sized ditch (prior to restoration), given that we had data on the cost of the creek. We met with an engineer and Chartered Quantity Surveyor, and also discussed this with the farmer. Each had a different view of the probable project cost:

Figure 11. Blenkinsop Creek Facing North (May 2008)

- The engineer suggested a rather large value of $10,000 for what we believe to be a fully loaded cost of an equivalent government contract for the construction and installation of a traditional pipe stormwater system. We believe this results in a project cost that is too high, since it reflects a traditional engineered solution to a problem previously solved by a simple ditch;
- The Chartered Quantity Surveyor (CQS) suggested an intermediate cost estimate could be applied, more in line with that of constructing a ditch, but indicated the cost would likely be nominal if the work could be done simultaneously with other work on the farm;
- The farmer did not consider whether or not there would be a cost because the machinery was already owned and creation and maintenance of a ditch is a simple task, one that is required and therefore not measured economically by the farmer (*i.e.*, a cost of doing business).

The views of the CQS and farmer closely coincide suggesting that the cost would be low or nominal, probably in the order of $2,600-$5,200 if the cost of machinery and time was properly estimated.[viii] This is considerably less than either the cost of an engineered solution or the restoration program that took place. However this solely assesses the project *cost* and not the projects *value*. Overall, we concluded that a traditional approach to install ditches might cost approximately $5,200 and the ecological restoration of the creek in the order of $375,000. On first examination, the extra expenditure is not warranted, however a more holistic evaluation of this difference shows that the extra cost is worthwhile.

Operations and Maintenance

Field Efficiency

The existing ditch separated the field into two parts, requiring the farmer to farm each as a distinct and separate field. This impacted efficiency due to the reduced turning radius of farm vehicles. Moving the drainage channel and converting it into a stream merged the different land areas into a single contiguous parcel able to be farmed more efficiently, thus reducing the amount of farmland lost through stream (ditch) setbacks and access roads. Aqua-Tex calculated the improvement in land area from the realignment to be approximately 7% more arable land, reported as yielding an additional net 1.5 acres (*i.e.*, as part of fields totalling approximately 21.4 acres).

Figure 12: Miniature Railway-Agritourism Feature of the Galey Farm

A review of farm land selling at the date of this report suggests that land of comparable size and nature may sell in the range of $50,000 per acre, since farmland in Blenkinsop Valley is considered desirable and sells well above the realistic economic value of the land in farm use. This suggests the improved value of the land is in the order of $75,000. In other words, in order to purchase an additional 1.5 acres of farmland equivalent to the arable land they gained, the Galeys would have to pay about $75,000. In essence, this reflects more speculative influences and lower expectations of revenue/investment return than appear to be justified by farm economics alone. However, since land prices in the Blenkinsop Valley are driven by factors other than suitability of a parcel for farming, the increase in potential productivity of the Galeys farm would have little bearing on its resale price.

Even for the Galeys, the $75,000 gain is less than the cost of the project and thus, based on this indicator alone, a traditional land appraisal analysis would reject the creek realignment project as unviable. Thus, the improved net area of land capable of being farmed is the only impact on land value we could identify.

Irrigation system

Prior to the project, the farmer had to move the irrigation system between different parts of the field and/or have duplicate systems operating. This meant moving the machinery and/or manual watering, which increased time and cost and reduced efficiency. In addition, irrigation water was being taken from the main regional drinking water supply, indirectly adding to the upstream costs incurred by the Capital Regional District. After the project, Mr. Galey realised the creek was capable of supplying water, since it remained filled even during the summer months when it had previously gone dry, and he held an existing water license on the creek. Since a sub-surface drainage system had already been extended as part of the creek restoration, it was possible to reverse the flow of the drainage pump and instead of pumping water from the field into the creek; the pump was reversed to pump from the creek into the fields and still maintain an adequate flow in the stream.

The amount of water that is used in this way is limited, because the farmer does not wish to excessively drain the creek and in consequence, negatively impact the upstream lake or downstream creek, thereby attracting criticism. The main advantage is that with a single irrigation system, the farmer is able to improve the amount of automatic irrigation and reduce the amount of manual intervention, thus improving efficiency (both of irrigation and farm labour).

It is interesting to note that had the existing surface irrigation system been used for creek water, it would not have complied with health standards, which prevent creek water from being sprayed on produce that is to be used directly for human consumption, due to the possibility of contaminants settling on the edible parts of the vegetables. However the same creek water that could not have been dispensed through the spray irrigation system can be safely irrigated using sub-surface distribution, with no other treatment. Unfortunately, the farmer (pre- or post-project) did not measure the impact on potable water usage, but the Galeys estimated the reduction at 7%. In order to estimate the value of potable water saved, we used provincial agriculture and irrigation statistics to determine a per hectare water usage of 6,614m^3/ha/year. Using current Capital Regional District water rates and the estimated reduction of 7% of potable water usage, we estimate that the net present value of the potable water reduction is $8,548.[ix] Furthermore, we anticipated an increase in crop yield from the increase in farmable land, but unfortunately, other factors such as differences in climate and crop rotation schedules meant that isolating the increased crop yield benefit was not possible.

Theft & Vandalism

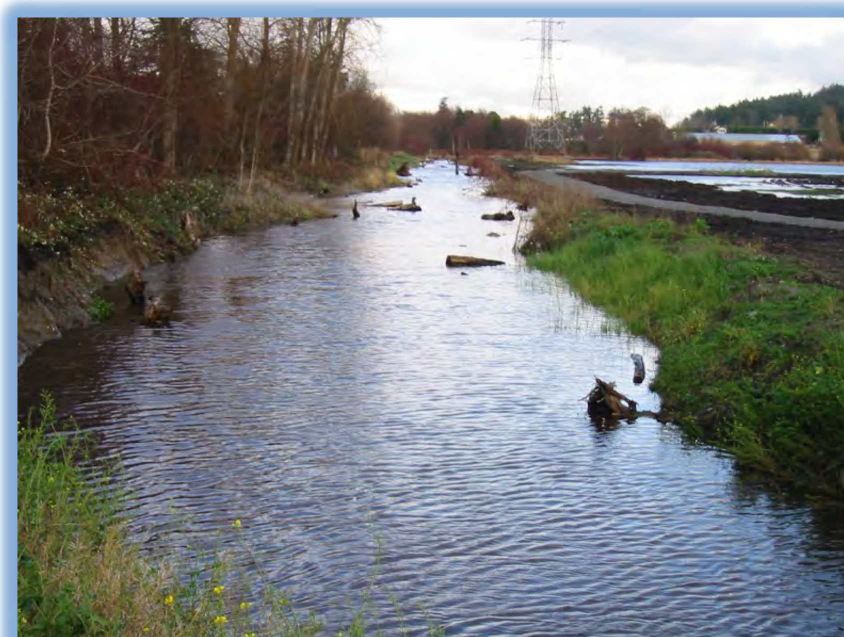
Interviews with the Galeys indicated that vandalism was higher prior to the completion of the project. Vandalism costs included:

- Theft of farm tools and implements. The cost of this varied but the labour cost included lost harvest time, and time staff had to go off site, purchase a replacement and return; the cost of time likely exceeding the cost of the tool;
- The theft of saleable crops. Largely experienced at night, areas of the farm located adjacent to areas of public access remote from farm security, experienced theft from saleable or consumable crops, reducing crop yield;
- Crop damage from people crossing the field from the adjacent housing development, as they attempted to reach Blenkinsop Road where transit access and further recreation exists. A favourite pastime of local teenagers was smashing pumpkins in the field, just prior to harvest;

Vandals and trespassers usually crossed onto the Galey farm from Galloping Goose Trail and then crossed the valley on Galeys' internal farm road which ran East-West through the Galey property and connected to Blenkinsop Road. The reason that there was not a public access through the site was that Saanich owned only a half-width road easement which was not large enough for a road or trail designed to municipal standards, and therefore Saanich could not install a road (or a trail) unless they had the Galeys' permission. Fearing that a road or trail would increase the vandalism (and associated stresses), the Galeys would not allow Saanich to install either one.

After construction of the creek (which effectively established a water-filled moat running north-south between the Galloping Goose Trail and the field), and as a direct result of the rapport and trust built between the Galeys, Aqua-Tex and Saanich, the Galeys agreed to allow Saanich to install a trail along the east-west easement to connect the Galloping Goose to Blenkinsop Road (provided the Saanich installed a high fence, on either side of the path). This also improved access to the land by farm vehicles (via the raised pedestrian and cycle path) during the early fall and late spring when soils tend to be boggy. Overall, this trail has had several benefits:

Figure 13: Blenkinsop Creek facing north (Post Project - December 2001). Note the barrier that the creek provides between the trail and the field.



- Reduction in property and crop damage, tool and implement thefts, and consequent improvement in avoidable capital and operating expenses. Although the Galeys had not tracked the damage, theft or other instances of vandalism, they estimate that the cost of vandalism and damage (*i.e.*, labour, crop costs, etc) exceeded $100,000 per year. After completion of the project, the realigned creek acted as a moat, keeping trespassers and vandals off of the property;
- Improvement in crop yield resulting from reduction in crop accessibility and associated vandalism, without offsetting costs;
- Improvement in farm access and farm efficiency, improving options for harvesting.

Pesticide

Prior to the commencement of the project, the ditch had little or no ecological function, providing minimal, if any, habitat value. However moving the creek adjacent to an existing hedgerow along the Galloping Goose Trail not only supported that hedgerow, but also in effect created a 'moat' reducing vandalism, as noted previously. As a by-product, the restoration and enhancement of hedgerow function meant that biodiversity has been enhanced, attracting predatory insects, birds and other animals.

Figure 14: Blenkinsop Creek facing north (February 2007)

The Galeys report that prior to the creek realignment, at the worst of times, pesticide application was almost weekly during the growing season. This resulted in high pesticide and herbicide expenses, vermin control and so on. By contrast, after the completion of the project, the newly-planted streamside vegetation began to establish and provide extensive habitat for birds and other wildlife. Over the years, pesticide use has gradually dropped until the Galeys recently quit applying pesticides, and allowed their pesticide licence to lapse. In effect, the natural systems eliminated the need for chemical applications. Farmers are normally concerned with situations that increase insects, birds and other animals for they tend to reduce crop yields. What has been noted at the Galey farm is in fact the opposite; birds (particularly raptors) and other animals that have been attracted to the site are predatory and therefore farm mice and other crop pests are a source of food supply. As a result, the Galeys have experienced appreciable savings in pest control, with pesticide usage dropping to zero.

The impact has been significant enough to persuade the Galeys to employ an integrated pest management system (*i.e.*, using ladybugs instead of sprays to control many crop pests). Mrs. Galey believes the farm could now qualify as an organic farm, if not for the proximity to other farms who use herbicides and pesticides (whose use cannot be guaranteed or controlled), as well as for the winter flooding of the fields with creek water that carries contaminants from road runoff in the upper watershed. Since isolation from contamination is a criterion for gaining designation as an organic farm, the farm cannot be designated. However it does mean they are able to distinguish their product in the marketplace and claim to achieve greater sales volume as a result, and/or higher revenues from sales. The farm has been recognized by The Land Conservancy (TLC) as a Conservation Partner[x].

Pesticide savings were estimated to amount to a cost of $1,650 per acre per year (this being a combined assessment of reduction is chemical costs and time/machinery costs) over 21.4 acres ($35,310/yr). Using a conservative discount rate (to reflect the secure nature of the benefit – *i.e.*, 5%), applied to the area of the farm estimated to have benefited but excluding areas beyond the immediate fields that may also have benefited, suggesting the NPV of the estimated pesticide savings in the order of $497,657.[xi] The NPV of the pesticide savings alone exceed the total project costs of $375,000; suggesting the project would have been viable based solely on pesticide reduction, however, the return on investment (ROI) is not very fast (*i.e.*, the rate is discounted at 25 years).

Creek Maintenance

Prior to the realignment and restoration of the creek, the Galeys reported that the ditch required regular maintenance. The shift to a natural stream channel required less maintenance and management. Whereas the old ditch was not self- managing and tended to "clog" due to in-growth of vegetation, agricultural run-off, and upstream sedimentation deposition, the natural stream channel, in contrast, does not rely on nor need regular digging to maintain its integrity, and therefore reduces costs. In addition, prior to creation of the creek, certain areas of the adjacent fields were noted as being boggy, impacting farming efficiency, crop choices and thus farm economics and crop yield.

After implementation of the project, and despite differences in seasonal temperature and rainfall, the farmer noted reduced field maintenance and gradual improvement in the soil stability. Most importantly from a value perspective, is that higher value crops could now be grown in areas previously incapable of supporting more viable and valuable crops. We enquired into these aspects and found some challenges in quantifying the improvements. Data tracking the higher yields and crop usages was either not available or agglomerated within larger data on crops and thus not capable of individual assessment. The farmer also felt that differences in seasonal weather conditions would mean that clearly evaluating the improvement would be difficult and therefore this aspect could not be quantified.

The farmer did not keep records of how often the ditch was maintained, nor what the associated cost was. Therefore, we estimated a maintenance schedule of a normal ditch to be on average every 5 years and in the case of the Galeys' ditch the estimated cost is approximately $2,600 every 5 years. To adequately compare costs and values for the purposes of this report, the discounted present value (PV) cost of the ditch over 25 years was applied using a 5% discount rate. In the case of the ditch amounting to the discounted maintenance values totalled $6,632.[xii]

Figure 15: The Galey Farm (Extent of the Flooding, 2003)

Municipal Infrastructure Cost

Flood Protection

The Galey Farm, and indeed much of the Blenkinsop Valley, acts to store floodwaters during extreme flow events. This is partly due to topography (it is an old lake bed) but mostly due to flow regulation on Blenkinsop Creek in the form of the Cumberland Dam. Intense hydrological modelling would be required to confirm and interpret the protective value of the farmland for downstream infrastructure, which is complex and requires legal advice; however, using values from the literature an estimate is provided.

Figure 16: Flooding of the Galeys’ Field

The Galey farm sits within a long-standing flood plain. In the late 1960’s[xiii], a dam was constructed at the south end of the Blenkinsop Valley at the request of local farmers “to control winter storage, drain off water in the spring for agriculture, and hold water in the summer for irrigation. An operating curve established by Saanich Engineering in consultation with stakeholders and administered by Saanich Public Works governs flood control in the effort to balance downstream flows and upstream storage. As agriculture is a significant land use in the Valley, managing stormwater to have a positive impact on producers is desirable” (Saanich, 2003). As weather patterns have changed, flood waters have been held later into the spring and fields begin getting saturated earlier in the fall. This has a negative impact on agricultural production.

While the dam has been a benefit to downstream development, it unfortunately results in the Galeys and other farms being flooded not only during the winter (when there are no crops in the ground) but also during seasonal and major storm events (due to preponderance of fine soils strata and commonly, Victoria Clay subsoil). The question was raised whether this is an unpaid "insurance benefit" that could be quantified.

Underlying this question is the concept of Public Interest Value (*i.e.*, that there is a public benefit in something happening that may not be properly reflected or compensated by market forces or traded property values). For example, acquisition of land for public roads arguably has similar comparisons (*i.e.*, the land is acquired because the public needs it, but government does not pay based on the benefit to drivers, but on the value of the land as if it had been sold for its current or permitted purposes, as if the road project had not happened). Since such lands are often compulsorily acquired, mechanisms exist for compensation and there are also provisions for compensation when land is, in effect, acquired even when there has not been a formal purchase (this is often referred to as "Constructive Expropriation").

The contention made to the authors during interviews is that the Galeys’ land is 'temporarily expropriated' during storm events, impacting crops and business yield, and thus land value. This happens because, rather than the runoff flooding homeowners and businesses developed downstream, farms in the Blenkinsop Valley flood. The impact reported can be extensive, with damage to crops and livestock, farm capital and operating equipment. The question is whether the land has, in effect, been expropriated through the creation of the dam, and whether the creek restoration benefits the residences and municipality downstream. In expropriation terms, compensation relates to the difference in the owner's situation before and after the expropriation. In this instance, it would require measuring the extent of the flooding prior to the installation of the dam and afterwards, as well as assessing the pre and post– project flood risk/damage. Unfortunately, our discussions could not confirm with certainty that the land did not flood as extensively prior to the dam being built. We also identified little clarity with respect to the extent and level of present flooding, reducing our ability to accurately quantify the impact on the farm's business. For example, in the last quarter of 2006 and first quarter of 2007 extended periods of heavy rain resulted in severe flooding to the lands in question, but farmers were so busy dealing with saving crops and livestock that accurate measurement and documentation of the extent of flooding was not done; rather we were provided with an estimate that 60% of the lands flooded at an estimated depth of 1m at the worst times.

The benefit of the creek compared to the farm ditch is difficult to quantify, however the Galeys reported that it has reduced the frequency and extent of surrounding land being boggy, and is believed to reduce impacts downstream. Furthermore, the restored portion of the creek and associated floodplain has been observed to retain water for longer due to the increased width/depth, available floodplain, and the creek's "U" shape (compared to the ditch's shallower "V" shape). The creek channel now has a higher capacity thereby addressing larger volume flows. Although hydrologic modelling has not been completed on the Blenkinsop system, and the true extent of the flooding cannot be properly established, an estimate can still be derived from the literature showing the potential value of the flood mitigation provided by the Galey (and surrounding) farms.

For instance, Ming *et al.*, (2007) calculated flood benefits, by identifying the capital cost of reservoir construction and converted the value to $\$/m^3$. Applying this value to the Galey farm study, the flood protection benefit provided annually by the Galey farm is estimated to be $54,313. Discounted over 25 years at 5% this benefit amounts to $765,485.[xiv] This value is intrinsically low, for if flood damage was to occur to residences downstream the cost is likely to begin in the million-dollar range; therefore showing how inexpensive flood protection is upon comparison to the actual cost of damage if downstream flooding was to occur.

The values identified by Braden and Johnston (2004) may be more accurate in this regard for they have shown that the economic value of flood protection services is within the range of 0-5% of market value; "the range is dependant upon the difference that retention makes to downstream exposure" (Braden & Johnston, 2004). Nevertheless, these proxy methods are cost related (*i.e.*, damage avoidance cost related) and do not take into account the measures of social welfare, nor do they account for individual preferences in the absence of such services. For example, the absence of flood protection provided by the Galeys' (and neighboring) lands may well induce individual action forcing the municipality to prevent flood damage, through the acquisition and restoration of land or other means. In addition, the US Army Corps of Engineers have shown that "flood peaks may be as much as 80 percent higher in watersheds without wetlands than in similar basins with large wetland areas" (Braden & Johnston, 2004). Specific to the Galey farm, the value of the farmland in public use would not only have a value in addressing storm situations but also in public amenity. It may be that local and provincial governments should carefully consider this if the situation worsens as a result of global warming and increased upstream urbanization.[xv]

Ecological Benefit

Prior to a detailed economic review of this project the ecological benefits derived were visible, but none had been quantified in financial terms. Though it is difficult to monetize ecological benefit, the following aspects have been examined by other researchers and rough estimates of their financial value can be made by considering the value of a functional stream (which incorporates the items listed below) vs. a non-functional ditch, which is missing these elements:

- The prior ecological condition of the ditch was rated as non-functional. Therefore, we conclude that the ecological value of the ditch would likely have been close to zero. This determination is based upon a literature review and photos of the area prior to the commencement of the project. The following excerpts from the literature support this conclusion:

  - The construction of dams, reservoirs and diversions for the purposes of decreasing flooding and flow volumes, results in interrupted sediment transport (Goodwin *et al.*, 1997; Green, 1996). Sediment is necessary for the rebuilding of soils and stability of streambanks. The Cumberland dam downstream of the Galeys' property decreases flooding downstream, but also reduces sediment transport downstream and may increase or alter the timing of flooding in the Blenkinsop Valley.

  - Increased urbanization (*i.e.*, watershed-wide disturbances such as farming, road construction, and logging) increase the amount of impervious surfaces resulting in higher peak flows, lower base flows, changes in runoff timing, and excessive sedimentation (Goodwin *et al.*, 1997; Green, 1996). As a result the freshwater system becomes degraded and is more likely to be irreparably damaged by a storm event (Green, 1996; Prichard, 1998; etc). Furthermore, sedimentation harms fish in lakes and streams by damaging spawning and feeding areas and by reducing respiratory efficiency (Olewiler, 2004).

  - The constriction of water movement (*i.e.,* due to ditching, or other stream modification) has been documented extensively that such practices result in high sediment loads and high water flows allowing for pollutants (*i.e.,* road run-off, fertilizers, pesticides, etc.) to move quickly through the watershed, causing serious damage reducing water quality and habitat value for both aquatic and upland species (Booth & Reinelt, 1993; CWP, 2003).

  - Excess nutrients that are not absorbed into the water system interact with soil to slow organic decomposition and destabilize nutrient and pH levels, leading to acidity problems, thereby reducing water quality and sensitive aquatic species (CWP, 2003; Olewiler, 2004).

  - Stream channelization (*i.e.,* straightening and berm construction for flood conveyance and land drainage), results in the simplification of the channel, isolation of the channel from the floodplain, loss of habitat, increased hydrological energy, reduced friction and increased runoff efficiency (Arnold & Gibbons, 1996; Goodwin *et al.*, 1997; Moses & Morris, 1998).

- Bird surveys were conducted along Blenkinsop Creek to provide baseline and comparative information for before and after construction of the realigned channel. Since the realignment, bird presence has notably increased (Malmkvist, 2002).

- An interesting side-benefit noted by Aqua-Tex during one inspection is the consequent benefit of restored biodiversity. For example the hedgerow acts as an incubator for local plants, so rather than using an expensive nursery, the hedgerow provides the new plant material to meet demand. This reduces costs in plant replacement. The value benefit is likely to be small and contributory rather than comprise a business, without impacting the ecological function.
- Although pesticide concentration in the stream was not measured prior to restoration, the discontinuation of pesticide use has an immediate benefit on the water quality of the creek.

When a system is restored to proper functioning condition, it has proper vegetation, shade cover, hydrological flows (suitable to the landscape), and soils, and is able to withstand high flow events when they occur. Varying studies have shown that functional streams provide important ecological values, such as water treatment and sediment deposition, thereby supporting salmonid populations, other aquatic organisms and wildlife (Langford, 1975; Ptolemy, 1982). In the case of the restored portion of Blenkinsop Creek, the permanent vegetative cover helps increase the productivity of the creek by preventing the creek from warming, reducing bank erosion and sediment loading, reducing nutrient input by buffering runoff, taking up nutrients, decreasing downstream flooding, reducing GHG emissions, providing carbon sequestration, and offering habitat to a variety of species.

By using other studies as proxies, a rough dollar value for the functioning portion of the Blenkinsop Creek can be estimated. A study completed by Ducks Unlimited (2004) noted a value estimate of the net primary production for each hectare of an estuary may annually be worth $22,832; lakes and rivers $8,498; temperate/boreal forests $2,007; and grass/rangelands $232. Although this study may not be able to accurately quantify specific variables or services (and these services can be highly speculative due to issues of generality, double-counting, and the appraisers objectivity/bias) that result from functioning ecosystems, such values do serve as a reminder of the lost value if a functional ecosystem is destroyed or degraded. Therefore in the Blenkinsop case study, we used values from a recent Capital Regional District (CRD) land purchase as a proxy. The CRD recently purchased more than 9,700 hectares of land for $64.7 million in order to protect the future of the region’s drinking water supply and to substantially add to the region’s park system. The CRD has acquired this previously logged watershed in order to protect it and allow the forest to regrow and naturally filter and purify the water entering the Leech River. Once the forest has regrown, the water will be suitable as a back-up supply for drinking water in the region (CRD, 2007). This is a direct local example of the value of ecosystem services. Applying the CRD proxy, we can estimate that the social value of a functional 650 meters of restored creek and riparian area (30 m wide zone including riparian buffers) that provide benefits such as water quality and biodiversity is worth $12,006.[xvi]

Regarding water clarity/turbidity and health-related performance, the creek's sinuosity helps significantly. Restored to create more natural alignment, compared to the ditch, the new creek can help slow the path of water and the riparian vegetation acts to "filter" the creek water enabling sediment deposition in the floodplain. Complementing this report is a year-long stormwater sampling study on various aquatic systems within the Colquitz watershed, which included monitoring the restored portion of Blenkinsop Creek. The results of the stormwater study are impressive, but unfortunately these results cannot be easily quantified because pollutant-loading rates had not previously been determined (this is a result of the lack of historical hydrological modelling). If the loading rates had been determined, substitution values for what it would cost a treatment plant to reduce values by such could be applied as proxies and calculated as a cost (or in this case benefit). For example, the costs of removing phosphorus vary from $21.85 to

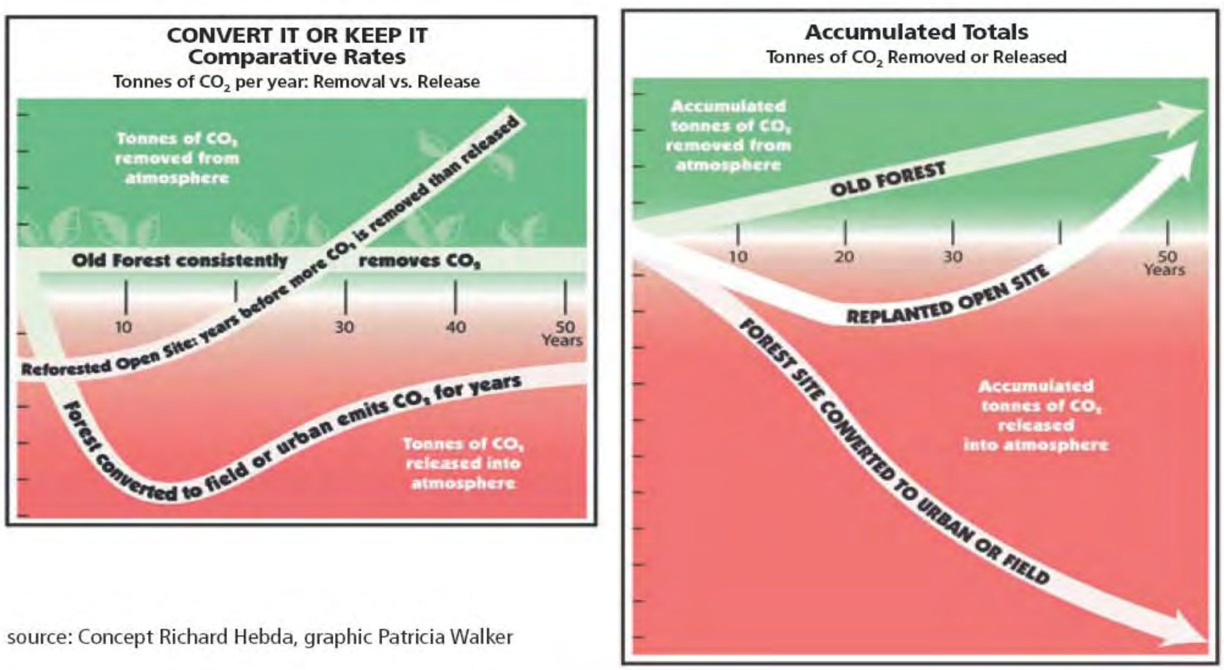
$61.20 per kilogram at Vancouver's primary and secondary waste treatment plants, while costs for nitrogen vary from $3.04 to $8.50 per kilogram (Olewiler, 2004). If the creek had been hydrologically modeled, a value for the average yearly loading or treatment (in kg) could be estimated.

Although we could not value the results of the sampling program because loadings are not available, the capabilities of the functional systems to treat stormwater are worth mentioning.

- Blenkinsop Creek was very effective at removing nutrients. The channel removed between -1.2% and 38.9% of the total nitrogen with an average removal efficiency of 18.8%. On average, the ammonia was reduced by over 55.6%, the nitrate by 20.15% and the nitrate by 13.9%. The ortho-phosphorus was reduced by an average of 20.1%.
- The restored channel reduced Total Suspended Solids (TSS) more than 50% of the time.[xvii]
- Oxygen values were very low, ranging between 0.07 mg/L and 11.8 mg/L at the lake outlet and between 0.21 mg/L and 10.8 mg/L. This is due to the eutrophic conditions in Blenkinsop Lake where the decomposition of the biomass strips oxygen from the water, and due to the fact that the reconstructed creek channel has very little gradient and therefore no opportunity for physical aeration.
- Heavy metals concentrations tested declined significantly. The effective removal of arsenic was 44.7%, cadmium 83.4%, chromium 19.8%, copper 39.9%, lead 90%, mercury 58.3% and zinc 64.7%. This suggests that Blenkinsop Lake, and not the neighbouring field, is the source of the heavy metals in Blenkinsop Creek and that the heaviest particulates to which the metals are bound, are settling out significantly before they reach Galeys' field. It is important to consider how the change in channel morphology, from a ditch intended to convey water quickly, to a sinuous stream channel intended to slow the water and create complexity, might have assisted in removing these heavy metals from the water column.

The vegetation also has an added benefit in its capacity to sequester carbon. In Figure 17 below, Wilson and Hebda (2008) show that as a forest is converted into an urban setting or field, the capacity of the system to sequester carbon dioxide is hindered and in fact, destruction of such systems releases carbon dioxide into the atmosphere. The consequence for this review is that few data were available to permit pre- and post-completion comparison. Furthermore, due to the small size of the project, the carbon sequestration component is small, but worth noting because the restored area has been extremely productive in vegetative growth (as can be seen in the photos). Applying carbon calculations derived from an urban forest study, completed by Rowntree *et al.*, (1991), we estimate that the Blenkinsop Creek riparian zone stores 78.1 tonnes of carbon (at maturity) and annually sequesters 1.76 tonnes/yr. Since the market does not yet grant credits for stored carbon, only sequestered carbon, we cannot use the storage value in the valuation of the riparian zone. The present value of the carbon sequestration is $496.13.[xviii] Although these values are small, when extrapolated to the municipal scale, the value can add up quickly. For example, the value of the canopy cover in Saanich was calculated as part of a larger CRD study using the CityGreen model. This model estimated that the 13,000 acres (5261 ha) of tree cover in Saanich sequestered 4355 tons (3951 tonnes) of carbon annually and represented storage of 559,502 tons (507,571 tonnes). The NPV of the sequestration is $1,113,869.00. As the BC provincial government moves towards carbon neutrality, restoring degraded land or streams to functional systems may, in fact, enable municipalities to achieve carbon neutrality goals, as well as generate revenue streams.

Figure 17: Reforestation and land conversion impacts on carbon storage



source: Concept Richard Hebda, graphic Patricia Walker

Social Benefit

The possibility that there might be First Nation interests on the Galey property was reviewed. For those sites in this report that were developments, this is a normal part of the development process in British Columbia. With respect to the Galey Farm, our preliminary reading and discussion suggested the area had been characterized as boggy prior to its current use, but its prior cultural tradition was not recorded. It is however, well understood that wetlands in the region were used by First Nations for wild cranberry harvest and several important plants were harvested from wetlands[xix].

The farm sits in a strategically important location between Blenkinsop Road and a portion of the Saanich trail system. Upon the development of the Galloping Goose trail system (prior to the project), large numbers of cyclists, hikers, and passers-by using the trail would trespass on to the Galey farm to access the road easement and connect to Blenkinsop Road. While Saanich owned a half-width right-of-way through the field, after completion of the project, the Galeys agreed to sell Saanich enough land to create a full right-of-way so that Saanich could install a connecting path along the easement. Saanich installed a high fence, on either side of the path, to prevent trespass, thus formally linking the trail system and Blenkinsop Road and forming a key connection the Saanich trail system (see Appendix A). In short, the site has significance for the community and the addition of the trail connector provided a community benefit.

From observation, the connector trail has been successful. Saanich Parks estimates that the connector is used for 500 trips per day, closely aligned with the neighbouring Galloping Goose (Lochside) Trail which receives 170,00 trips per year or 465 trips per day (Fleming, pers. comm.). Although we have not extensively studied the benefit derived from the trail and connector, we can utilize varying studies to speculate on the economic social benefits that may have been achieved:

- Creating an interconnected system of parks and open space is manifestly more beneficial than creating parks in isolation.[xx] In addition cities can use parks to reduce public costs for stormwater management, flood control, transportation, and other forms of built infrastructure (McMahon & Benedict, 2003);

Figure 18: Blenkinsop Connector- Galloping Goose Trail Extension (2004)

- Access to parks and trails can increases the frequency of exercise. There is strong evidence that when people have access to parks, they exercise more. "In a study published by the Centre for Disease Control, creation of, or enhanced access to, places for physical activity led to a 25.6 percent increase in the number of people exercising on three or more days per week" (Sherer, 2006). Furthermore, studies reviewed in the American Journal of Preventive Medicine showed that "creation of or enhanced access to places for physical activity combined with informational outreach" produced a 48.4 percent increase in frequency of physical activity" (Emily *et al.*; Task Force on Community Preventive Services, 2002);
- Increased cycling, walking and contact with nature has both physical and psychological benefits and with further study, this benefit could be quantified as a reduction in costs to the public health care system in British Columbia[xxi];
- Obesity is more likely to occur in unwalkable neighbourhoods, but decreases when measures of walkability go up (*i.e.*, dense housing, well-connected streets, and mixed land uses reduce the probability that residents will be obese) (Sherer, 2006);
- Increased real-estate values of property; "In a 2001 survey conducted for the National Association of Realtors by Public Opinion Strategies, 50 percent of respondents said they would be willing to pay 10 percent more for a house located near a park or other protected open space. In the same survey, 57 percent of respondents said that if they were in the market to buy a new home, they would be more likely to select one neighborhood over another if it was close to parks and open space" (Sherer, 2006);
- Green space and habitat is highly valued. For example, a survey from Okotoks, Alberta, showed that 81 per cent (of a survey of 1000 individuals) of respondents stated they would pay $2-5,000 more for a home in a neighborhood with linked opens spaces and habitat features (Fisher, 2002).

- Pratt *et al.*, (2000) concluded from a survey of 20,041 respondents in the Unites States that if the portion of survey respondents (43.2%) who reported no regular physical activity during the survey became regularly active, an estimated annual direct cost savings would accrue to the health care system between $330 and $1,053 per person;
- Jones & Eaton (1994) estimated that a $4.3 billon dollar cost savings would accrue if the entire sedentary population in the United States began walking regularly; and
- Wang *et al.*, (2005) studied trail usage in Lincoln, Nebraska concluding that the per capita net benefit of trails was $564.41 which exceeded the total sum of per capita cost of trail usage, construction and maintenance, and equipment and travel.

Figure 19. Blenkinsop Connector March 8, 2008 (Bill Irvine photo)

Specific to British Columbia, the Ministry of Health states that the cost of physical inactivity in British Columbia for 2005 was $211 million a year in direct costs (hospital, physician, drug, institutional and other costs) and $362 million each year in indirect productivity losses due to premature death and disability, totalling to an annual cost of $573 million (Province of BC, 2008). The increased installation and usage of trails can help reduce this cost. For instance, applying the lower value from Pratt *et al.*, (2000) adjusted for time and currency, the estimated annual benefit of the Blenkinsop Connector portion of the trail can be estimated. Saanich staff estimate the usage of the trail to be approximately 170,000 trips per year (3269 one way rips per week)and the connector is approximately 500 m long. The health benefits of moderate activity can be obtained with as little of 20 minutes of exercise, 3 times per week. It takes approximately 10 minutes to walk the length of the Blenkinsop connector and back (e.g. return trip), but most users will access the trail via the neighbouring trail system and therefore walk longer. At 1635 return trips per week, 545 people could each take 3 return trips. Applying the Pratt *et al*., (2000) value of health care cost reduction from improved physical activity, and adjusting it for time and currency ($430), 545 users, 3 times per week results in a total trail benefit of $234,295/year. Therefore, the net present value of the connector trail discounted over 25 years at 5% (assuming no increase in trail usage) amounts to a community benefit of $3,302,784. This does not include the benefits of: improved air quality, reduction in fossil fuel use, value of a reduction in traffic congestion, or value of improved pedestrian and cyclist safety.

Stakeholder Perspectives

Developer/Owner

Figure 20: Developer Interest in Galeys' Experience

From an owner/developer's perspective, the project has been deemed viable since the cost was exceeded by the returns received through improved benefits to the occupant [the Farmer], business efficiency and productivity, as well as public profile.[xxii] However many farms are currently challenged in their economic viability. The inability to tap into funding, as well as the slow return on investment (ROI) may dissuade many farmers from undertaking habitat restoration even though it is beneficial to them and to the surrounding community. Furthermore, from a farmer's perspective, ditching a creek increases hydrological flows, thereby ensuring that water drains off of the land as fast as possible and enabling the farmer to access the land sooner to plant varying crops for the season (an economic motivator). From an ecological point of view, ditches tend to have little function with regard to riparian and upland vegetation, and aquatic and biodiversity habitat, which tends to require available floodplain, amongst many other aspects (*i.e.*, vegetation, large woody debris, etc). As farmers are financially constrained due to increasing land and input cost values, while food prices are kept artificially low, the farmer's short-term economic viability supersedes the benefits of ecological restoration, and therefore little restoration of the Colquitz watershed along agricultural lands (or residential for that matter) has occurred. Ditching a creek may be considered a HADD (harmful alteration, disruption or destruction) and requires permits and compensatory work under the Federal Fisheries Act, enforced by DFO. The Farm Practices Protection Act, a coordinated effort between the Ministry of Agriculture and Lands and the ALR, gives farmers the "Right to Farm" (*i.e.*, farmers have basic rights to farm land without the fear of lawsuits), therefore over-riding the federal requirements.

Municipal

From a municipal perspective, the project provided considerable community benefit. It opened up a new trail system connector, improved visual appeal, reduced theft and vandalism, increased stormwater attenuation and provided flood protection; attributes that would be politically saleable. Despite this, Aqua-Tex identified regulatory barriers when filling in the ditch and realigning the creek. From a community planner's / policy maker / politician's perspective, if the goal of the OCP or the Strategic Regional Plan is to reduce stormwater, provide downstream flood protection, improve water quality, increase greenspace, etc., municipalities will need to establish a scheme upon which farmers (such as the Galeys) or landowners are paid for the service their land provides as well as the forgone opportunity cost of crop sales or development. From an elected official's perspective, this project provides support for agriculture and support for community goals noted previously: augmentation of green space, natural environment protection and support to agriculture, and general community benefit of trail systems, GHGs and human health.

Community

From the community's perspective there was considerable public community benefit: the Galeys' farm is less labour intensive to farm, and therefore (all other things being equal) more viable. This improves the likelihood that the farm will remain in production and continue to provide locally produced food to the community. This also preserves the rural views from the Galloping Goose Trail. The new creek and riparian zone provide significant habitat, especially for birds, which add interest to the trail and provide active enjoyment for the dedicated group of birders in the Victoria area. As a result of realigning the ditch, it became possible for the Galeys to develop a miniature railway around the field. This is an added recreational amenity for the region, particularly for the children. It also provides an educational opportunity for children to learn about how and where their food is produced. The Blenkinsop Trail connector, which was agreed to by the Galeys as a direct result of this project, is a very well-used and much desired community amenity that reduces traffic congestion on neighbouring roads, significantly improves safety for cyclists and pedestrians, and provides a recreational amenity that improved the activity level and health of local citizens. Though not obvious to most residents, the air quality benefits of less traffic and more vegetation are also significant. The community value of this project was recognized by the Federation of Canadian Municipalities in 2002 when the project was awarded the FCM/CH2M Hill Sustainable Communities Award.

Barriers

Federal regulation would normally require going through an application process to obtain permission under the Federal Fisheries Act and the Water Act to fill in the farm ditch, especially where this might impact a riparian zone.[xxiii] The time and costs to undertake approvals can be so extensive that it acts as a barrier to more sustainable practices. Furthermore, the provincial regulations associated with the setbacks were negotiated; specifically, the Streamside Protection Regulation under the Fish Protection Act[xxiv] that is enforced by the Ministry of the Environment (MOE). Though it does not apply to agricultural land, the SPR normally requires significant setbacks surrounding all water bodies on private land that is being considered for development or redevelopment. In this instance, the SPR did not apply, but in a show of good faith the Municipality of Saanich, the Department of Federal Fisheries (DFO) and the Ministry of the Environment (MOE) representatives met on-site with Aqua-Tex and negotiated appropriate riparian setbacks, as it was recognized that the existing ditch had very little ecological value and the new stream would be a net benefit. In this instance, 15 m setbacks were negotiated on either side of the creek and a Section 9 Notification under the Water Act was required and an application submitted. The setbacks were reduced because the regulators involved viewed this project as an improvement; as such, the creek was re-aligned to the western portion of the property, thereby utilizing an existing buffer of vegetation that ran parallel to the trail that was Saanich's property. Strategically re-aligning the creek ensured that SPR regulations would be complied with (as 15m of the setback would be situated on Saanich's property which consisted of a vegetated buffer and the Galloping Goose Trail), but with less of an encroachment on the farmable land (only 15 m setback on the Galey property, rather than an entire 30 m). The regulations surrounding riparian vegetation have changed post-completion of this project, but continue to exempt both institutional and farm uses, it is expected that the setbacks negotiated would have been the same if the project were to commence today.

Neither Aqua-Tex, nor others interviewed, specifically identified planning implications or barriers, although these may exist in different circumstances. Most arise through community benefit, which planning should reflect. Planning benefits accrue from the retention and augmentation of green space, enhancement of the natural environment, protection and support for agriculture, and community benefit in expanding trail systems, reducing GHGs and improving human health which fall under the goals of most Official Community Plans (OCP) and Regional Growth Strategies (RGS).

This project was jointly funded by numerous federal, provincial and local funding sources, at no cost to the farmer (other than foregone profits from his crop that year). This is the major barrier to most similar projects- most farmers could not afford to finance such project, regardless of the return on investment or savings in labour, as they do not have access to ready cash.

Value Discussion

Since indirect or incidental economic benefits were not anticipated from the outcome of the project, specific data relating to these outcomes were not tracked prior to project commencement, or after project completion. The expected outcomes for the project were related to re-aligning and rehabilitating the creek so that it could achieve Proper Functioning Condition and Aqua-Tex and the landowner indicated this was achieved.

Though the lack of economic information has hampered the accuracy of the values determined, this is not altogether surprising and should not be interpreted as criticism: projects breaking new ground such as this have a degree and extent of impact that often cannot be predicted. Furthermore, the extra cost of capturing data prior to works, and comparing by post-completion audit, can add considerably and unacceptably to project cost. Commonly therefore it is not the first project that undertakes detailed pre- and post-completion analysis but subsequent projects, since the probable impact is better known, and an assessment process identifying specific criteria (as well as the audience) can be determined and measured before, during and after the commencement of a project.

Though there is little ability to reconstruct a review that accurately identifies the value of the project, this does not mean there has been no benefit. We have concluded that given the various identified aspects of cost and revenue using actual information and proxies, the net value of the project was positive by the measurable reduction in pesticide use alone.

The key quantifiable value aspects are:

- Restoration increased arable land by approximately 1.5 acres. Based on land sales at 2007 values, suggests a net benefit to the land of $75-90,000 in total. Agricultural land values do not appreciably fluctuate in this location;
- Pesticide use has halted as a result of habitat restoration. This affected fields totalling approximately 21.4 acres on the Galeys’ farm, and presumably benefited other lands. The savings were amounted to some $1,650 per acre per year. The present value (PV) of these savings discounted at 5% over 25 years amount to a savings of $497,657;
- Reduced potable water used in irrigating lands. The present value of this benefit is $8,548.
- Elimination of vandalism costs to the Galeys. Prior to commencement of the project, vandalism costs averaged approximately $100,000 per year. If the project had not been

completed, vandalism costs would have continued to mount; this yearly cost discounted over 25 years would have amounted to $1,409,394;

- As the climate changes and storm events increase in frequency and magnitude, downstream flooding may become more of a political issue than it is today. Using proxies to estimate the value (or cost) of flood protection, the discounted value of flood protection is $765,484.[xxv] Upon comparison to actual flooding costs that occur (*i.e.*, in the millions), such an insurance value paid to a landowner would be relatively cheap in comparison.
- We estimate that the present value of ecological benefit that has resulted from the restoration of Blenkinsop Creek and riparian area is $12,006..
- The present value of carbon storage and sequestration for 650 m of restored creek amounts to $496.13. Although, this value is small, carbon sequestration aggregated over the entire municipality results in quite a large value ($1,113,869.00) (see Blyth and Laing, 2008).

The financial summary (see below) shows that this is a viable project for the farmer. This is an important point to note as the farmer or land-owner would likely be burdened with the cost of the project, and rarely do farmers have enough liquid capital to undertake such projects. In total, we estimate that the costs to the farmer prior to the restoration of the creek exceed $1.4 Million dollars over 25 years, with little value accruing to either the municipality, farmer, or those affected by water flows downstream. By comparison, by taking into account the cost of the project, as well as a conservative loan (although one was not required as this project was taken at public cost and no finance rate applied[xxvi]), the estimated net benefit (PV) to the farmer from the realignment and restoration of 650 m of Blenkinsop Creek is $1.6 Million. In addition, there is a net benefit to the municipality and surrounding community; the expected net present value of their benefit is estimated to be $4.0 Million.

Data Gaps/ Further Study

In our opinion there is a structural problem with how projects of this nature are appraised. Because land appraisals are generally undertaken for purposes of asset security, etc., they may not always identify business benefits, in this instance received by the farmer. Such appraisals would also be unlikely to identify community benefits because many of the business and community benefits are unlikely to trickle through to the land value, so evidence would not be available to prove a benefit to capital asset value. Accounting methods may be more likely to highlight cost savings without identifying the market value benefit to either the business or to the asset and especially, are unlikely to assess the "Public Interest Value" (*i.e.*, the broader array of interests such as flood protection, societal and cultural benefits, health improvement, etc). Once these issues are fully evaluated and the costs taken into account, it may be that the retention of this land with improvement of creek function would be sufficient to justify continued farm use or in the event that farm use was discontinued, the municipality could justify conversion to parkland and floodplain protection. Furthermore, current valuation standards and process standards in Saanich, as with other municipalities, do not generally contemplate the broader evaluation of Public Interest Value. Even on the basis of highest and best use and value, the creek restoration project would have been justified, but policy would need to be changed to require public interest assessment where doing so would be valuable.

Figure 21: Galey Farm Financial Summary

Blenkinsop (Traditional)	Municipality	Farmer
Installation of Ditch		($5,200.00)
PV of Ditch O&M		($6,631.69)
PV of Vandalism Costs		($1,409,394.46)
Total Present Value	$0.00	($1,421,226.14)

Blenkinsop (Sustainable)	Municipality	Farmer
Cost of the Restoration		($375,000.00)
Cost of the Connector Trail	($500,000.00)	
PV of the Cost of Financing		($26,607.17)
PV of Pesticide Savings (adjusted for the cost of integrated pest management)		$497,657.18
Increased Value of Land		$75,000.00
PV of Potable Water Savings		$8,548.33
PV of Flood Cost Avoidance to the Municipality	$765,484.59	
PV of Ecological Benefit	$12,006.19	
PV of Value of Carbon Stored and Sequestered	$496.13	
PV of Trail Connector Benefit	$3,302,784.65	
Total Present Value	$3,580,771.55	$179,598.34
Net BENEFIT	**$3,580,771.55**	**$1,600,824.48**

Willowbrook & Glanford Station

Project Description

Figure 22: Willowbrook Subdivision

Willowbrook Subdivision was developed by Cadillac Homes Ltd. and is an urban in-fill development of 31 single family detached residences on former agricultural land. It is partially within the 200-year floodplain for Swan Creek in Saanich. Swan Creek was upgraded from an agricultural drainage ditch, relocated and restored through the site (with 17% of the property dedicated to Saanich as parkland), as an addition to a neighbouring linear park. Six ponds were created to manage stormwater, extend wildlife corridors, connect local public walking trails and provide habitat. Approximately 750 meters of fish bearing creek was restored to conditions similar to the 1930's before urban development. A sewer right-of-way was used as a space to provide additional wetland stormwater treatment and to construct a walking trail- thus adding functionality to otherwise unused space and retaining full access for repair and maintenance.

Two different developers had previously approached the municipality with development proposals that included traditional engineered solutions to stormwater management and flood control. These failed to obtain requisite approvals as the traditional methods did not meet City bylaw requirements or sufficiently address floodplain liability. The projects also did not receive community support. Under Cadillac Homes, hydrological requirements were established and the new 200-year floodplain determined by hydrological modelling of the flows in Swan Creek. This approach was essential to address due diligence with regard to flooding. The design of the urban stormwater treatment ponds and wetlands was based on the Proper Functioning Condition (PFC) criteria, and used to define how the subdivision and road layout would be developed given the need to keep water on the land as long as possible. The design also incorporated public safety issues, wildlife habitat requirements plus aesthetic and recreational benefits to the new park.

Glanford Station is a detached single-family residential subdivision of 22 homes plus a pre-existing subdivision of 6 homes that manages stormwater from both subdivisions by using wetlands constructed between Swan Creek and an adjacent Garry Oak preservation area. The stormwater drains from the subdivisions into a cascading series of ponds and wetlands, constructed by the developer, before entering Swan Creek.

Site Plan

Figure 23: Willowbrook/Glanford Site Plan

Analysis

For purposes of this analysis we have considered the two projects as a single contiguous whole.

Project Aspects

The wetland reconstruction and creek restoration permitted the Willowbrook development to proceed whereas this had not been achieved by prior private development proposals. Furthermore, the proposal went through the necessary permits and approvals processes on an expedited basis. This had both cost and risk benefits to the developer.

Figure 24: Willowbrook Trail

Support for an ecological approach was so strong that permits from all the regulatory authorities were obtained in less than two months. During the period when this project was undertaken, the traditional permitting process on projects involving riparian and floodplain regulations was often in the order of two (2) years. Approval processes requiring Department of Fisheries and Oceans (DFO) approvals due to working in or around fish habitat or fish bearing streams could take up to three (3) years to obtain. According to Aqua-Tex, confirmed (but not quantified) by the developer, the expedited approach saved the developer enough money in borrowing costs on the land to pay for the stream restoration program. Aqua-Tex reports the restoration cost was in the order of \$120,000. By choosing to develop the property in conjunction with the restoration and stormwater treatment, the developer was able to expedite approvals and start construction in 63 days.

Working with the regulatory agencies enabled a relaxation of building setback requirements. As portions of the site are within the 200-year floodplain, careful design allowed some mitigation of setback requirements for buildings by constructing the habitable floor areas of the homes above the level required by statute. Thus some foundations are within the 200-year floodplain boundary. This permitted the retention of the allowable number of housing units to enhance viability of the project.

The geology and hydrology of the site required special measures if the site were to be developed. Given the magnitude of the dedicated open space, and to encourage similar restoration-related projects, a new subdivision bylaw was instituted to accommodate small lot sizes of +/-290 m^2 (3,000 sq. ft.) with reduced setbacks. While the lots were up to 50% smaller than the traditional lots in the neighbourhood, the impact was only a 15% to 20% reduction of traditional lot values. The developer stated that the profitability was restored to some degree by cost savings associated with the compact configuration of the lots and the corresponding servicing cost reduction due to the shorter span of utility and other lines such as collector pipe, lamp standards required, road length installed, etc. It is unclear what impact the added open space had on mitigating the smaller lot size of the subdivision. Furthermore, donating 17% of the land enabled the developer to achieve 14 additional lots in density bonusing bringing the lot count from 17 to 31.

In the case of the Glanford subdivision, restoring the wetland and applying ecological principles to the development enabled the developer to utilize a public utility corridor to accommodate stormwater treatment and management off-site. The benefit to the developer was that he reduced the area needed for dedication by not having to build stormwater treatment within his development. Costs were estimated to be approximately equal if the stormwater treatment facilities were built on-site or off-site. Thus the benefit to the developer was the increased lot yield, and associated revenues are estimated at a sum in excess of $200,000. This added lot yield had an indirect value to the municipality as well as increased overall tax base revenues.

Figure 25: View of the wetland between Willowbrook and Glanford, 2003

The implemented ecological stormwater solution was found to be cheaper than a traditional pipe solution would have been, if allowed. The estimated cost of construction for the entire stream and stormwater project for Willowbrook was $120,000 for construction and consulting fees. The hydrology modelling costs were approximately $60,000 representing 50% of the total restoration costs. Due to the proximity to Swan Creek, an alternative solution would have required a traditional stormwater management system that would control discharge into the nearby creek. Such a solution would have been to construct a stormwater holding tank under the street with a pump system, at a cost estimated at $260,000 to $300,000. Although expensive, it would not achieve the same degree of particulate and contaminant treatment achieved through the restorative method.[xxvii] It would also have failed to contribute to the habitat or visual amenity of the community, as the creek would not have been restored.

In terms of direct market value, those buildings fronting the wetland had not been specially marketed, in other words, the developer felt the proximity to wetland had no incremental benefit and thus, did not market or design the housing to take advantage of the natural amenity. We observed that little was done to the architectural treatment to increase views at the upper floor levels, and ground levels have no view of the wetland area. We researched property records to assess whether the wetland has subsequently shown to have added value to those lots fronting or viewing the area. A review of sales and tax assessment information from 2004 to 2006 of homes in the project failed to show any special differences between those houses fronting the wetland and those that do not.[xxviii] On the face of it, this tends to suggest that there is no special relationship to open space proximity and value premium for this project. Furthermore, it is reported that the project, due to uncertainty around the impact of the restoration project, was not marketed to take advantage of the open space and added recreational features, nor were the homes designed to take advantage of the proximity to the open space.

The paper "*Corridors of Green and Gold*" by Hamilton & Quayle (1999), prepared for Fraser River Action Plan, Department of Fisheries and Oceans looked at the benefit of greenways in riparian zones.[xxix]

Unfortunately the study area did not include the District of Saanich as the data were not available during the author's assessment of the Colquitz system. As a result, the authors concluded, "*the results were very disappointing*." The reason was non-availability of data, the same problem affecting our analysis. Generic conclusions were nevertheless drawn from other assessments, that there is additional value:

"Our general conclusions support both the perception of increased economic value on the part of those living in the study areas, and a statistical increase of increased real property prices to residential suburban properties due to proximity to a greenway. The statistical results indicated an order of magnitude of a 10% to 15% increase in value, after controlling for other factors such as age, location, and other adjacent amenities."

Various other studies have supported the linkage between the distance to greenspace and real estate values as well:

Figure 26: Rear of the Willowbrook Subdivision (2003)

- A study of property values near greenbelts in Boulder, Colorado, noted that housing prices declined an average of $4.20 for each foot of distance from a greenbelt up to 3,200 feet. In one neighborhood, this figure was $10.20 / foot. The same study determined that, other variables being equal, the average value of property adjacent to the greenbelt would be 32 % higher than those 3,200 feet away (Correll *et al.*,1978);
- In Oregon, a study found that urban land adjacent to the greenbelt was worth approximately $1,200 more per acre than urban land 1,000 feet away from the greenbelt boundary (all other things being equal) (Nelson, 1986);
- A study of market appreciation for clustered housing with permanently-protected open space in Amherst and Concord, Massachusetts, noted that clustered housing with open space appreciated at a higher rate than conventionally-designed subdivisions (appreciation was measured as the percent increase in open-market sales prices) (Arendt, 1996);
- The clustered homes studied in Amherst appreciated at an average annual rate of 22%, as compared to an increase of 19.5% for the more conventional subdivision. This translated into a difference in average selling price of $17,100 in 1989 between the two developments (Arendt, 1996);
- In 1991, Environment Canada examined the selling prices of homes in Windsor, Ontario within 915m (3000ft) of green spaces and noted that there was an increase in property value of approximately $26.24 per m ($8.00ft) closer to greenspace;

- An American Lives Inc. real estate study found that 77.7 percent of potential homeowners rated natural open space as "essential" or "very important" in planned communities (American Lives, 1999);
- In The Green Building Council of Australia's recent publication "Valuing Green - How green buildings affect property values and getting the valuation method right" the authors state: "*All respondents identified the Discounted Cash Flow (DCF) approach as being the most suitable method to assess the valuation of green buildings*." As sustainability in a wetland or in a building have shared characteristics, there is a clear bias to the DCF approach as being helpful in valuing sustainability;
- A study by the Royal Institution of Chartered Surveyors, "Urban parks, open space and residential property values," published in July 2007 identified a range of improved values between 0.44% and 19.97%. This is a wide range and the report references other international studies, including hedonic analyses (*i.e.* assessments based on larger data sets and thus likely to be less prone to anomaly). One study identified a statistically significant 16% extra value for properties within 450 m of public open space (Dunse *et al.*, 2007).

Hamilton and Quayle's study demonstrates that a portion of the benefit is only obtained if the properties are oriented so the view of the riparian zone is optimized. The Willowbrook development was not; it was oriented to the street front, with almost no windows overlooking the riparian zone. Available real estate data underscored this, with no clearly demonstrable difference in values between identical houses one block back from the riparian zone and those fronting it.[xxx] There were, however, fewer sales fronting the riparian zone than identical homes a block off the riparian zone, suggesting homeowners are happier with the limited extra benefits of riparian frontage afforded by the designs. We feel the building orientation could have been improved to maximize the value of the visual appeal of the creek from the houses and some homeowners had extended their deck use as the only way of exploiting this benefit. In short, the subject project probably did not optimise value. If the houses had been oriented and marketed with views of the green belt, we conservatively estimate an increase in value in the order of 3%.

Figure 27: Views of the back side of the houses which face the wetland. Views are not optimized.

Ecosystem Services

Figure 28: Home purchased based on the views of the wetland.

Stormwater run-off from the site is treated on-site, the benefit of this having been paid for by the developer. The treatment of water, storage channel and pond system is expected to improve flood control, and has been noted to treat various elements of stormwater, creating a tangible benefit to the municipality. Unfortunately, similar to the Blenkinsop case study, no historical hydrological modelling is available and consequently neither loading rates nor values can be applied to this study. If values could be associated, we would expect the values to be similar to what other studies have reported. For example, Olewiler (2004) concluded that the present value (50 years at a 6% discount rate) per acre of waste assimilation (*i.e.,* nutrient filtering) and water supply services provided by wetlands in Massachusetts is $75,196 and $291,357 respectively. In addition, the same study performed a literature search identifying a range of values between $5,792 and $24,330 for each hectare of wetlands (values for habitat; water supply; erosion, wind, wave barrier; storm and flood control; and recreational opportunities) (Olewiler, 2004). Furthermore, when discussing such values, it should be noted that the value estimates for either net primary production of an ecosystem or a specific service such as the savings of water treatment costs provided by nature, are likely to underestimate the total value because such calculations do not reflect society's total willingness to pay for the ecosystem service(s) provided (Olewiler, 2004). For example, the willingness to pay for drinking water quality improvement provided by wetlands in the US Midwest ranges from $70 to $87 per person per year. In Saanich, when asked to allot an imaginary $100 to a selection of 10 capital projects, residents choose to allot the largest portion, $13.02, to roads and traffic control, followed closely by parks and trails at $11.15, the municipal water system at $10.81 and the sewer and drains system at $10.53.[xxxi] Surprisingly, residents value their parks and trails more than their drinking water system, though no specific monetary value can be calculated from these findings..

Specific to water quality, the results of the 2006/07 sampling program are as follows:

- The wetland at the Willowbrook subdivision was effective at removing nitrogen from the water. On average, the inflow concentration of total nitrogen (as calculated by summing the ammonia, nitrate, nitrite and Total Kjeldahl Nitrogen) was 1.86 mg/L and the outflow concentration was 1.54 mg/L. Outflow concentrations were higher than inflow values in the fall of 2006, but lower on all other occasions. This wetland was consistently a significant exporter of ortho-phosphate. On average, concentrations leaving the wetland were 239 µg/l or 1103% higher than concentrations entering the wetland. This is likely because the sediments have been allowed to build up in the wetland, and, combined with the accumulation of dead plant material, the wetland plants are now unable to use up all the phosphorus that is entering the water either through new inputs from stormwater or from decomposition processes.

- The wetland was effective at reducing the total dissolved solids (TDS) in the water. On average, TDS was reduced by 167 mg/L (average removal efficiency of 32.7%). The average removal of Chloride was 21.7%.
- The Willowbrook wetland was less effective at removing suspended solids than anticipated since periodic maintenance has not occurred (*i.e.,* the cleaning out of sediment deposition chambers). The average outflow concentration was 16.85 mg/L compared to an inflow concentration of 6.88 mg/L.[xxxii] The Glanford wetland, by comparison, removed an average of 17.7 mg/L of TSS (average reduction of 28%) because it was maintained by Saanich during this period. This underscores the need for education of City staff and scheduling of maintenance for these systems, as with any other form of infrastructure.

Costs to treat these pollutants by conventional means are outlined in the Blenkinsop Case study, above, though since loadings are not available, no monetary value can be calculated.

Maintenance

Periodic maintenance of the restored creek system is less onerous than the operating and maintenance (O&M) costs required by servicing a storage tank (and pumps), various catch basins, and dredging a ditched creek. Furthermore, in addition to operation and maintenance costs, the traditional infrastructure would eventually require replacement, requiring an infusion of capital and borrowing costs. In contrast, the restored wetlands and creek do not depreciate (rather they appreciate and can be self-maintaining provided there is proper management). In addition, periodic maintenance for the reconstructed wetland channels and treatment ponds with restored creek is estimated on an annualized basis to cost the municipality approximately $2,000, which, during interviews, the municipality identified as being less than might have been the case had a traditional approach been used, although the exact amount was not quantified. Furthermore, there had been no pre-project audit of the above items and post-project data could thus not be compared to quantify the exact difference. Our conclusions are limited to literature reviews, interviews, and observations from the limited pictures taken prior to the project, compared to evidence on site today. These conclusions are as follows:

- Neighbourhood floodplain storage capacity was enhanced to defer or avoid downstream flood hazard in collector areas compared to traditional pipe solution (no previous such attempt);
- Improved water quality and sediment reduction;
- Reduced stormwater volumes discharged. Consequently, downstream flooding was reduced through the reduction of peak flows and the total volume of runoff. The wetlands and the north end of the project treat and slow stormwater from an older subdivision as well as the

Willowbrook site. The wetlands at the south (near McKenzie Avenue) only treat and slow Willowbrook's stormwater, while the wetlands at the center of the property treat and slow Glanford Subdivision's stormwater. These three areas work together to treat and slow stormwater prior to entering Swan Creek thereby reducing peak flows and the associated downstream ecological and property damage that can result;

- Improved quantity and connectivity of public open space (this had been a goal of Saanich Parks Department) and recreational amenities in the area with trails (the land owner donated 17% of his land to park space, versus the normal municipal requirement of 5%). Connectivity of public open space in an enhanced state to other neighbourhoods, schools and other wetland segments in the watershed catchments area (previously private property);
- The restored area has educational value and opportunity. Nearby schools have used the area as an outdoor classroom and a site for schools involved in planting programs. Furthermore, various studies have reported that parks enhance education by serving as destinations for local field trips and outdoor classrooms that illustrate natural and life science lessons (Heffernan, 1994; Lucas, 1995; Klemmer *et al.,* 2005).
- Improved biomass generation creating improved carbon sequestration and reducing localised heat gain (limited previous biomass from grasses, limited additional growth, compared to more substantive growth of willow, and other wetland/upland species); and
- Enhanced fish, bird and wildlife habitat within an urban environment (there had been little habitat in this area previously).

One of the important benefits of the project is the conversion of a single-purpose sewer line corridor into an upgraded proper functioning wetland, and linked neighbourhood trail system, thus adding functionality to otherwise unused space and retaining full access for repair and maintenance. This has added bird and wildlife habitat at developer cost, and improved a public right-of-way in a way that benefits the community. It also provides park space, recreation, and habitat, as well as stormwater management in a single corridor and treats runoff from both the new and existing subdivisions.

Some studies have noted concerns about creating park space that will attract crime, but this may simply be a design issue. For example, designing greenways to "minimize potential homeowner - park user conflicts and maximize the access and views of the greenway can help to avoid a decrease in property values of immediately adjacent properties" (Seattle Office for Planning, 1987). The Crime Prevention Through Environmental Design (CPTED) program has codified this process and is in use in new developments in Saanich. Furthermore, The American Planning Association has concluded that "park-like surroundings increase neighborhood safety by relieving mental fatigue and feelings of violence and aggression that can occur as an outcome of fatigue" and that barren spaces are more prone to crime than parks landscaped with greenery (McMahon *et al.*, 2003). In the case of the Willowbrook subdivision, as one purchaser liked the proposed concept he decided to purchase a key lot with views over the wetland. Unlike other homes backing on to the park, the homeowner did not install a fence barrier between his home and the public trail and, in fact, orientated and installed large windows to look out over the wetland (Figure 27). This home has no evidence of vandalism or break-in, where in contrast, homes with fences erected backing onto the park, have evidence of vandalism.

We identified a potential barrier to effective management of the wetland, because the municipal jurisdiction for long-term management sits with the Saanich Parks Department, whereas the ongoing maintenance with the wetland is an engineering department concern and responsibility. We expect this may lead to eventual possible challenges in maintaining the function of the wetlands (to capture sediment and consequently treat water before discharging into Swan Creek, as has been noted in the water sampling). Furthermore, we also noted that the management techniques currently being applied that could eventually degrade the wetland's utility as part of the trail system (*i.e.*, inadequate maintenance schedule to remove invasive species which have now overgrown). What appears to be required is the development of a "management manual" to guide the long-term management and maintenance of the wetland and surrounding area.

Figure 29: Willowbrook, 2002 & 2007

Stakeholder Perspectives

Various stakeholders had appreciable benefits from the project. By managing stormwater on site using engineered wetlands prior to discharging into Swan Creek, water quality, and biodiversity have improved. This project reutilized a corridor that added little aesthetic benefit and converted it to a linked trail system that provides an attractive contribution to the community thereby adding valued public amenity at no cost to the public.

Community

From the surrounding community's perspective, the ecological solution met their required collective criteria of not impeding the 200-year floodplain; an issue that was not addressed by prior development proposals. This was a key factor affecting the outcome and contributed to the expedited public process. From the perspective of residents of the development, the ecological solution likely provides greater assurance that properties will sell faster and potentially at higher prices. For the municipality, this solution provides increased utility from an existing asset, which was developed at no cost to the municipality because the developer covered this expense. In addition, the long-term maintenance and management of this ecological solution is expected to be cheaper than the costs associated with a traditionally engineered solution.

Developer

For the developer, there was increased revenue from density bonusing, lowered capital and borrowing costs from utilizing green infrastructure (rather than traditional), as well as reduced permitting delays. The wetland persuaded the community to support the project whereas others had failed, so clearly it was instrumental in producing a successful project or any project at all. Originally the land had been zoned for 17 lots with a 5% parkland contribution. By enabling the community to participate in the development process as well as proposing to use green infrastructure, restoring a portion of Swan Creek, and donating 17% of land to parkland, the developer was able to rezone his property to 31 lots. The ability to use public land to install infrastructure reduced the impact on the developer's lands and consequently mitigate cost impacts. From the developer's perspective, the ecological solution minimized loss of value, and avoided extra cost that would have resulted from traditional engineering solutions for stormwater management. Unfortunately, the layout and design might have leveraged the added amenity better than it did, but the project was successful nonetheless.

Regulatory

From a regulatory perspective, this approach required negotiations with the same authorities as described in the Blenkinsop case study. This approach required the same regulatory approvals (*i.e.,* Section 9 approval from the Ministry of the Environment, approval from the Department of Federal Fisheries (DFO)) and setbacks negotiated with all parties (including the municipality) under the Streamside Protection Act. If the project was to commence today, it would face a different regulatory environment and unlike the Blenkinsop case study, the Willowbrook subdivision would not have fallen under the institutional qualification today. As a result of the changed regulatory requirements surrounding riparian vegetation (*i.e.,* larger setbacks – 30m [at the high water mark based upon the current stream width]), the installation of the stormwater ponds adjacent to the creek may not have been approved, for the new Riparian Area Regulations (RAR) states that no stormwater treatment facilities can be placed within the Streamside Protection and Enhancement Area (SPEA). Consequently, it can be speculated that the developer may have been forced to install more traditional infrastructure, and may have lost some density as a result of the new regulations.

Municipal

Rezoning, density increases, and securing development permits proved to be the key barrier to prior attempts at development because they failed to win public support. In certain respects therefore, but solely due to the community's desire for better solutions, regulation and public process in fact worked in favour of sustainability. This does not mean to say that current engineering requirements were easy to resolve, for this required extensive site visits, hydrological modelling, and community seminars on the benefits of improved creeks for the municipal staff, the developer, and the community. Furthermore, considerable education and policy shifts are required to connect the municipality's Parks and Engineering departments, processes and budgets in order to further enable projects of this nature. As a result of the prior point, there is a clear benefit from a planning perspective. The questionnaire undertaken by the authors of "Corridors of Green and Gold" has clearly demonstrated public support for planning policies favouring sustainability. This point identifies the benefit that can accrue to politicians and planners wishing to meet community preferences as well as the benefit in orienting Official Community Plans (OCP) and rezoning processes to support public interest. Planners may wish to consider positively supporting sustainable projects in some way (*i.e.,* shorter processing or cost incentives) depending on community interest in sustainability.

Value Conclusion

From available information we conclude:

The cost of a traditional storage tank system with pumps was estimated to cost the developer between $260,000 and $300,000. In contrast, the ecological approach that was undertaken cost the developer $120,000, creating an immediate savings of $140,000 to the developer.

The project could have made greater use of the potential value from the creation of the wetland, but the design of lots fronting the wetland did not optimise views or access. The main value to the project was securing approvals and expedited municipal process (63 days versus 2-3 years, which was not quantified); without approvals, the land would have had limited utility and value, so the ecological approach essentially created the value. This is not to say that an alternate "green" but less ecologically progressive approach might not also have secured approvals, however it would likely not have increased lot yields (that created additional revenues of $200,000 in the case of Glanford and $650,000 in the case of Willowbrook) by applying innovative stormwater management practices. Therefore, by rehabilitating Swan Creek from an agricultural drainage ditch, creating stormwater wetlands to manage stormwater, extend wildlife corridors, connect local public walking trails and provide habitat, and dedicating this 17% of the property to Saanich as parkland created a net benefit to the developer of $850,000.

The municipality also gained from this approach as well. If the traditional method had been approved, the developer would have installed a containment and pump system at his cost, but the long term operations and maintenance cost would have fallen on the municipality. Using Blenkinsop's ditch proxy, we expect that the portion of Swan Creek that runs the length of the property would not have been restored to a functional condition and therefore would have required a similar maintenance schedule as well as cost.[xxxiii] Furthermore, the infrastructure installed would have yearly electric and routing maintenance and every 10 years would need to have the tanks pumped out and the pumps replaced; discounting for time (25 years) at a 5% interest rate, the maintenance of the Swan Creek ditch as well as operation and maintenance of the stormwater infrastructure would have a present value cost to the municipality of $17,560. In contrast, we estimate that the current system will require maintenance (*i.e.,* removing sediment from natural deposition chambers) every 6 years at a cost of approximately $2,000. This value discounted for time (25 years) at 5%, would amount to a present value cost of $4,057, therefore in operations and maintenance alone the net benefit of an ecological approach to the municipality is estimated to be a benefit of $13,503. Similar to the Blenkinsop study, accounting for estimates of other benefits such as carbon storage and sequestration ($2,680) as well as benefits such as water quality and biodiversity ($12,470), increases the total net benefit to $28,653. Although a small amount accrues form the carbon component, the GHG impact is worth noting by the ample illustrations in Figure 27. We estimate that due to the increase in vegetation and provision of bird habitat there is also a pest control value.

Another value that has been infrequently studied within the literature is the educational benefit arising from the environment. For instance, Shafer *et al.,* (2003) concluded that the educational benefit arising from forested areas is approximately $3.70/person/year. As many schools have used the area for study, we can roughly quantify the value of this benefit. Therefore, adjusted for time and currency, Shafer *et al.,* (2003) value in today's dollars is $5.75/person/year. In the context of the Willowbrook study, there are four schools within walking distance of the site: Pacific Christian School, Rogers Elementary, Glanford Middle School and St. Andrews. In total, approximately 2,119 students attended these schools this past year. Assuming only 20% of the students walk through the site and/or have had a class at the site, the educational value could be estimated to be $2,437 per year; discounted over 25 years at 5% results in a present value benefit of $34,345. As Baxter Pond (Rogers Creek study) is in close proximity, it is hypothesized that it too would have such a benefit. In total, the present value of the net benefit to the municipality is $62,998. In order to better measure the intangible benefits, a Public Interest Value approach would be necessary where not only are the Triple Bottom Line accounts evaluated but also, several recipients' contributions and benefits are valued. While discussions with residents, Saanich officials and others identified a sense that there was extra value, but there was no hard data to substantiate this common view. As such, this type of "three dimensional valuation" is uncommon and costly.

Figure 30: Willowbrook/Glanford Financial Summary

Willowbrook/Glanford (Traditional)	**Municipality**	**Developer**
Cost of the Traditional Stormwater System		($260,000.00)
PV of Ditch Maintenance	($7,651.95)	
PV of Costs for Future Capital Replacement of Stormwater Infrastructure	($9,908.03)	
Total Present Value	($17,559.97)	($260,000.00)

Willowbrook/Glanford (Sustainable)	**Municipality**	**Developer**
Cost of Restoration		($120,000.00)
Increased Lot Yield		$825,000.00
PV of Wetland Maintenance	($4,057.28)	
PV of Educational Value	$34,344.83	
PV of Ecological Benefit	$12,470.09	
PV of Value of Carbon Stored	$515.30	
Total Present Value	$43,272.94	$705,000.00
Net BENEFIT	**$60,832.91**	**$965,000.00**

South Valley

Project Description


Figure 31: South Valley Bioswale and Creek (2005)

The South Valley Creek project is located within the District of Saanich in the Wilkinson Valley, an area of small acreage holdings in transition to urban infill of single family detached and townhouse development. The infill developments are being completed in several phases as previous owners' properties are assembled. The valley's land use plan is designed to be continuous and linked as the redevelopment of the area occurs. The proposed neighbourhood plan identifies the area for residential infill allowing various forms of residential development providing the overall density does not exceed the permitted units per hectare.

Peers Creek, a tributary to the Colquitz River, has been ditched along the valley bottom. In a portion of the development it has been restored to a functional condition. The restored portion of the creek in the newly created subdivisions was relocated and restored to a functioning condition for stormwater management, habitat enhancement and recreational amenity. The exception was a segment south of Tulip Avenue on South Valley Drive. This development primarily comprises single-family homes with an installed underground culvert to accommodate the pre-existing creek under the road which discharges into the restored Peers creek north of Tulip Avenue where the case study segment begins.

This case study overviews four of the phases of the infill redevelopment in Wilkinson Valley and looks at the details of one segment, highlighted on the site plan in Figure 32 on page 46. The Tulip Avenue and South Valley Drive segment is comprised of 6 single-family lots and a single townhouse component of 8 detached and semi-detached units. Total land assembly for this phase was +/-3.15 acres (1.275 Ha).

Within the 18 m road right-of-way is a 6 m road, 3 m trail, bio-swale along the east side of the paved road and a portion of the relocated creek. The road allowance was enhanced by 5 meters to include the creek restoration and was dedicated as park. The bio-swale and trail were designed to accommodate the existing sewer line.

Site Plan

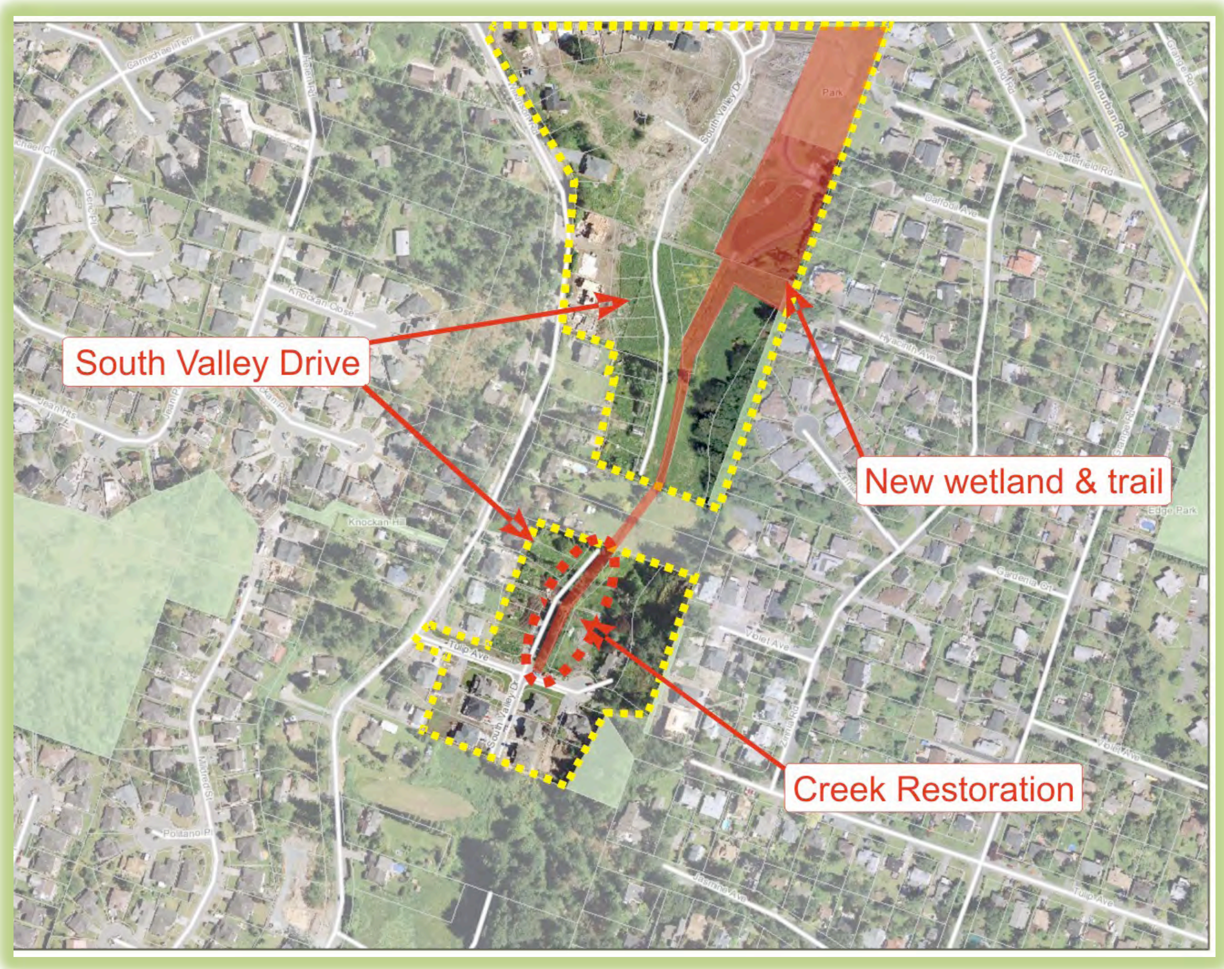


Figure 32: South Valley Drive Site Plan

Analysis

Project Aspects

The overall project benefit was one of substantially improved visual appeal, creating a linear park from what is essentially, a stormwater drain. The attraction of the creek was deemed sufficient that an artist's rendition of the creek was used for the main marketing board and material. This aspect is worth highlighting, because the appeal and value of natural solutions when compared to traditional engineering solutions is easy to miss, but provides appreciable value.

The point is best illustrated by contrasting the two approaches. On the one hand, it is difficult to envisage that a traditional stormwater pipe would ever form the focus of a sales and marketing campaign; on the other hand, natural approaches to rainwater management are not just environmentally and ecologically appropriate, but are also aesthetically pleasing, sufficient to form the poster for marketing. Clearly from our interview of the contractor/developer, this was deemed an aspect that would help sales – both values achieved and the speed of sales.

Other aspects of the project identified include:

- The Wilkinson Valley Action Plan required a 5-metre setback from the creek. Rather than adhering to the regulations the municipality allowed the developer to meander the creek within that total area (meaning that in some places the setback is less than 3 metres and in some areas more). Furthermore, the municipality also allowed the developer to install the bioswale, trail and creek within the road right-of-way (ROW). If the municipality had not been flexible with these regulations, the developer would have required an additional 5-7 metres for the creek and riparian zone enabling the developer to minimize the impact on the number of lots built, albeit they would be smaller. Specifically, this enabled the townhouse cluster fronting Tulip Avenue to be sized and configured to maximize value within the allowed density. By changing the setbacks without negatively impacting the function of the restored creek, the density achieved provided the revenues that permitted the developer to fund the creek restoration.

Figure 33: Grasscrete at South Valley

- The application of low impact development (LID)[xxxiv] techniques (*i.e.*, the roadside bioswale, grasscrete, and other stormwater best management practices) as well as the restored creek provides an added landscape feature over traditional curb and gutter boulevards. This helps to differentiate the project from other subdivisions, thereby enhancing value through faster lot sales, as reported by the developer.

- Overall unit density was maintained over the development through a mix of single family and townhouses. This may be more dense than might otherwise have been envisaged, but is consistent with densification and minimisation of excess land use, which itself is consistent with Smart Growth.

Figure 34: South Valley Trail and Creek

- There is a reported benefit in improved marketing of townhouse development (anecdotal from the developer as units had not sold at the time of interview). In justification of this claim, the developer related an instance of a prior purchaser seeking out this project due to superior landscaping and amenity features, including the restored creek. The developer considers that this kind of investment in his projects over a traditional minimalist development approach has benefits in terms of absorption (that is, time it takes to sell) and the price achieved. He considered the investment in extra costs would be recouped as the features improved the perception of a superior quality neighbourhood.

- A beneficial aspect is that the agricultural drainage ditch that had little ecological function (similar to Blenkinsop and Willowbrook) was upgraded and restored to a proper functioning creek. The benefit of this (apart from visual appeal) is the additional carbon sequestration, expected increase in water quality and decrease in downstream sediment transport, but also natural solutions generally require lower maintenance cost and time than engineered or managed solutions as has been documented with the Blenkinsop and Willowbrook case studies.

- Part of the project included creating and expanding the public trail corridor through the subdivision and connecting to the larger regional trail system. For homeowners interested in such connections, proximity is an added sales feature and attraction, further benefiting sales. Balancing this, others are concerned that public access via trail systems can lead to vandalism, putting off potential buyers by this feature. On balance, sensitivity to design can overcome negative aspects of public accessibility.

- Enhanced park and open space dedication (estimated at approximately 10% versus 5% required dedication) at no additional municipal cost, benefiting the municipality in avoided costs (*i.e.*, purchase of the land) and to residents since it adds to amenity visible form their property.

Figure 35: South Valley Agent's Marketing Image

- Costs were unclear because there was no external audited assessment and as the costs are private, the developer declined to make the costs available. Attempts to estimate the cost independently were unsuccessful as we identified duplication of costs between the stormwater pipe and creek and we concluded data could not be adequately separated to be meaningful in any way. The developer indicated that the duplicate costs were in the order of $120,000, but this did not include delays identified during the approvals process and we could not substantiate the sum mentioned.

- Additional value to homes from constructing the creek, at the time of the writing of this report, are not yet clear, but will be once the remaining homes sell and are publicly registered. An interview with the developer identified that 'the extra cost was worth it in terms of extra value' in the developer's opinion. Sales of the lots were deferred until completion, which is common in the local market appealing to local buyers, who want to see completed product. Unfortunately, the market dipped part way through construction and thus absorption slowed, so evidence on absorption and prices is expected to be inconclusive given the change in market, sales method and small data set. Asked whether the developer would do the same again in another project (*i.e.*, apply low impact development techniques to manage stormwater and creek restoration), his answer was that he would. This is the only indication available of extra value from applying low impact development techniques to manage stormwater and from the restoration of the creek, but it is an important one.
- The trail system was built to meet Saanich's standards, and this precluded using permeable solutions. Preferably, alternate approaches such as crushed rock or permeable concrete could be used and further reduce the need for stormwater infrastructure (*i.e.*, catch basins, etc), since this solution would reduce or eliminate the need for rainwater runoff management. This highlights the need for an alignment between Engineering and Parks department standards in order to facilitate sustainable practices.
- Stormwater treatment and management on-site, plus treatment and management of stormwater from the adjoining subdivision, lowered the downstream stormwater

management cost to the municipality (increased pipe capacity and management systems handling)

Stakeholder Perspectives

This aspect has been separated due to the complexity we identified. It highlights a common but complex issue of how municipalities struggle to adapt to an ecologically-centric approach to planning, engineering, codes, and development itself. It is stressed that while the following identifies room for improvement in the system, it should not be deemed a failure. It is symptomatic of change.

We identified that contrary to initial claims, there had been an avoidable duplication of stormwater solutions on the project. Originally it was claimed that there had been cost savings through undertaking the project but when meeting the developer on site, he noted and we confirmed the circumstances illustrated in Figure 37, which attempts to illustrate the layout of the storm drainage on the site. Reference is made to this diagram to explain the issue.

The first phase of approvals for the site related to the lots marked "A." These included provision for traditional engineered solutions of underground stormwater drainage taking the runoff from single-family development (*i.e.*, both road and sidewalk surface drainage, and house rainwater runoff). After this was approved, a move was made to encourage more sustainable approaches, resulting in the restoration of a portion of the creek, the inclusion of the bioswale and other low impact development techniques to address the extension of the existing stormwater pipe, as well as road and building rainwater runoff from the adjacent multifamily development ("C" in Figure 37). Stormwater runoff pipes were also required for the second phase single-family development, noted as "B."

The storm drain discharges into the creek, which absorbs the rainwater energy through the use of natural design and acts as something of a "reservoir" in storm events, something the storm drain cannot do. Important to identify here is that the creek is able to function not only to address the inability of the storm drain, but also provides drainage for the adjacent lands, noted as "C" on plan. The underground storm drain that links "A" and "B" in Figure 37 is designed to handle runoff from the houses behind but also, to address road runoff. This seemed peculiar since the intent was that the bioswale would manage this. On enquiry, we were advised this is because the road "crowns" (*i.e.*, the centre of the road is slightly higher than the edges, sending the rainwater to one side or the other). We questioned why the road could not have been sloped entirely towards the bioswale and thus have a single drainage solution, and were told that a crowned road is the municipal standard.

Figure 36: South Valley Stormwater Drain

We also enquired about residential building runoff and were told that the new houses (noted as "B" in Figure 35) needed to drain to somewhere and that the municipal standard is to use stormwater pipes. We noted that other jurisdictions do not require this and that the multi-family directly opposite was using grasscrete systems[xxxv] and drain tile. We were told that "B" needed a different, piped solution due to site characteristics (*i.e.*, slope and the need to stop water rising into the basement).[xxxvi] We are unable to verify this and from observation, training and experience, note that very old buildings have long existed on sites with greater slopes while draining into soakaways. The usual requirement is to require hydrostatic pressure to be addressed in combination with good insulation (to offset interstitial or surface condensation), vertical and horizontal moisture-proof membranes.

The result of this is a duplicate drainage system and an increase in costs that we believe may have proven avoidable or capable of mitigation, with sufficient commitment to effecting change. The problem appears to be that existing practices, standards, codes and bylaws have created barriers to change and more sustainable practices. In the case of the South Valley project, the municipality was not flexible in policies surrounding the trail width or the application of permeable paving (a LID technique), as a consequence, this appears to have actually doubled sidewalk widths and increased the amount of impervious area and stormwater run-off. As low impact development techniques are continually applied and documented elsewhere, it is hoped that the municipality will become more flexible in its policy towards the application of such practices. As it stands, the municipality's strict adherence to policy requirements increased costs impacting the project's value and the developer's revenue.

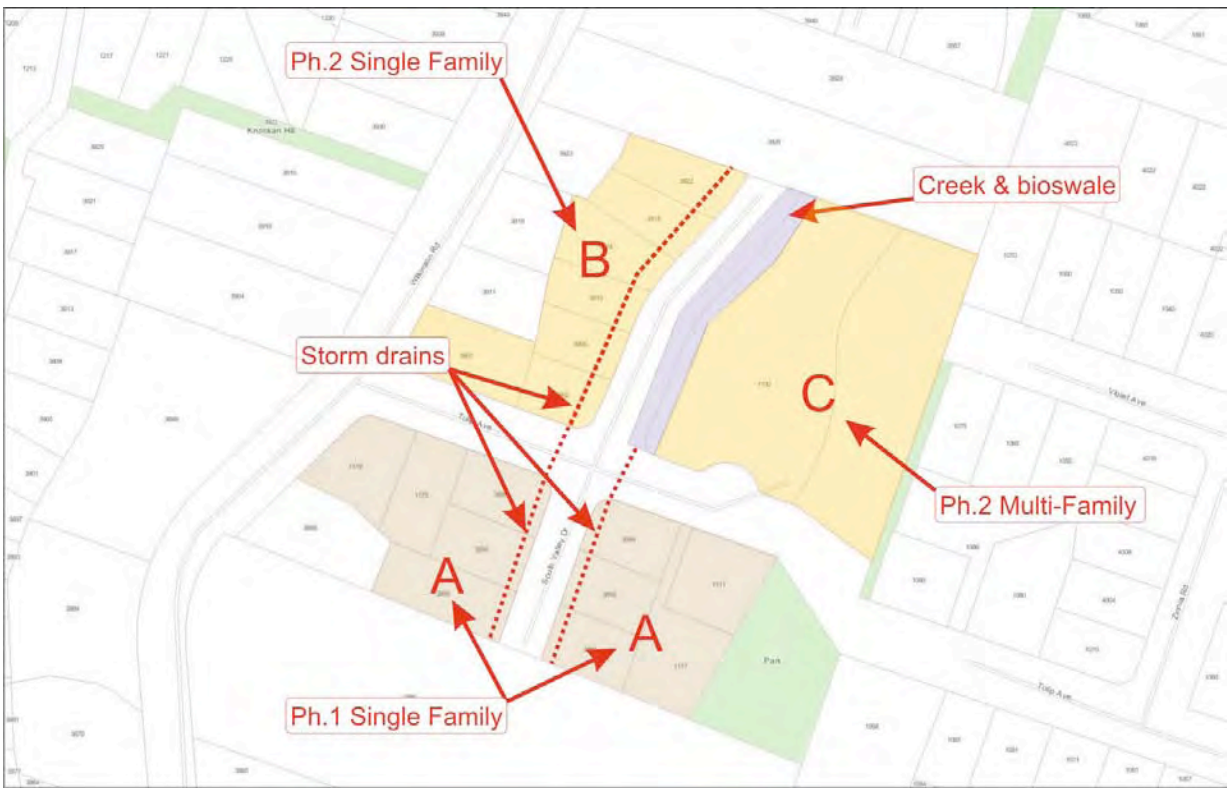


Figure 37: South Valley Drainage & Phase Diagram

The foregoing represents complex stakeholder issues. Clearly there is political direction for an ecological approach to stormwater management, which from "Green into Gold" mentioned previously, we believe responds to community interest and Official Community Plan (OCP) guidelines.[xxxvii] However there is engineering department hesitance, largely supported by historic practice and stated reliance on building codes and bylaws. Interviews with staff identified risk aversion as the driving influence: concern was expressed that storm drainage would be needed to avoid groundwater infiltration to basements. On the face of it this makes sense, however we point out that the creek has not resulted in moisture issues on the opposite side of the street and we conclude that this may be more a function of change in strategies for stormwater management than bylaw or code issues. Notwithstanding, the province has initiated a green building code review and ongoing review of municipal bylaws and practices will be needed. Thus:

- We documented that there are engineering issues with the low impact development approaches taken (and those proposed – *i.e.*, porous pavement). These impact process and risk and appear out of sync with other stakeholders' perspectives;
- From our discussions with municipal staff there are perceived risk issues with the ecological approach, however the evidence does not substantiate the claim and we conclude the risk is low and capable of simple mitigation;
- Political and community interests support an ecological approach;
- There is perceived value (the developer supports the ecological approach) but this cannot yet be quantified with the South Valley case study (this has been shown with the Blenkinsop, Willowbrook and the Rogers Subdivision case studies);
- As other developments have now used South Valley, Willowbrook, and Rogers subdivisions as models, there is clearly broader stakeholder interest in applying an ecological model to development.

Value Conclusion

While there may be direct property value from a project of this nature, at the time of review the homes adjacent to the bioswale and creek were not available for sale. It may be possible to revisit the project when fully occupied and assess what incremental value was obtained, however it is considered more likely that the steps taken reduced the time to sell out the project rather than add distinctive value. We consider the relatively small number of homes would create difficulty in providing conclusive evidence of increased sales price.

From our discussion with the developer, there were no cost savings to the developer from this approach, because the bioswale and creek duplicated traditional engineered solutions (on the opposite side of the street). We do estimate that because of the flexibility with regulatory setbacks in regards to the right-of-way and the creek, the developer was able to maximize the density of the development and therefore increase his overall revenues. In time, we expect increased awareness and different approaches to handling stormwater will lead to changes in Codes, bylaws, statutory constraints and increased awareness amongst engineering, planning and other staff, councillors and others, such that an ecological approach can be more appropriate and cost effective than the alternative. Governments at all levels will need to take steps to effect this change however, and introduce measures[xxxviii] to reduce barriers to more sustainable solutions, for there are valuable benefits that can be derived from such solutions (pollution abatement, protection of downstream water sources (*i.e.*, flooding), ground water recharge, improved water quality, habitat improvements, and increased aesthetic values).

There is arguably a small benefit from the dual use of the roadway at the rear of housing fronting the creek. Basically, the roadway serving some of the houses has been laid as grasscrete and will be linked to the public trail system when other adjacent sites are developed. It remains to be seen whether this will be an actual long-term saving since the more logical pathway immediately fronts the stormwater feature and the trail can easily be redirected at no cost. The savings are thus considered negligible because the difference in cost between different surface types and treatments is likely small, but the benefit ecologically from using grasscrete is that tree roots and water flows are disturbed less than with other alternatives.

Rogers Subdivision

Project Description

Rogers subdivision is a 72-house, phased development on Christmas Hill (previously known as Rogers Farm) in the District of Saanich, BC. Rogers Subdivision is situated the east side of a major Highway (the "Patricia Bay Highway" – Highway 17), which serves as a connection from the City of Victoria to the airport and ferry terminal, as well as other communities on the Saanich Peninsula.

Figure 38: Baxter Pond 2007

Seeking to subdivide and develop Rogers Farm, the developer was initially asked to provide on-site stormwater detention reservoirs which, given the geology of the site, would have required blasting and excavation of bedrock on an area of land equivalent to three single family residential lots. The stormwater from these detention ponds would have been conveyed by storm drains directly into Gabo Creek, situated across the highway and accessed via underground stormwater pipes. The cost of the on-site treatment was expected to be expensive and after several years of conflict with the municipality, the developer sought a more cost-effective ecological alternative.

A wetland on a linear parkway at the base of Christmas Hill had previously been used as a fill dump and was no longer adding functionality to Gabo Creek. As part of the Rogers Farm subdivision construction, this wetland was restored and expanded, called Baxter Pond. Public parkland was used to manage stormwater, as it would allow the wetland to capture stormwater from the new Rogers Subdivision, a segment of Highway 17 and a portion of two older adjacent subdivisions, thus maximizing protection of Gabo Creek.

As a result of the approach using existing public land as a stormwater treatment solution, the ecological function of Baxter Pond and a portion of Gabo Creek were restored to a functional condition creating a significant amount of waterfowl, songbird and aquatic habitat. The community permitted the use of public land and, in return, received stormwater treatment for the entire sub-watershed plus a restored park at the developer's cost.

Site Plan

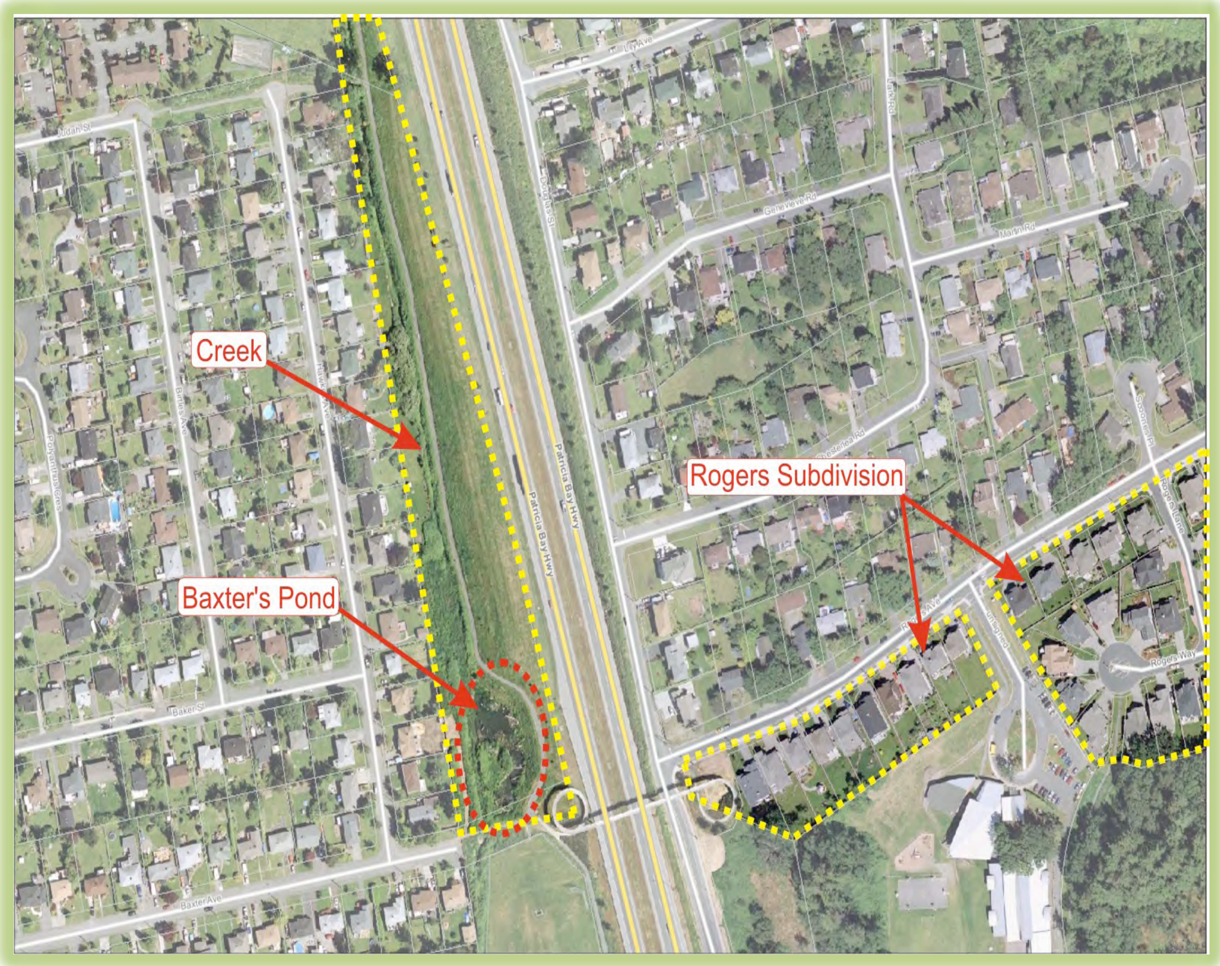


Figure 39: Baxter Pond Site Plan

Analysis

Project Aspects

The key aspects of the project are:

- The off-site stormwater treatment and management reduced cost and helped expedite development permit applications and approvals. The cost for traditional on-site treatment was estimated at in excess of $275,000, whereas the cost of rebuilding the wetland on public land was $75,000. There was an immediate cost saving of $200,000 to the developer.

- From the District of Saanich's perspective this solution meant a cash injection of $75,000, which restored previously lost ecological function but also created a significant public amenity as an improved trail/park facility.

- From the developer's perspective this approach meant that three building lots were saved that would otherwise have to be committed to on-site stormwater management. The financial benefit of this saving is estimated at in excess of $345,000 ($115,000 per lot in 2002).

- This solution had greater benefits than simply the treatment for Rogers Farm subdivision, since, in effect, the developer funded stormwater treatment and management solutions for a portion of two existing subdivisions and a segment of the Pat Bay Highway (Hwy 17).

Figure 40: Rogers Subdivision Across the Pat Bay Highway from Baxter Pond

- Restoration of Baxter Pond resulted in the enhanced treatment and retention of stormwater runoff. As in other projects, large rainfall events are managed by the ecosystem, providing enhanced rainwater retention (although we could not quantify this value). Estimated benefits that arise from the project are carbon sequestration and storage ($2,498), educational value ($34,345) and the social benefit ($11,623) which is likely to encompass protection of downstream water sources (*i.e.*, flooding), ground water recharge, improved water quality, and habitat improvements. Such benefits could not be easily and cost effectively achieved with traditional engineered solutions.

- The issue of enhanced recreational amenity recovery is difficult to place a value on, due to its intangible nature. However, during our assessment of this project we spoke to several local residents using the trail system and there is clearly local approval for the Gabo Creek restoration as an enhanced amenity.

Figure 41: Baxter Pond Prior to Restoration

Stakeholder Perspectives

Community

The neighborhood has received an attractive amenity which, in turn, prompted the improvement of the local trail. The area includes an adjacent school (and three others nearby). We observed children watching the wildlife (*without* this being part of a class exercise) and there is thus an educational benefit. It also represents a possible liability risk, but steps have been taken to mitigate this through fencing and an engineered egress from the pond.

Developer

For the developer, adopting sustainable practices both improved overall financials and expedited permits. It increased lot yield and facilitated increased gross revenues. It also resolved a long-standing conflict between the municipality and the developer. There was a clear net gain to the developer.

Regulatory

This project set a precedent for treating stormwater on common (municipal) property that may be applicable to other similar situations where the public benefit outweighs the cost. Though Gabo creek has limited fisheries value, it is a tributary to the Colquitz, which is a very high value stream. This project has been showcased by the Ministry of Environment's case studies and is used as a positive example in their educational presentations to developers and design professionals[xxxix].

Municipal

For government and the community, there was a clear net gain. Not only did the developer fund the restoration of municipal lands, other benefits accrued. These included amenity improvements, visual improvements, addressing previously unaddressed highway runoff treatment, resolving stormwater impacts (improved water quality, sediment detention, and downstream flooding) from other subdivisions at no additional cost, and reduced long-term maintenance costs and all of this at no cost to the taxpayer. It also addressed acting as a holding area for storm event discharges. This provided both engineering and planning benefits in terms of a greater buffer from storm events.

Value Conclusion

The expected increase in the value of homes adjacent to the restored area is assumed to be nil because they back on to the creek which is not visible from their yards. Nor, did we identify any extra value accruing to the developers of Rogers Farm from this project: the development's location the other side of the Pat Bay Highway effectively severs the development from the project and the lack of immediate proximity (as well as the negative externality of the highway) means provable economic benefit is too distant. The benefit to the developer is thus largely the cost savings from undertaking this project relative to alternatives, plus additional lot yield.

Overall benefit to the developer was comprised of savings from blasting, avoidance of having to use three lots for stormwater management, and reduced costs of implementing a stormwater management solution. From estimates provided to us, we conclude the net benefit to the developer was $545,000, despite contributing $75,000 to public community improvement. This value was derived from stormwater engineering cost savings of $275,000, less costs of $75,000, plus increased lot yield valued at $345,000. It is worth noting that the developer made other contributions through development cost charges etc. that would have raised this amount but also comment that if Saanich had undertaken a development viability analysis of the savings and contribution being made, it may have sought a larger sum as a public contribution. Other municipalities have occasionally adopted this approach, successfully, with both the developer and the community mutually benefiting.

As noted previously, the developer was a clear beneficiary of the project, but so was the municipality. The financial net benefit to the municipality was $75,000. If other estimated benefits are accounted for the net benefit to the municipality amounts to $123,466. Furthermore, although not quantified financially, important to note is the level of improved water quality, sediment capture and storage the wetland provides. The results of the sampling program are as follows:

Figure 42: Sediment captured by Baxter Pond

- On average Baxter Pond removed 40.84% of the Total Nitrogen and reduced specific conductance by 4.4%. The pond was effective at reducing sodium, and to a lesser extent, at reducing mercury and zinc. Between the inlet and the middle of the pond, cadmium declined by an average of 26.2%, chromium declined by 9.7%, mercury by 24.1%, lead by 39.35% and zinc by 38.5%.
- Baxter Pond was very effective at removing large, heavier particles, as seen in Figure 42 following a winter snowstorm. Sand from the Pat Bay Highway and neighbouring streets was washed into the pond and trapped.[xl]

Although it cannot be measured for the same reason as the loading rates, the potential for downstream flooding has been reduced due to the restoration of Baxter Pond. Prior to the development, Baxter Pond was designed and engineered to be a dry pond (*i.e.*, the pond completely dries out in the summer); as a consequence, there was no vegetation due to the lack of water and constant mowing by the municipal staff (Figure 41). During winter storms the area would fill with water, buffer some of the flows and then subsequently discharge into Gabo Creek. During more frequent storm events, the pond would fill up and any additional flows would be discharged into Gabo Creek with no reduction in velocity or volume. The restoration of Baxter Pond included complete redesign to create a deeper and larger pond thereby accommodating not only the existing flows, but the additional flows from Rogers subdivision as well. The design and layout (*i.e.*, depth, length, and vegetation) buffer frequent storm events by retaining and detaining stormwater and, as a result, slowing the discharge rate and high flows that would have traditionally been discharged into Gabo Creek. Not only does the municipality benefit from the reduction in downstream flood risk, the public do as well. Furthermore, the public have also benefited from the increased aesthetic value from the restoration as well as the improved trail.

As in other projects, we conclude that a traditional appraisal approach would not identify most of these values. Appraisers have to use a development residual analysis in order to identify the net benefit, and in our experience at best only 10% of this cost saving will trickle through to the land value. In most cases however, by the time savings of this nature are identified, the land has already been purchased and the benefit is to the developer's profit, which may be reallocated to risk management, quality improvement in the development or other aspects that improve sales value of the completed buildings.

Figure 43: Rogers Subdivision Financial Summary

Rogers Subdivision (Traditional)	**Municipality**	**Developer**
Cost to Install On-Site Stormwater Detention Systems		($275,000.00)
PV of Dry Pond Maintenance	($4,057.28)	
Total Present Value	($4,057.28)	($275,000.00)
Rogers Subdivision (Sustainable)	**Municipality**	**Developer**
Cost of Restoration		($75,000.00)
Value of Increased Density		$345,000.00
PV of Wetland Maintenance	($4,057.28)	
Avoided cost of Restoring Property	$75,000.00	
PV of Educational Value	$34,344.83	
PV of Ecological Benefit	$11,622.52	
PV of Value of Carbon Stored	$480.28	
Total Present Value	$117,390.35	$270,000.00
Net BENEFIT	**$121,447.63**	**$545,000.00**

Vancouver Island Technology Park

Project Description

Vancouver Island Technology Park (VITP) is a renovation of an existing set of buildings previously owned by the Province of British Columbia, known as Glendale Lodge. Built in 1973, it was a residential hospital for severely disabled patients but was vacated in 1996, due to its unsuitable design. Following abortive attempts to sell the property, the province granted approval to renovate the 165,000-square-foot former hospital into a research technology park (VITP). Work started in October 2000 and the project became fully leased in 2004/05.

The provincial government, through an interest-only loan, financed the project with the plan being to create a business park to support the University of Victoria and adjacent Camosun College, amongst other original participants in the venture. This was seen as an exit strategy alternative to selling the asset; it was felt that the renovation would create an investment capable of sale. When the project commenced, the high tech boom was in progress and leveraging educational and business aims was considered to be supportive for the economy, a primary driver for the concept.

Figure 44: VITP's Grasspave/Gravelpave Parking Lot

One vital fact is often overlooked, for the original funding application was based on a budget for a "traditional" renovation of the facility. As such, no "green" components were originally budgeted or envisaged. During planning however, rising construction costs elicited suggestions to deconstruct rather than demolish internal structures and to determine ways to utilize the surrounding lands more sensitively. Consequently, it was decided that an environmentally sensitive method would be applied in the construction of the project; upon completion, *VITP achieved the LEED™ Gold standard whilst remaining within the original (i.e., "traditional") budget*. This is important to note, since VITP was the first accredited LEED™ building in Canada, showcasing the ability to achieve sustainable development without the extra costs often claimed.

Site Plan

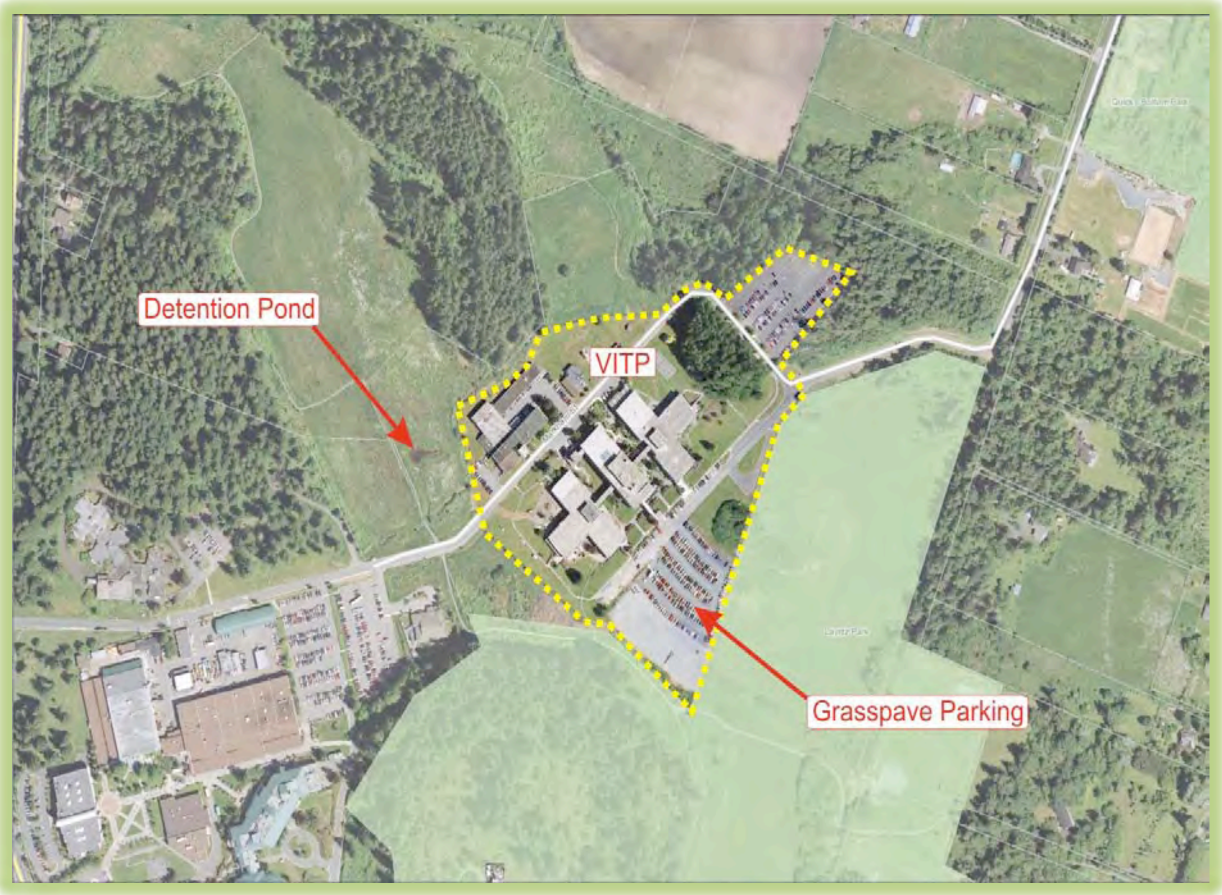


Figure 45: VITP Site Plan

Analysis

Project Aspects

Because VITP is a large project of which the water component is relatively small, it formed no part of the original business case and only a small (but important) part of the eventual development. We have thus restricted our comments to the main water-related components of the project.

- We attempted to obtain details of the project. We approached Accommodation and Real Estate Services (ARES) (formerly BC Buildings Corporation), VITP (now part of UVic) and those involved in the original project. None of the original costs for the project could be found, although the original business case and authors were identified and all main contributors were independently interviewed. We understand that, had the cost data been available, it may not have separately identified each of the ecological aspects of the project sufficiently to be useful. Individual aspects are commented on as follows.

Figure 46: VITP Master Plan (2008)

- The original development had caused Goward Springs Creek (Viaduct Cr.) to become less than ideally functional. The project worked with Saanich and the community to restore the stream as part of school education. This helped gain community support and engagement, which has been attributed by the developer as a contributor to gaining development approval. Prior to this development proposal, the community had rejected alternative development proposals.

- With creek restoration linked to developing trails through the property, work was needed to mitigate runoff from paved areas. A solution was needed for the large parking area and VITP executives identified a U.S. product and worked with a local group to licence and manufacture the product in BC. The solution is GrassPave™ and GravelPave™ both of which use a permeable structured solution embedded in the ground through which grass (for GrassPave) can grow or for gravel (GravelPave) and yet provides support for vehicles. This soil-based solution bio-remediates any deposits from vehicles and allows direct groundwater recharging without the need for stormwater collection, oil traps and piping. Furthermore, the parking lot was designed as a reservoir to handle the stormwater volume from a 10-year storm event.

Figure 47: VITP Bioswale

- Upon comparison to more traditional paving solutions for the 5,500 sq meter parking lot, the Grasspave / Gravelpave solution is estimated to have cost the owner approximately $146,120. In contrast, a traditional solution would have been an asphalt parking lot which would have required the standard stormwater infrastructure costing in the range of $680,000-$700,000. Using the lower cost value for the asphalt parking lot and stormwater infrastructure, the alternative parking lot saved the owner $533,880.

- To complement the Grasspave solution, swale restoration and curb cuts were used to mitigate stormwater management. Bio-swales and bio-filtration ponds were used on site to treat stormwater to remove contaminants and control rate of flow. The Grasspave parking lot stores the equivalent runoff of a 1 in 10 year storm event. These were essentially retrofit projects since the road system already existed, therefore we could not identify direct financial savings from these components.

- The project uses waterless urinals, dual flush toilets, infrared sensor sinks, shower flow restrictors, and has made provision for future rainwater collection. Also, VITP does not use potable water for landscaping, although temporary measures were used to establish native plant species. VITP could not provide data on water consumption that would have allowed us to compare this development with a traditional project. Review of Capital Regional District charges however, shows there would only be a small financial saving. The larger benefit is likely to be biodiversity improvement, which adds to the visual appeal of both the project and the surrounding area. One clear and identifiable benefit of reducing potable water consumption is that there is decreased need for new major infrastructure projects such as dams, treatment plants, piping and so on. These upstream costs are not always reflected in water charges.

Figure 48: GrassPave Damage

- The total green space for the development is 76%. Approximately 17% of the site is treed, with a further 40% of open green space comprised of field and wetlands. Wildlife habitat has been restored with native plantings through the integrated stream and wetland areas. All clustered treed areas on the site have been retained and trees tagged and surveyed, with over 99% of trees being protected. Future development will be on previously disturbed lands or lands with minimal ecological impact. This is an unusually high proportion and commitment, and is more a legacy factor from the previous use and ownership. It was also necessary in order to gain public approval. It adds to the attraction of the project and undoubtedly helped contribute to the faster lease-up, which was represented by two independently interviewed participants in the project as having achieved 20% faster lease-up than the original budget, which itself was based on market norms for this type of project.

- As part of the ecological restoration program, a process of community engagement was undertaken. This included working with schools and community groups to undertake stream restoration, which both improved stakeholder involvement and reduced construction costs. The long-term benefit that will likely result is reduced vandalism and greater respect for the ecological works. The cost saving from this was not tracked or accounted for, but is likely to have been small relative to the benefit of community engagement. This latter is thought to have helped with expediting process and municipal approvals.

- We noted damage to certain of the aspects of the stormwater management system. This was identified as both a vandalism and maintenance issue as vandals have been using vehicles to tear up the GravelPave. Furthermore, a lack of maintenance of the parking lot (*i.e.*, closing off parking areas to allow for the grass to grow, fixing areas that are pulled up immediately, and raking bare areas) was evident. This may be caused partly by knowledge transfer issues (staff have changed and the original understanding of how to manage the installation may not have been transferred), and partly due to the experimental nature of the installation (*i.e.*, GrassPave depth, structure and parking use intensity). We were advised during enquiries that high-intensity-use portions of the parking lot may be need to be paved to reduce long term maintenance (*i.e.*, introducing catchments, traps, filters and other items that formed part of the original benefits and savings).[xli]

Stakeholder Perspectives

Developer/Owner

From the owner's perspective, the prior use had become redundant and without community approval there was no possibility of viable use of the site. The ecological aspects of the project were sufficiently appealing to the public to obtain approvals, but were paired with a financial business case that made the project viable. The most important aspect to note is that an environmentally suitable approach was successfully used as a cost management measure and the fact that this could be achieved within a budget already set by a traditional development expectations, demonstrates the viability of an environmentally sensitive approach to development. As previously noted, we only have verbal indications of this cost management benefit, as the data to quantify and confirm it was unavailable.

Figure 49: VITP Parking Lot (Aerial View)

This project was the first LEED™ development in Canada. As such, there was great incentive to deliver the project on time and on budget. The substantial savings in stormwater infrastructure greatly assisted in meeting these goals. The ecological aspects of this project also supported the marketing campaign and contributed to the profile of the project, whose coverage has been very extensive across Canada and internationally. This in turn, supported the creation of the Canada Green Building Council (which was first housed at VITP) and has accelerated the adoption of green building practices in Canada.

Community

For the public, prior proposals to develop the site had proven unacceptable whereas this proposal proved popular and acceptable. Without addressing the ecological concerns, the development could not have been undertaken. In addition, restoration of creeks and integration with expanded trail systems have clearly added considerably to public amenity. Engagement with the community was deliberate, which improved stakeholder involvement and conferred educational long-term benefits upon those who participated in the process.

Regulatory

The restoration of Goward Springs Creek (Viaduct) required the normal environmental approvals, however no obstacles were encountered. The use of porous paving did, however, require an amendment to municipal engineering standards, as municipal standards required asphalt.

Municipality

While the project was intended to resolve reutilization of a redundant asset, for the municipality and broader economy, the project added jobs while respecting the environment and community. Prior attempts to develop the site had been refused (*i.e.*, the way the project and community communications were handled – of which this was a key part – added jobs which had previously proven impossible). The additional value of the ecological aspects proved politically popular and restoration was undertaken at minimal cost to the owner. This approach also acted to minimize downstream impact on stormwater management, and upstream requirements for increased potable water capacity.

The economic impacts of the technology park itself included tax benefits comprised of employment taxes, development cost charges, property taxes, corporate taxes and expenditure in the community (with associated re-spending effects, probably in the ratio of: or 3:1, estimated with regard to community dependency ratios). These economic benefits are realized at federal, municipal and provincial levels. An assessment of this was undertaken by VITP in 2005 and the VITP Economic Impact Study identified direct and indirect benefits amounting to 2,000 jobs and $280M in direct, indirect and induced revenues.

Value Conclusion

The key value conclusion is that sustainable approaches to development can be undertaken within traditional budgets to achieve a highly recognized building standard [LEED™ Gold]. Specifically related to alternative infrastructure, the benefit to the owner included savings from building a traditional parking lot that would have required traditional stormwater infrastructure, reduced maintenance costs, and capital replacement. From estimates provided to us, we conclude the immediate net benefit to the developer was $533,880. This value was derived of stormwater engineering and asphalt pavement cost savings of $680,000, minus costs to install the current GrassPave/GravelPave parking lot of $146,120. There is an additional benefit to the owner as the current GrassPave/GravelPave parking lot has a potential life of 60 years (provided it is maintained), whereas in contrast an asphalt parking lot typically lasts only 20-25 years and then needs to be recapped. Accounting for this additional cost as well as the costs to maintain the GrassPave/GravelPave parking lot, a net benefit still accrues to the owner as the present value of recapping a similar sized parking lot is $32,813 whereas the present value maintenance cost of the current parking lot is $23,547; a difference of $9,267. [xlii] Therefore the total net benefit to the owner is $543,147.

There were other ecological components (*i.e.*, stormwater wetlands designed for future expansion) of the project could not be adequately isolated to prove distinct added value. However, from discussion with tenants and the development team, it is clear that they added an amenity that contributed to the green component of the park achieving a 20% faster lease-up. Leases are now being renewed and separate studies in the next few years may identify whether there is a rental premium for being green, to which the current case study contributed.

Because VITP is something of a test project in British Columbia and many new concepts were brought together for the first time, the cost savings were clearly not as high as they might be today, given a greater experience with sustainable approaches. Also, almost all the executive and many staff have dispersed to other projects and with the sale of the property there is little corporate memory of the original development principles, making it more difficult to manage the assets sustainably (as seen with the parking lot) in the long term. This is likely to increase costs and elicit proposals to replace the sustainable infrastructure with more traditional solutions unless re-education can be undertaken. Of note, is that the manager of this project, Mr. Joe Van Belleghem, has now extended the lessons learned from VITP to his new, highly successful residential and commercial brownfield redevelopment project in the heart of Victoria. Dockside Green is intended to be the first LEED™ platinum community in the world and in July 2008 received the highest number of LEED™ points ever awarded, for its first building. The lessons of VITP are thus resonating throughout the region and province.

For appraisers, the key aspects demonstrated by this project are that sustainable approaches can improve the speed of occupancy considerably, at market rents equivalent to comparable projects. We were unable to identify an increase in rent initially, but with in effect no tenant turnover, there is an expected benefit to the net investment yield with improved lease renewals, rent free periods and tenant inducements. As components of the project reduce operating costs we expect the owners will be able to increase rent and improve both income security and overall yields over the life of the project. This is because tenants can afford to pay more rent while maintaining the same total operating costs they might otherwise pay in competing buildings. The link between these benefits and the subject of this case study is however, indirect. The benefits are attributable to a range of aspects and not just the stormwater management initiatives.

Figure 50: VITP Financial Summary

VITP (Traditional)	**VITP**
Cost to Prepare Site and Install Asphalt Paving and Connect to Existing Stormwater Infrastructure	($680,000.00)
PV of Costs for Future Capital Replacement (Recapping) of Parking Lot	($32,813.45)
Total Present Value	($712,813.45)
VITP (Sustainable)	
Cost to Prepare Site and Install the Grasspave /Gravelpave Parking Lot	($146,120.17)
PV of Operations and Maintenance	($23,546.55)
Total Present Value	($169,666.72)
Net BENEFIT	**$543,146.73**

*** PV calculations use a time frame of 25 years @5% (No values have been adjusted for inflation).**

Appraisal Commentary

Appraisal Methodology

There are two main categories within which valuation methods fall for analysing the economic benefit of riparian zones: market-based approaches to value, and non-market approaches. The former is evidence-based and the latter relies more on interview and opinion. Within these categories, several approaches to assessing value may be appropriate and some discussion is provided, relative to the case studies:

- The comparable approach is a market-based approach that uses evidence of actual sales to determine differences in value. Within this approach, data may be statistically significant (usually using hedonic models) or rely on individual (non-statistical) evidence. None of the case studies had sufficient evidence of value differential to provide reliable indicators (*i.e.,* there was not enough sales evidence over time to demonstrate a difference in value).
- The discounted cash flow (DCF) approach is potentially helpful in quantifying cost savings and takes inputs from costs and revenues (*i.e.,* it is evidence-based and permits adjustment for specific costs).
- The contingent valuation approach uses market survey to determine whether there is evidence of increased value. This is based on opinion (*i.e.,* willingness to pay) and is thus a non-market approach that is not based on evidence of value or cost savings. This is helpful in identifying preferences and has been used extensively in the literature reviewed, but it falls short of establishing market value differentials.
- Public Interest Valuation is the assessment of value to the public. Some valuers hold this to be a controversial technique because it does not establish market price but rather, identifies the values to multiple stakeholders across multiple accounts. Since the case studies accrued multiple types of value and savings, to multiple different interest groups, Public Interest Value is an important consideration for these case studies. It can combine both evidence-based, market and non-market (opinion) values, but is best implemented by reference to tangible value. It has in essence been used to assess the multiple accounts of public benefit, but fallen short in most instances of identifying each account's actual value due to the difficulties in assessing actual value.
- Highest and best use and value play a role. This is where market transactions occur because one party is able to pay more for an asset or feature than another. In the case studies and taking into account Public Interest Value, development happens because the developer has a higher value from development than the public does in the use of land as a park.
- In a traditional market valuation, the developer's benefit might be shown clearly by a DCF calculation if undertaken to sufficient level of detail, but the lack of clear differential benefit for riparian proximity makes a DCF of less utility for a market-based analysis.

The case studies discussed within this report identified multiple benefits accruing to multiple parties, characterizing (from experience) development projects that incorporate the conditions within BC, since these are for the most part in the public domain. Market-based analyses would not capture the other benefits (non-use values) obtained by others such as the public, nearby residents and so on. In order to capture such values, a Public Interest Value approach would be needed where not only are the Triple Bottom Line accounts evaluated but also, several recipients' contributions and benefits are valued. This type of "three dimensional valuation" is uncommon and is not a driver of developments, unless some form of transfer pricing mechanism is in place so that the benefits from one party are transferred to another. In all the case studies, projects proceeded because there was sufficient benefit to a single recipient who was able to fund the project. In other words, the benefit accrued to the financer (*i.e.*, developer/owner) exceeded the cost. It is important to note, that the public and other benefits were found to be in essence ancillary with the real driver being the overall net benefit to the developer, but as these case studies have noted, the developments could not have occurred without community support.

Conclusions & Recommendations

Figure 51: South Valley Stormwater Channel

Though we experienced problems in reviewing and obtaining cost and value data for virtually every project, each project demonstrated a net benefit to the owner, municipality and community in addition to many intangible benefits. The difficulty in obtaining data can be attributed largely to the "pilot" nature of the projects, which results in many of the outcomes not being capable of prediction prior to undertaking the project. We do not believe any blame attaches to this, as it is a reasonably common experience, but it is not entirely consistent with meeting taxpayer accountability for project funding decisions. In addition, privacy, commercial interests and confidentiality issues restricted availability of some information and finally, lack of quantification significantly hampered our analysis (upon which we applied proxies, but these have the restriction of benefit transfer[xliii]). Those whose collaboration was needed in supplying data had little or no incentive to support this study and the data obtained (being detailed and difficult to assess) was thus largely insufficient as most data was simply unavailable.

The provincial government of British Columbia typically addresses this by using pre- and post-completion audit processes that are set up prior to project commencement and we therefore recommend similar practices:

- For significant pilot, test or exemplar projects especially, consider establishing and adopting a formal process to evaluate whether the project has met success criteria. Set the criteria for measurement and define success prior to commencement.
- Establish a baseline assessment of the main aspects likely to be affected by a project. Include those aspects affecting each identifiable stakeholder. At an agreed time during and subsequently after completion of the project, review any changes to the baseline data and assess whether any have changed. Periodically revisit the baseline and post-completion assessments to understand whether any long-term aspects of the project are found.
- Establish and use Triple Bottom Line methodology to develop assessment criteria for project reviews and ensure that there is fair assessment under each of the three accounts (*i.e.*, do not

ignore financial and economic impacts). Consider whether Full Cost Accounting – or more accurately, "Full Value Accounting" can be undertaken and do so where possible, even if non-financial aspects are difficult to quantify or set proxies.

Specific to stormwater infrastructure studies, we recommend that separate generic assessment be made:

- The study should assess the savings of treating stormwater with managed wetlands and ponds and restoring neighbouring streams based on several models: a parking lot, a road and buildings. Scalable sizes should be chosen so municipal officials, designers and developers can make calculations accordingly. The calculations should include sequestration benefit from stormwater redirection resulting from biomass increase and include biomass-harvesting frequency in a DCF model. It should also evaluate GHG and cost/maintenance impacts for the ecological approach. It may not be possible to add in value benefits for proximity of property (*i.e.*, adjust for housing proximity to greenspace and benefit to housing values) because this is dependent on multiple factors, but some discussion and attempt to model this may be possible.

Figure 52: Baxter Pond (Pacific Christian School in the Background)

- The calculations should differentiate from savings (*i.e.*, separately enumerate piping and pumping costs, maintenance, electrical energy savings and upstream GHG impacts resulting from marginal power consumption; use the GHG footprint for marginal power consumption – typically coal-powered).
- Since the cash flows and life cycles will differ substantially, and so will water flows depending on climate and location, these too must form part of the model. Ideally the model would be a spreadsheet that allows simple recalculation by adjusting for local circumstances and individual variable.
- As might be appreciated, the above scope illustrates why we could not undertake any kind of reliable analysis of the economic benefit of this item: the data was not available and too complex to undertake in the absence of sufficient base information. Saanich may wish to commission this when the next opportunity arises, but *undertake the analysis simultaneously with an actual project*. The lack of data captured during the project or access to it subsequently, made it impossible to restructure an analysis.

Although all very successful projects, underlying each were identified bylaws, codes, statutory and other process obligations and practices that consistently acted as barriers to "doing the right thing." Historical professional training and practices, and occasional political intervention, to make ecological and financially sensible proposals incapable of being accepted or implemented, compounded this. Although the developers were largely successful in establishing alternative methods to stormwater infrastructure, at times the barriers resulted in occasional duplication and redundancy and as a consequence contributed to dissuading developers and owners from sustainable efforts. All the projects that had a commercial aspect had expedited process as a result largely of community support. However *we could not confirm that any of the projects had reduced development cost charges*. Since development cost charges are intended to cover municipal infrastructure, in theory there should be a reduced charge where ecological approaches are used and, since ecological and sustainable initiatives reduce the burden on public infrastructure, requiring less review to ensure compliance with public objectives (as well as reduced future costs), consideration should be given to establishing the following policies:

- Use the development review process to consider the use of variances and density bonusing to secure or restore public amenities (*i.e.,* open space, riparian areas, landmarks, or cultural features).
- Utilize development control bylaws to achieve a more appropriate development in terms of streetscape, pedestrian environment, view protection, overall site design, and compatibility with the function of the landscape and (if applicable) the aquatic ecosystem.
- Require that site designs reduce the amount of impervious surfaces and incorporate features that will encourage ground water recharge such as vegetated swales, pervious paving material, as well as being open to considering ecological approaches to stormwater management. Ensure that policies are consistent amongst municipal departments.
- Support the understanding of growth management and sustainable development best management practices (*i.e.,* low impact development), through public events and online and printed information.
- Encourage accessibility through the incorporation of building support systems as design features and where appropriate, make them visible to the public (*i.e.,* green roofs, energy and water use monitoring).
- Work with private landowners to acquire trail rights-of-way, easements, or other services provided (*i.e.,* flooding) by donation or bequest of privately owned lands or payment for services provided.

There is a clear demand from the public for increased sustainability and these case studies show they can be achieved at the developer's cost rather than depending on taxpayer revenues. Especially for projects with a heavy stormwater engineering component, it is possible to benefit upstream and downstream infrastructure by using ecological solutions. We recommend that ecologically sensible development solutions can be achieved with greater benefits to government and the public, as well as the developer, if traditional stormwater engineered solutions are always considered alongside and compared to ecological alternatives. A process change of this type could be quickly instituted as part of municipal policy, where appropriate.

Although some members of the development, finance and appraisal sectors have historically been slow to adopt more sustainable practices, these case studies illustrate there is a clear benefit in terms of expedited approvals processes, improved cost management, improved profit and we believe in due course, will show tangibly higher values – across capital, rental and yield accounts. Furthermore, these projects show that the real estate sector will benefit from considering sustainable practices. Only one of the projects reviewed was a LEED™ project, demonstrating that ecological solutions make sense even without trying to achieve recognized certification.

Ecological solutions to stormwater and watershed management affect not only financial accounts, but also social and environmental accounts, and multiple stakeholders. Traditional cost accounting fails in that these aspects are rarely considered on the balance sheet. Currently, most businesses, lenders, and governments obtain appraisals or evaluations of the financial aspects of projects, each of them evaluating their perspective independently of the others, usually with unstructured analysis of the social and environmental implications of a proposal and often, without the balance of comparing all three triple bottom line accounts equally and transparently. This especially fails to take account of the multiple beneficiaries and stakeholders involved in such decisions and each of their gains or losses and will tend to perpetuate unsustainable solutions and practices, due to making decisions that favour a particular account or perspective. This is at the heart of Public Interest Valuation, the very thing that the appraisal industry appears loath to address. We recommend that municipalities consider not only a Triple Bottom Line assessment of a project but also evaluate *who* the stakeholders will be, and *how much* cost or benefit they will obtain. This goes beyond full cost accounting and most valuation approaches, but we believe is both achievable and desirable.

Data Collection Checklist for Future Projects

This project has highlighted the need for better tracking of information to enable full value analysis. The following list outlines some of the items necessary for a reasonably complete valuation:

Ecological Service Benefits:

- Pre and –post project data on the size/type/hydrological flows/hydrological data/water storage of a system;
- Water/sediment quality data pre and –post project;
- Locations of point/non-point source pollution;
- Water clarity (e.g. turbidity, TSS) pre and –post project;
- Stormwater catchment area;
- Biotic, fish, and wildlife inventories pre and post project;
- Ecological function of the system pre and post project (e.g. PFC assessment or other objective measure);
- Estimate of carbon storage and sequestration pre and post project;
- Canopy cover pre- and post-project
- Ambient air temperature of the area pre and post project;
- Local air pollution pre and –post project;
- Rainfall interception by vegetation canopy pre and –post project;
- Pest surveys pre and post -project (*i.e.,* West Nile Virus).

Economic Benefits:

Developer/land-owner:

- Construction finance rate;
- Design and construction cost (*i.e.*, professional fees, cost of building wetlands, cost of hydrological modeling, etc);
- Cost of stormwater infrastructure avoided/installed (*i.e.*, holding tanks, etc)
- Savings accrued from reduced regulatory delays or costs of regulatory barriers (*i.e.*, time delays due to council, municipal staff, provincial/federal regulations);
- Development cost charges;
- Value of lots or value of increased density (or lost revenues);
- Record of sales of the development and similar developments within the same time frame (*i.e.*, faster sales);
- Water usage pre and -post project (if applicable);
- Value of crop yields pre and -post project (if applicable);
- Costs of stress due to vandalism;
- Process barriers;
- Avoided costs of clearing and grading land (e.g. in conservation subdivisions or higher density projects).

Municipality:

- Costs of financing replacement infrastructure;
- Costs of stormwater infrastructure (*i.e.*, asphalt pavement, pipes, catchbasins, holding tanks, etc);
- How often stormwater infrastructure is maintained and/or replaced;

- Operation and maintenance costs (*i.e.,* managing invasive species, cleaning out catchbasins/sediment detention ponds, maintaining/installing ditches);
- Value of land donated;
- Value of increased tax revenues due to increased density;
- Flood models for the area of study.

Community/homeowners/landowner:

- Trail usage pre and -post project;
- Number of bird watchers, recreational use;
- Local health benefits accruing from the project;
- Value of project to the surrounding community (inclusion);
- Costs of downstream flooding;
- Costs of local air pollution;

In order to estimate the amenity benefits of greenspace researchers use hedonic models to compare how different characteristics (*i.e.,* amenity values, distance to greenspace, lake/river views, quality, etc) affect the price of similar marketed goods (most commonly used is real-estate). To complete such an analysis would require considerable time, experience with statistical models, access to statistical models and extensive data including: the size of the lots and homes in question, cost, market value, age, elevation, type of structure, number of bedrooms/bathrooms, and other features of the house, including type of electrical wiring, whether it contained a revenue suite, nature of heating. Other variables required include locational attributes (*i.e.,* distance from the city center, congestion and noise levels, crime level, population levels, climatic effects (*i.e.,* flooding), access to regional recreational facilities, such as golf courses, parks, bicycle trails, schools and libraries, etc). Aesthetic amenities variables must also be measured; this may include the presence and distance of a river, wetland, lake, or other waterbody, water clarity (*i.e.,* turbidity) as well as whether or not the homes in question have a view.

Future Study

During the period of research for this project, the authors, including Aqua-Tex, expanded the concept of green infrastructure valuation to include all facets of municipal water, wastewater and waste management. Many of those ideas arose directly out of this study. The result was another study undertaken for the BC Ministry of Community Services entitled "Resources From Waste: An Integrated Resource Management Phase 1 Study Report[xliv]." This study examined how energy, biofuels, water, heat, fertilizer and other resources can be extracted from liquid and solid waste and return a financial net benefit to the community, while providing tertiary sewage treatment, eliminating landfills and restoring urban aquatic habitat. A synopsis of this study is in press with the Journal of Industrial Biotechnology and will be published in 2008. Aqua-Tex is also extending the Nature's Revenue Streams (NRS) study through the work of graduate student, Mr. Daniel Hegg, University of Victoria, whose thesis will be available in 2009. All three projects are critical to helping municipalities overcome their mounting infrastructure and finance burden due to deferred infrastructure maintenance and replacement. Though relatively small in scope, it is hoped that this NRS study provides incentive for developers, municipalities and researchers to extend this work and re-examine infrastructure and development decisions under the lens of full valuation and not simply cost.

Literature Cited

Agricultural Land Reserve. (n.d). About the Agricultural Land Reserve. Retrieved, April 20, 2008, from http://www.alc.gov.bc.ca/alr/alr_main.htm.

American Lives. (1999). Community Preferences. In American Lives Inc. Retrieved June 2, 2008 from http://www.americanlives.com/.

Arendt, R.G. (1996). Conservation Design for Subdivisions: A Practical Guide to Creating Open Space Networks. Island Press: Washington, D.C.

Arnold, C. L., Jr., and C.J. Gibbons (1996). Impervious surface coverage: the emergence of a key environmental indicator. Journal of the American Planning Association, 62(2), 243-258.

Barraclough, C.L., and W.P. Lucey. (2005). Nature's Revenue Streams: Project Proposal. Aqua-Tex Scientific Consulting Ltd. Victoria, B.C.

BC Assessment. (2008). Assessment Authority Act and the Assessment Act. In BC Assessment website. Retrieved April 27, 2008, from http://www.bcassessment.bc.ca/index.asp

Beaulieu, S. and L. Di Pietro (2003). Canadian farm families more dependent on off-farm income. Vista on the Agri-Food Industry and the Farm Community. A Stats Can publication catalogue no. 21-004-XIE

Blyth A. and I. Laing. Casyls Consulting Ltd. (2008). Urban Forest Canopy Cover Mapping and Analysis in the Capital Regional District 1986-2005. Prepared for the Urban Forest Stewardship Initiative, Habitat Acquisition Trust (HAT). 150 pp.

Bolitzer, B. and N.R. Netusil. (2000). The impact of open space on property values in Portland, Oregon. Journal of Environmental Management, 59, pp 185-193.

Booth, D. B., and Reinelt, L. E. (1993). Consequences of urbanization on aquatic systems - measured effects, degradation thresholds, and corrective strategies. Watershed'93, 545-550.

Braden, J., and D. Johnston. (2004). Downstream Economic Benefits from Storm-Water Management. Journal of Water Resources and Planning Management, 130(6), pp. 498.

Capital Regional District (CRD). (2008). CRD Land Purchase from TimberWest Forest Corp. In Capital Regional District. Accessed on August 1, 2008, from **http://www.crd.bc.ca/water.**

Center for Watershed Protection. (2003). Impacts of impervious cover on aquatic systems. Center for Watershed Protection. Ellicott City, MD.

Cheshire, P. and S. Sheppard (1998). Estimating the demand for housing, land and neighbourhood characteristics. Oxford Bulletin of Economics and Statistics, 60, 3, pp 357-382.

Convening for Action on Vancouver Island (CAVI). (2007). Leadership in Water Sustainability initiative.

Waterbucket.ca. Retrieved April 27, 2008, from
http://www.waterbucket.ca/gi/sites/wbcgi/documents/media/58.pdf

Correll, M., J. Lillydahl and L. Singell. (1978). The Effects of Greenbelts on Residential Property Values: Some Findings on the Political Economy of Open Space. Land Economics, 54(2), 207-217.

District of Saanich (2004). 2004 Travel Behaviour Survey. In the District of Saanich website – Retrieved April 27, 2008, from
www.saanich.ca/resident/roads/travelsurvey.pdf

Dunes, N., C. Dehring, and M. White. (2007). Urban Parks, Open Space and Residential Property Values. In RICS Newsroom. Retrieved August 2, 2008 from
http://www.rics.org/Newsroom/Researchandreports/RICSEducationTrust/urban_parks.html

Elkington, J. (1998). Cannibals with forks. The triple bottom line of the 21st century business. Gabriola Island, BC: New Society Publishers.

Kahn, E., L. Ramsay, R. Brownson, G. Heath, E. Howze, K. Poewll, E. Stone, M. Rajab and P. Corso. (2002). The effectiveness of interventions to increase physical activity. American Journal of Preventive Medicine, 22(4), pp. 72-107.

Espey, and Owusu-Edusei. (2001). Neighbourhood parks and residential property values in Greenville, South Carolina. Journal of Agricultural and Applied Economics, 33(3) pp 487-492.

Fleming, G. 2008. Personal Communication with Mr. Gerald Fleming, Park Planning and Design Manager, Parks and Recreation Department, District of Saanich. August 2008.

Fisher, S. (2002). Sustainable community design demonstration in Okotoks, Alberta: Testing consumer receptivity. Canada Mortgage and Housing Corporation. Retrieved April 27, 2008, from
https://www03.cmhc-schl.gc.ca/b2c/b2c/init.do?language=enandshop=Z01ENandareaID=0000000033andproductID=00000000330000000015

Fisheries and Oceans Canada (2008). Regulations and Legislation. In Fisheries and Oceans Canada. Retrieved April 27, 2008, from http://www.dfo-mpo.gc.ca/acts-loi-eng.htm

Geoghegan. (2002). The value of open spaces in residential land use. Land Use Policy, 19, pp91-98.

Goodwin, C. N., Hawkins, C. P., and Kershner, J. L. (1997). Riparian restoration in the western United States: overview and perspective. Restoration Ecology, 5(4S), 4-14.

Green, C. (1996). The wetlands restoration revolution. Erosion Control (November/December), 24-37.

Harnik, P. (2003). The excellent city park system: What makes it great and how to get there. The Trust for Public Land. Retrieved April 27, 2008, from www.tpl.org/content_documents/excellent_city_parks.pdf

Healing America's Cities: How Urban Parks Can Make Cities Safe and Healthy. (1994) Green Cities Initiative. San Francisco, CA: TPL, 1994.

Heffernan, M. (1994). The Children's Garden Project at River Farm. Children's Environments, 11(3): 221-231.

Irwin, E.G. (2002). The effects of open space on residential property values. Land Economics, 78(4): 465-480.

Jones, T. F. and Eaton, C.B. (1994). Cost-benefit analysis of walking to prevent coronary heart disease. Archives of family medicine, 3(8).

Klemmer, C.D., Waliczek, T.M. and Zajicek, J.M. (2005). Growing Minds: The Effect of a School Gardening Program on the Science Achievement of Elementary Students. Hort Technology. 15(3): 448-452.

Leschine, T., K. Wellman, and T. Green (1997). The economic value of wetlands: Wetlands' role in flood protection in Western Washington. Washington State Department of Ecology. Retrieved April 27, 2008, from http://www.ecy.wa.gov/biblio/97100.html

Lucas, B. (1995). Learning through Landscapes: An Organization's Attempt to Move School Grounds to the Top of the Educational Agenda. Children's Environments, 12(2): 233-244

Lutzenhiser, and Netusil. (2001). The effect of open space on a home's sale price. Contemporary Economic Policy, 19(3): 291-298.

Malmkvist, L. (2002). Blenkinsop Creek restoration and relocation, design and construction. University of Victoria M.Sc. Thesis. Victoria, B.C.

McMahon, E., and M. Benedict. (2003). How cities use parks for… green infrastructure. The Conservation Fund's Center for Conservation and Development. Retrieved, April 20, 2008, from www.greeninfrastructure.net/node/313

Ming, J., Xianguo, L., Linshu, X., Lijuan, C., and Shouzheng, T. (2007). Flood mitigation benefit of wetland soil — A case study in Momoge National Nature Reserve in China. Journal of Ecological Economics, 61(2-3).

Ministry of the Environment (MOE). (2008). Riparian Areas Regulation (RAR). In Environmental Stewardship Division, Ministry of the Environment. Retrieved April 27, 2008. from http://www.env.gov.bc.ca/habitat/fish_protection_act/riparian/riparian_areas.html

Ministry of Health. (2008). The cost of physical inactivity in British Columbia. Retrieved June 1, 2008 from http://www.health.gov.bc.ca/prevent/pdf/inactivity.pdf

Meyer, B. and Degorski, M. (2007). Integration of multifunctional goals into land use – the planning perspective. In U. Mander, H. Wiggering and K.Helming (Eds.), Multifunctional Land Use: Meeting Future Demands for Landscape Goods and Services (pp. 153-166). Berlin: Springer.

Morris, S., and Moses, T. 1999. Urban stream rehabilitation: a design and construction case study. Environmental Management, 23(2): 165-177.

National Park Service. (1995). Economic impacts of protecting rivers, trails, and greenway corridors. A resource book. Rivers, trails and conservation assistance. The National Park Service. Retrieved April 23, 2008 www.nps.gov/pwro/rtca/econindx.htm

Nelson, A. (1986). Using Land Markets to Evaluate Urban Containment Programs. In APA Journal. Spring, 156-171.

Olewiler, N. (2004). The value of natural Capital in settled areas of Canada. Published by Ducks Unlimited Canada and the Nature Conservancy of Canada. 36pp.

Pratt, M., Macera, CA., and Wang, G. (2000). Higher direct medical costs associated with physical activity. Physician Sportsmed, 28(10), 63–70.

Prichard, D. (1998). A user guide to assessing Proper Functioning Condition Supporting Science for Lotic Areas. Riparian Area Management TR 1737- Department of the Interior, Bureau of Land Management. Denver, CO.

Quayle, M., and S. Hamilton. (1999). Corridors of green and gold: Impact of riparian suburban greenways on property values. Prepared for Fraser River Action Plan, Department of Fisheries and Oceans.

Rowntree, R., and Nowak, D. (1991). Quantifying the role of urban forests in removing atmospheric carbon dioxide. Journal of Aboriculture, 17(10).

Saanich Draft Official Community Plan. (April 2007). Hardcopy from the District of Saanich Municipality.

Saanich (2003). Blenkinsop Local Area Plan. http://www.gov.saanich.bc.ca/business/development/laps/blenkinsop/blenkinsop_lap.pdf

Salkin, P. E. (2003). Smart Growth and the Law. In M.J. Lindstrom and H. Bartling (Eds.), Suburban Sprawl: Culture, Theory and Politics. (pp. 213-234). Lanham: Rowman and Littlefield Publishers, Inc.

Schueler, T. (1995). Site planning for urban stream protection. In The Practice of Watershed Protection. Center for Watershed Protection. Ellicott City, MD.

Schueler, T. (2000a). The architecture of urban stream buffers. In The Practice of Watershed Protection. Center for Watershed Protection. Ellicott City, MD.

Schueler, T. (2000b). The benefits of better site design in commercial development. In The Practice of Watershed Protection. Center for Watershed Protection. Ellicott City, MD.

Seattle Office for Planning. (1987). Evaluation of Burke-Gillman trail's effect on property values and crime. Seattle, WA.

Shafer, EL., Carline, R., Guldin, RW., and Cordell, HK. (1993). Economic amenity values of wildlife: Six case studies in Pennsylvania. Journal of Environmental Management, 17(5).

Sherer, P. (2006). The benefits of parks: Why America needs more city parks and open space. The Trust for Public Land. Retrieved April 24, 2008, from www.tpl.org/content_documents/

parks_for_people_Jan2004.pdf

Suggett, D., and B. Goodsir. (2002). Triple bottom line measurement and reporting in Australia: Making it tangible. In The Allen Consulting Group. Retrieved April 24, 2008, from ttp://www.environment.gov.au/settlements/industry/finance/publications/triplebottom/index.html

The Australian Green Building Council. (2007). Valuing Green - How green buildings affect property values and getting the valuation method right. In The Australian Green Building Council. Retrieved April 27, 2008, from http://www.gbca.org.au/gbca.asp?sectionid=6anddocid=1464

Ulrich, R. S., O. Lundén, J. L. Eltinge (1993). Effects of exposure to nature and abstract pictures on patients recovering from heart surgery. Paper presented at the Thirty-Third Meetings of the Society for Psychophysiological Research, Rottach-Egern, Germany. Abstract published in Psychophysiology, 30 (Supplement 1, 1993): 7.

United Nations Environment Programme. 2005. Millenium Ecosystem Assessment Assessment Series v. 1. Ecosystems and human well-being: current state and trends: findings of the Condition and Trends Working Group / edited by Rashid Hassan, Robert Scholes, Neville Ash. http://www.millenniumassessment.org/en/index.aspx

United States Department Of Labor Bureau of Labor Statistics. (2008). Consumer Price Index Table. Retrieved June 1, 2008 from http://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt

United States Environmental Protection Agency (2007). Reducing stormwater costs through Low Impact Development (LID) strategies and practices. United States Environmental Protection Agency Nonpoint Source Control Branch - Publication Number EPA 841-F-07-006. Retrieved April 27, 2008, from http://www.epa.gov/owow/nps/lid/costs07/documents/reducingstormwatercosts.pdf

Wang, G., Macera, C., Scudder-Soucie, B., Schmid, T., Pratt, M., and Buchner, D. (2005). A Cost-Benefit Analysis of Physical Activity Using Bike/Pedestrian Trails. Health Promotion Practice, 6(2), 174-179.

West Coast Environmental Law. (n.d.). Urban growth and development: Smart bylaws guide—Working lands. Retrieved April 21, 2008 from**http://209.85.173.104/search?q=cache:zDxH0QuqBPYJ:www.wcel.org/issues/urban/sbg/Part2/workinglands/+Deborah+Curran+%22West+Coast+environmental+law 22+ALRandhl=enandct=clnkandcd=1andgl=ca**

Wilson S., and R. Hebda. (2008). Mitigating and adapting to climate change through the conservation of nature. The Land Trust Alliance. Retrieved April 27, 2008, from www.landtrustalliance.bc.ca/docs/LTAClimateChangeWebSingleP.pdf

Wright T., J. Tomlinson, T. Schueler, K. Cappiella, A. Kitchell, and D. Hirschman. (2006). Direct and indirect impacts of urbanization on wetland quality: Wetlands and Watersheds Article #1. Center for Watershed Protection. Washington, DC.

Yahoo Finance. (2008). Retrieved June 1, 2008 from http://finance.yahoo.com/currency/convert?amt=1andfrom=USDandto=CADandsubmit=Convert

Zegarac, M. and T. Muir. (1996). A catalogue of benefits associated with greenspaces and an analysis of the effects of Greenspaces on residential property values: A Windsor Case Study, Environment Canada. Environment Canada.

End Notes

[i] TBL is originally credited to John Elkington in his book "Cannibals with Forks."

[ii] IVSC is an NGO (Non-Government-Organization) member of the United Nations and works cooperatively with member States, organizations such as the World Bank, OECD, International Federation of Accountants, International Accounting Standards Board, and others including valuation societies throughout the world to harmonize and promote agreement and understanding of valuation standards (http://www.ivsc.org/).

[iii] We found this caused greater uncertainty over approach rather than improved certainty and this is noted in the report.

[iv] One conclusion we quickly reached is that each project proceeded with a basic sense that the business case would be viable, but not with a more traditional [financial] analysis proving each project's worth. This made the scope difficult to pursue to the extent we would prefer or recommend in future, adding appreciably to complexity and time.

[v] The Agricultural Land Reserve ("ALR") was established by a provincial statute that provides protection of designated lands and preserves them for farming use. Further information is available from: http://www.alc.gov.bc.ca/alr/alr_main.htm.

[vi] Jointly developed by the U.S. Bureau of Land Management, the U.S. Forest Service and NRCS, Proper Functioning Condition (PFC) is a qualitative assessment tool based upon quantitative science that measures the state and health of riparian-wetland areas. The PFC assessment is not based upon values (*i.e.*, whether the stream is visually pleasing, suitable habitat for fish, etc), but rather on stream function (*i.e.*, whether the stream is stable from a hydrologic, vegetative, and soil perspective) (Prichard, 1998). PFC utilizes 17 criteria to determine stream health, thereby enabling users to rank rehabilitation priorities. The result of the PFC assessment is qualitative indicator identifying whether the system is in Proper Functioning Condition (PFC), Functional-at-Risk (FAR; with an upward or downward trend), or Non-Functional (NF). When a system is classified as PFC, it is in state of 'resistance" enabling it to withstand disturbance without "coming apart" during high flow events. Functional-at-Risk (FAR; with an upward or downward trend) has elements of a resilient system by remaining in a functional context, but has a soil, water, or vegetative attribute making the system susceptible to degradation. A Non-Functional (NF) system is a system that is one that is not clearly able to dissipate energies associated with high flow events (due to a lack of adequate vegetation, landform, etc) and thus cannot reduce erosion, improve water quality, provide habitat, etc. These ratings provide a "means of prioritizing areas for restoration so that when development occurs, resources can be allocated to the most critical areas" of the system, thereby preventing degradation of healthy areas by the rehabilitation (of function) of areas currently at risk or may soon be (Barraclough & Lucey, 2005). The assessment is checklist based upon the *capability* and *potential* of the system characterized by the interaction of the three components, hydrology, vegetation, and soils. Potential is defined as the potential natural community a system could achieve "given *no* political, social, or economical constraints" (Prichard, 1998). Important to the proposed project, potential can identify if the system is in "balance with the landscape setting" in terms of its ability to perform critical functions (*i.e.*, habitat, reduction of erosion, etc). Furthermore, capability is defined as what *could be* achieved given current the political, social, or economical constraints. Therefore, in the context of urban system, it is recognized that some systems can or may be constrained by various limitations that may be insurmountable (*i.e.*, urban land use, major roads, zoning, political barriers, etc); not precluding rehabilitation, but may limit the systems function. Important to note is that PFC *is not* "a replacement for quantitative inventory or monitoring protocols. PFC is meant to complement more detailed methods by providing a way to synthesize data and communicate results" (Prichard, 1998).

[vii] Ray and Judy Galey, personal communication.

[viii] A value of $2-$4 per cubic meter was applied to price out the cost of digging out and shaping a ditch. The higher value of $4 was applied to price out the initial cost of the ditch (using ditch dimensions of 1m deep x 2m wide x 650m long). Furthermore, ditch maintenance would occur every 5 years and was priced at a lower value, due to decreased time to clean out an existing ditch and placing spoils on the side.

[ix] If we had access to the CRD water bills paid by the farmer we could better estimate the value in reduced potable water usage. Unfortunately, this information was not available but was advised that there was an estimated increase in water savings of approximately 7% after the completion of the project. According to the province of BC, in 1996 there were 115,374 ha of irrigated land in BC that used 763 million cubic meters of water that year. This results in an estimated 6,614m3/ha/year. Applying this usage to the Galey property and estimated reduction of 7% of potable water usage per year, we estimate this has resulted in a reduction of

463m^3/ha/year of potable water. Applying this to the current CRD water rate of \$1.31/m^3 and discounting this value at a rate of 5% for 25 years results in a PV value of \$8,548.

[x] The Conservation Partners Program is an initiative of The Land Conservancy which aims to forge a mutually beneficial partnership between Conservation and Agriculture in BC. The purpose of the program is to protect and enhance important habitat on privately owned agricultural lands by providing recognition, incentive and assistance to growers who are committed to conservation of natural habitat on their farm. The program is in no way meant to interfere with the agricultural potential of the property.

[xi] Amount was discounted over a time frame of 25 years, with a nominal realdiscount rate of 53% (Nominal interest rate of 5%, less 2% inflation).5%.

[xii] \$6,632 was calculated by applying the PV formula to the re-occurring 5-year cost to maintain the ditch of \$2600. A discount rate of 5% was applied over a 25-year period.

[xiii]Under the direction of Cliff Warren, Saanich Municipal Engineer

[xiv] Ming *et al.,* (2007) calculated flood benefits, by identifying the capital cost of reservoir construction in \$/m3. The value of \$0.88/m3 was adjusted for time and currency prior to being applied to the Galey Study. Per our conversations with the Galeys, we have been told that the fields flood approximately 60%. Using this value and an average depth of 1m, the flood protection benefit provided annually by the Galey farm is estimated to be \$52,968. Discounted over 25 years at 5% this benefit amounts to \$746,523.

[xv] Increased amount of urbanization (*i.e.*, buildings, roads, and compacted soils) reduce absorptive capacity of the land. "In suburban areas, 20–50% of the land is impervious to precipitation. In inner cities and commercial zones, imperviousness can exceed 80%. According to Schueler, Johnston et al,2006 and the Center for Watershed Protection (2008) the hydrologic functions of streams change with as little as 5–10% imperviousness and they change profoundly when imperviousness approaches 25%). (Braden & Johnston, 2004, pp.1).

[xvi] The CRD purchased approximately 9700ha of land for the purposes of protecting drinking water and park space for \$64.7 million. This amounts to a per hectare value of \$6,670.10. Applied to 18,000m2 of restored creek, the one time social value of this system is valued at \$12,006.19. We anticipate that this is likely the lower value of the system, as it does not account for other social values such as value is derived from the option to preserve ecosystem services for their use in the future by individuals (option value) or by others/heirs (bequest values)

[xvii] Important to note is that the in many of the sampling areas, the vegetation encroached upon the channel , making it to easy to dislodge fine sediment from the surface of the vegetation when accessing the stream channel and therefore difficult to obtain a clean sample.

[xviii] See Rowntree *et al.,* (1991). Quantifying the role of urban forests in removing atmospheric carbon dioxide. We calculated the values using a type 1 tree canopy (young trees less than 10 years) with 7-12 inch diameter breast height using a per tonne carbon value of \$20. To be conservative, we applied a 60% canopy cover value. The sequestration value is discounted at 5% over 25 years.

[xix] Neighbouring Rithet's Bog is a known historical source of cranberries for local bands
http://www.rithetsbog.org/humanhistory/history_fall2004.htm

[xx] When asked to list things they like about Saanich, residents most frequently identify its central location, its quiet, friendly, safe neighborhoods, and its great parks/trails network. Furthermore, over 84% of residents use a Saanich municipal park or trail several times per year or more and give particularly high praise to Saanich's fire fighting, parks, ***trails***, recreation, facilities and programs, and landscaping of public property (District of Saanich, 2004).

[xxi] A more extensive study to understand the health care benefits and link these two community and personal value as well as cost savings and cost avoidance would in our opinion be possible but it goes beyond the scope of this current study. To undertake this, an assessment of the extent of use of the trail would be needed (*i.e.*, analysis of vehicle avoidance, GHG reduction/pricing and quantification of travel use, trail usage pre and post project, and by extension and connection to healthcare studies on health benefits of cycling and walking, estimation of the reduction in provincial health care funding costs).

[xxii] On their famous train-ride surrounding the property, the tour-guide shares an educational story about how the creek was once a ditch, and the benefits from its restoration.

[xxiii] "Under Department of Federal Fisheries, the fisheries act applies to all Canadian waters that provide or are capable of providing habitat for fish during any life stage. This includes wetlands, ditches, streams, rivers, lakes, coastal waters, estuaries and marine offshore areas. The act also applies to areas that are not permanently wetted but may provide habitat opportunities when wetted. These areas include shorelines, riverbanks, mudflats and floodplains and manmade fish habitat that is intentionally or unintentionally created. The provisions of the Fisheries Act apply to publicly and privately owned land" (Section 3.1.1 Fisheries Act Fisheries and Oceans Canada, 2008). Although Blenkinsop Creek (prior to the project) had little (if any) neither ecological habitat, nor any fish, the ditch in question was connected to a fish bearing system and was therefore regulated by the Fisheries Act. The infilling of the ditch is considered a HADD (harmful alteration, disruption or destruction) of a salmon bearing system and therefore falls under Section 35(1) of the Fisheries Act upon which "No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat," and the Water Act regulated by the Ministry of the Environment (MOE). Thus the land owner (the Galeys) had to file for a Section 9 authorization that under section 35(2) of the Federal Fisheries Act and the Water Act that would

allow for such work to be completed. Although it is not documented, if a HADD does occur, DFO normally requests a habitat compensation ratio of 3:1.

[xxiv] The RAR is intended to protect riparian areas and the natural features and functions that support fish life processes and to facilitate intergovernmental cooperation among the Ministry of Environment (MOE), Department of Fisheries and Oceans (DFO) and Union of British Columbia Municipalities (UBCM). The RAR applies to industrial, residential and commercial developments, and to ancillary activities planned, at least in part, within the "riparian assessment area" (RAA) alongside a stream. The RAR does not apply to agricultural or institutional development or to reconstruction or repair of a building if the structure remains on its original foundation (Riparian Areas Regulation, Ministry of the Environment, 2008).

[xxv] This calculation is only an estimate using a proxy from another study and is not representative of the true costs of downstream flooding. The purpose of the exercise was to show that there is a value associated with the service provided.

[xxvi] If a conservative loan was provided by government at a 5% rate over a 25-year term, the project cost could have been financed at an annual expense of approximately $26,607. Given the relative certainty of the project and asset security, a low rate is considered suitable for finance, discount and reversionary (*i.e.,* residual) capitalization.

[xxvii] Such systems are designed to contain and hold stormwater, subsequently releasing the water at a low volume to reduce downstream flooding. It is estimated that the system would enable some particulates to settle prior to discharge, but there would be little if any nutrient or heavy metals treatment prior to being discharged into Swan Creek.

[xxviii] We accessed BC Assessments website to determine the value of the homes. BC Assessment is an independent Crown corporation, established in 1974 by the *Assessment Authority Act and the Assessment Act*, with the main to classify and assess the market value of all property in British Columbia. BC Assessment defines market value as the price that would be expected if a property were to sell on the open market, and that both the buyer and the seller are properly informed about the property's features. The Assessment Act requires that properties be assessed at their actual value as of July 1st of the year proceeding the tax year. For example, valuation day for 2006 assessments was July 1, 2005. Furthermore, actual value means market value and it is the most probable price at which a property would sell in a competitive market, if it had been listed long enough to become generally known to real estate agents and prospective purchasers. It also assumes that both the buyer and seller are willing (*i.e.*, it is not a forced sale), that both parties are prudent and knowledgeable and that the parties are considering only factors that most other buyers and sellers would consider (BC Assessment, 2008). As such, since the properties adjacent to the parkland have not sold, their actual market value has not been properly assessed for the anticipated increase in green space value.

[xxix] "Corridors of Green and Gold" by Hamilton & Quayle, Department of Fisheries and Oceans, April 1999. Both Professor Hamilton and Dr. Quayle were UBC Faculty Deans at the time of writing. Dr. Quayle is currently Deputy Minister of Advanced Education, government of British Columbia.

[xxx] None of the reviews identified in our research pointed clearly to a specific adjustment that could be made for proximity to riparian zone. The range of adjustments was from 0% (no difference) to 20% higher value, and some studies even suggested no difference in value for riparian frontage (as appears to be the case in the Willowbrook study), but an increase in value if living further away from the riparian zone. Some studies considered this logical anomaly to be due to insufficient differentiation between the multiple characteristics of riparian proximity.

[xxxi] Saanich 2006 citizen survey. http://www.saanich.ca/municipal/docs/pdfs/citsurv_complete2006.pdf

[xxxii] There is no question however, that the wetland was very effective at trapping sediments historically, because the flap gate over the inlet structure is nearly buried in sediment, highlighting the need to clean out the accumulated material so that the wetland can resume trapping material. At present, it would appear that the stormwater is mobilizing accumulated sediment from the wetland into the creek. The Willowbrook wetland generally exported metals during the rainy winter months, and acted as a sink for metals during low flow periods. Arsenic, copper, lead, mercury, sodium, tin and zinc were all lower at the outlet than at the inlet in the fall of 2006. While the wetland continued to take up sodium, with the onset of winter rains, metals values at the outlet began to exceed the inlet. In January and February 2007, lead and arsenic were not detectable in the water at the inlet, but were present at the outlet, suggesting mobilization from the wetland sediments. It is therefore apparent that the wetland is effective at sediment removal provided the system is ***maintained on a regular basis*** by the municipality.

[xxxiii] Using the cost to maintain ditches in the Blenkinsop Study, we estimate that ditch maintenance of 750 meters of Swan Creek would have accrued a cost of $3,000 every 6 years (we expect that this is an underestimate of actual cost). This maintenance value discounted over 25 years at 5% results in a present value of $7,651.95.

[xxxiv] "LID is comprised of a set of approaches and practices that are designed to reduce runoff of water and pollutants from the site at which they are generated. By means of infiltration, evapotranspiration, and reuse of rainwater, LID techniques manage water and water pollutants at the source and thereby prevent or reduce the impact of development on rivers, streams, lakes, coastal waters, and ground water" (United States Environmental Protection Agency, 2007).

[xxxv] A French drain system usually underlies a GravelPave system so that if the soils become too saturated, the perforated pipe collects the excess water and carries it to a roadside bioswale.

[xxxvi] Per a discussion with a municipal engineer, homes need to be protected and therefore perimeter drains connected. In addition, the normal return period for stormwater management systems is to manage the more frequent storms (6 month to a year return period) and the higher intensity less frequent (10 year, 25 year and up to 200 year return period) storms. Typically, engineers must design systems

that can ensure a 10-year storm (25 year on a trunk) event can be accommodated without any flooding, and a 200 year return period has access to enough overland flow routes that eliminate or at least minimize the extent of flooding. It seems than on certain sites a combination of traditional infrastructure and ecological infrastructure may be the best way to protect homes whilst keeping the freshwater aquatic ecosystem functional. Other sites (depending on climate, geomorphology, soils, slopes, vegetation, access to flood plain, etc) may not require such traditional infrastructure.

[xxxvii] These will vary by community and we have thus not researched this item in detail but repeat the facts as stated by District of Saanich staff.

[xxxviii] Municipal planners largely evaluate development proposals on the density applied for and what is reported by a registered Professional Biologist (R.P.Bio.) under an environmental assessment. If there is a aquatic system (*i.e.*, creek, stream, wetland, bog, ditch, etc) on the landscape proposed for development the developer must adhere to the federal or provincial (depending on whether Salmon habitat is involved) regulations surrounding (*i.e.*, setbacks, etc). These regulations are prescriptive, and apply a regular "cookie-cutter" approach to what setbacks are required. These regulations do not take into account on whether or not the regulatory setbacks may inhibit any or all development (and whether this is a benefit to all stakeholders involved), nor do they measure the level of function of the system or how the system can be enhanced using the development permit process. Furthermore, municipal policy tends to favour more traditional methods of stormwater solutions, rather than applying ecological solutions (*i.e.*, wetlands to manage stormwater) or low impact development techniques (*i.e.*, porous pavement, smaller road and trail widths, etc).

xxxix An Economic Rationale for Integrated Stormwater Management
http://www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/case_studies/pdfs/54.pdf

[xl] We estimate that approximately 2.5 – 3 cubic yards of sediment was captured by Baxter pond over a 1-year interval.

[xli] These would now lose LEED® points and today it could be speculated on whether LEED® Gold certification would be achieved without the permeable paving.

[xlii] We were provided a cost estimate by a local contractor to recap the parking lot ($20/m2). To develop our estimate, we assumed the parking lot would last 25 years. With regard to the GrassPave/GravelPave maintenance, we were advised by a supplier of the product that a reasonable estimate of maintenance would be 2 man hours per week. Maintenance involves raking bare areas of the parking lot to redistribute the gravel on a weekly basis. In order to calculate the present value cost we used $15/man hour, discounted at 5% for 25 years.

[xliii] Considerable effort is required to ensure considerable similarity between the two sites (*i.e.*, wetland type, nature and extent of use) so that the transfer of values makes logical sense and is defensible. Furthermore, benefit transfer may not be accurate, except for making gross estimates of recreational values, unless the sites share all of the site, location, and user specific characteristics.

[xliv] Ministry of Community Development. http://www.cd.gov.bc.ca/ministry/whatsnew/irm.htm

Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Biomass and Bioenergy 28 (2005) 219–228
BIOMASS & BIOENERGY
www.elsevier.com/locate/biombioe

Development of short-rotation willow coppice systems for environmental purposes in Sweden

Jaconette Mirck[a], J.G. Isebrands[b], Theo Verwijst[a,*], Stig Ledin[c]

[a]Department of Short Rotation Forestry, Swedish University of Agricultural Sciences, P.O. Box 7016, S 750 07 Uppsala, Sweden
[b]Environmental Forestry Consultants, LLC, P.O. Box 54, New London, Wisconsin 54961, USA
[c]Department of Soil Sciences, Swedish University of Agricultural Sciences, P.O. Box 7014, Uppsala, Sweden

Abstract

During the last three decades, driving forces behind the development of short-rotation willow coppice (SRWC) in Sweden have been changing from a primary focus on biomass production towards emphasis on environmental applications. In most cases, current commercial SRWC practice is geared towards a combination of biomass production for energy purposes and environmental goals. The latter goals range from decreasing the impact of specific contaminants in the environment to organic waste handling in a recycling system in urban and/or agricultural areas.

Where biomass production and pollutant management overlap, the science of phytoremediation has its practical application. Through phytoremediation, waste products that previously have been a burden for the society can be used as valuable resources to increase short-rotation willow biomass production.

In this paper we will present the terminology and definitions of different types of phytoremediation. We also give an overview of five different cases of phytoremediation activities with a potential for large-scale implementation. Some of the types of activities are already commercially used in Sweden; others seem promising but still need further development.

Keywords: Heavy metals; Phytoremediation; *Salix*; Sludge; Vegetation filter; Wastewater

1. Introduction

The original driving force for willow research in Sweden, which started in the late 1960s, was a predicted shortage of raw material for the pulp and paper industry. When that prediction appeared to be an artefact of national inventory methods, the energy crisis in the early 1970s provided a new motivation to continue research on willows [1]. In the 1980s, the need for non-fossil fuels started to increase and willow growing for energy was commercialised in Sweden [2].

*Corresponding author. Tel.: +46-18-672550; fax: +46-18-673440.
E-mail address: Theo.Verwijst@lto.slu.se (T. Verwijst).

0961-9534/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biombioe.2004.08.012

Agricultural policy, employment issues, and finally the growing concern for the environment were added to the forces that motivated an extensive research on willow growing systems in Sweden [3]. Consequently, research on short-rotation willow Coppice (SRWC) has been going on in Sweden for three decades, and this has led to a large theoretical knowledge base and variety of practical applications of willow growing systems, both for energy purposes and for other goals.

Large-scale implementation of SRWC for biomass production, in combination with environmental goals, is currently driven by the increasing needs to incorporate organic waste handling in a recycling concept, and by the notion that SRWC may play a function in redirecting heavy metals from the human food chain [4]. Environmental applications of SRWC are developing rapidly and exploit the heritable plant physiological characteristics of willow that govern the uptake and processing of water, nutrients and other elements [5].

Where biomass production and pollutant management overlap, the science of phytoremediation has its practical application (Fig. 1). Through phytoremediation, waste products that previously were regarded as a burden for the society can now be used as valuable resources to increase short-rotation willow biomass production. Depending on the fate of contaminant, the substrate type and the plant physiological processes involved, specific aspects of phytoremediation are addressed in different terms. This paper sets out to clarify the terminology associated with phytoremediation and gives some Swedish examples of practical implementation of SRWC for phytoremediation in combination with biomass production for energy purposes.

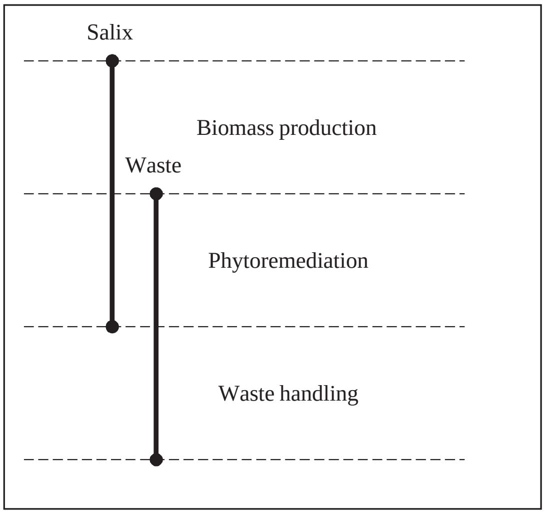


Fig. 1. Biomass production and waste handling can be combined in phytoremediation applications.

2. Phytoremediation in perspective

2.1. General definition of phytoremediation

Phytoremediation is the intentional use of living plants for remediation of contaminated soil, sludge, sediment and groundwater. Using a managed vegetation system, contaminants may be removed, degraded or stabilised, thereby improving the environment in the intended direction. Phytoremediation can be used to clean up environmental contamination by some heavy metals, pesticides, solvents, explosives, crude oil, polyaromatic hydrocarbons, radio nuclides and landfill leachates [6]. Phytoremediation may also provide a solution in the case of organic pollutants in agricultural soils.

2.2. Principles of phytoremediation

Phytoremediation is a general term for ways in which plants (*phyto* = plant) are used to decrease the impact of pollutants on the environment. From the plant's point of view pollutants may be considered as nutrition (macronutrients like N, P and K, and all micronutrients). In suitable concentrations, these may be used to increase biomass production, but can be harmful to the plants at higher concentrations. Pollutants may also contain a number of elements that are not essential for plant growth. This category never contributes to plant growth, but may have negative effects on biomass production.

To understand phytoremediation more specifically, and to address specific processes, substrate type or active plant tissue, an extensive terminology has come into use [7]. This terminology is described below.

2.3. Types of phytoremediation

Phytoremediation can be separated on the basis of the fate of the contaminant and its location in the substrate or plant tissue. At sites contaminated with inorganic pollutants such as metals, plants can either stabilise or remove these contaminants by three mechanisms: phytostabilisation, phytoextraction, and rhizofiltration. At sites polluted with organic compounds, such as N, P and K, plants either break down or remove these compounds by three mechanisms, phytodegradation, rhizodegradation, and phytovolatilisation. As already seen from the above terms, a separation can be made between phyto- and rhizoremediation to indicate the specific plant tissue involved. "Phyto" suggests that the whole plant is involved, the pollutant being transported from the roots to other (above ground) plant parts. In contrast, "rhizo" indicates that the remediation process occurs in the rhizosphere, that adsorption or precipitation onto plant roots or absorption into the roots takes place, without further upward transportation. This cleaning process may not only be generated by the plant itself but also by its mycorrhiza and by soil-based microorganisms in the rhizosphere. Finally, when improvement of soil physical conditions is targeted, the term phytorestoration can be used. It should be noted that in many cases, several of the processes described below are acting simultaneously.

2.3.1. Phytostabilisation

In phytostabilisation, plants immobilise contaminants in the soil and groundwater through adsorption onto roots or precipitation within the root zone of the plant. This process not only decreases the mobility of contaminants but also the availability for entry in the human food chain. Stabilisation may also occur by keeping the medium, which contains pollutants, in place. Common types of measures to prevent soils from eroding by wind or water may thus involve the containment of pollutants and may provide examples of phytostabilisation. When roots or a dense vegetation of aquatic plants keep water from moving, the term 'hydraulic control' is used. Evapotranspiration of abundant precipitation, and thereby preventing pollutants to be moved by excess soil water, is also a form of phytostabilisation.

2.3.2. Phytoextraction

Phytoextraction refers to the uptake and translocation of contaminants by plant roots from the soil into plant parts. The contaminants are removed when the plants are harvested. If plants are incinerated, the contaminants may end up in an ash fraction that may need to be handled as chemical waste. In some cases, recycling of the contaminant is possible.

2.3.3. Rhizofiltration

Rhizofiltration is the use of plant roots to remove pollutants from water or soil solution. The plants used for this purpose are raised with their roots in water, once a large root system has developed, contaminated water is collected from a waste site where it is substituted for their water source or the plants are planted in the contaminated area itself. Rhizofiltration is similar to phytoextraction, but the plant species are used primarily to remediate contaminated groundwater rather than soil.

2.3.4. Phytodegradation

Phytodegradation is the breakdown of contaminants taken up by plants through metabolic processes within the plant or the breakdown of contaminants external to the plant through the effect of compounds produced by the plant, such as enzymes. Pollutants are used as nutrients and degraded into harmless compounds that are incorporated into the plant tissue during the growing process.

2.3.5. Rhizodegradation

Rhizodegradation is the breakdown of contaminants in the soil through microbial activity that is enhanced by the presence of the root zone. This process is much slower than phytodegradation. Microorganisms can digest organic substances such as fuels or solvents that are hazardous to humans and break them down into harmless products in a process that is called 'biodegradation'.

2.3.6. Phytovolatilisation

Phytovolatilisation is the uptake and transpiration of a contaminant by a plant. The contaminant, or a modified form of it, is released into the atmosphere. Phytovolatilisation occurs when plants take up the organic contaminants together with water. Some of these contaminants can pass through the plants and reach the leaves where they evaporate into the atmosphere.

2.3.7. Phytorestoration

Phytorestoration is the re-establishment of soil physical conditions, like oxygen diffusion rate and water and/or nutrient holding capacity, through plants and their roots. An example is the reversion of soil compaction in agricultural soils, by means of tree plantings.

2.4. Potential of large-scale applications of phytoremediation

Pollutants may arrive in two ways to a remediation site. Either the soil at the site itself is polluted, and in situ remediation is required, or pollutants are transported to the remediation site and thereby treated at a distance from the originally polluted site.

Three main causes for in situ pollution exist: The first is a natural high background, such as for Cd and Cu in many parts of the Swedish landscape. The second reason may be long-term agricultural practices, which gradually have caused a build-up of high values of Cd and P in the soil by means of artificial fertilisers. Finally, in situ pollution may be a single event, such as radionuclide fall-out. Agricultural areas in the central and northern parts of Sweden were contaminated with radionuclides after the Chernobyl accident in 1986. A possible way of treating this land is to remove the radioactive ^{137}Cs (Caesium) and ^{90}Sr (Strontium) by SRWC plantations, but in the case of radiocaesium, uptake to the wood is very low [8].

In contrast to in situ pollution, pollutants may also be transported to a remediation site. Examples include industrial and hazardous waste that is collected in a landfill. Leaching and erosion of pollutants from these landfills may be decreased with a vegetative cap. In this case the vegetative cap decreases both surface runoff and water flow through the substrate by evaporation and thereby increases the chance that the pollutant remains in the landfill. Another kind of pollutant that is transported to a remediation site is organic waste. This organic waste has to be considered as nutrition for the plants that conduct the remediation process. Examples of such organic matter containing wastes include municipal wastewater, (sewage) sludge, and landfill leachates.

In Sweden we often use willow-vegetation filters [9] at remediation sites; these SRWC plantations may be used for bioenergy production in combination with waste handling (Fig. 1). Different applications of phytoremediation at five places in Sweden are described below, and their climate, represented by monthly normal temperatures, is illustrated in Fig. 2.

3. Applications of phytoremediation in Sweden; 5 examples

3.1. Månstorp

A non-commercial test site, used to investigate a surface distribution technique with polluted agricultural drainage water in willow stands, was located at Månstorp (56°29′N, 13°00′E, 10 m above sea level). Månstorp lies in the south-west of Sweden, where most of the agricultural soils are sandy. On these soils the heavy fertilisation regimes used by the farmers have caused percolation of large amounts of fertiliser, mainly nitrate, to the groundwater. This percolation results in groundwater pollution [10]. The goal of the trials at this site was to obtain an assessment of a new surface irrigation technique and of willow vegetation filter performance when dealing with nitrogen-polluted agricultural drainage water. The growing season in Månstorp (threshold value of 5 °C) is normally about 220 days (Fig. 2).

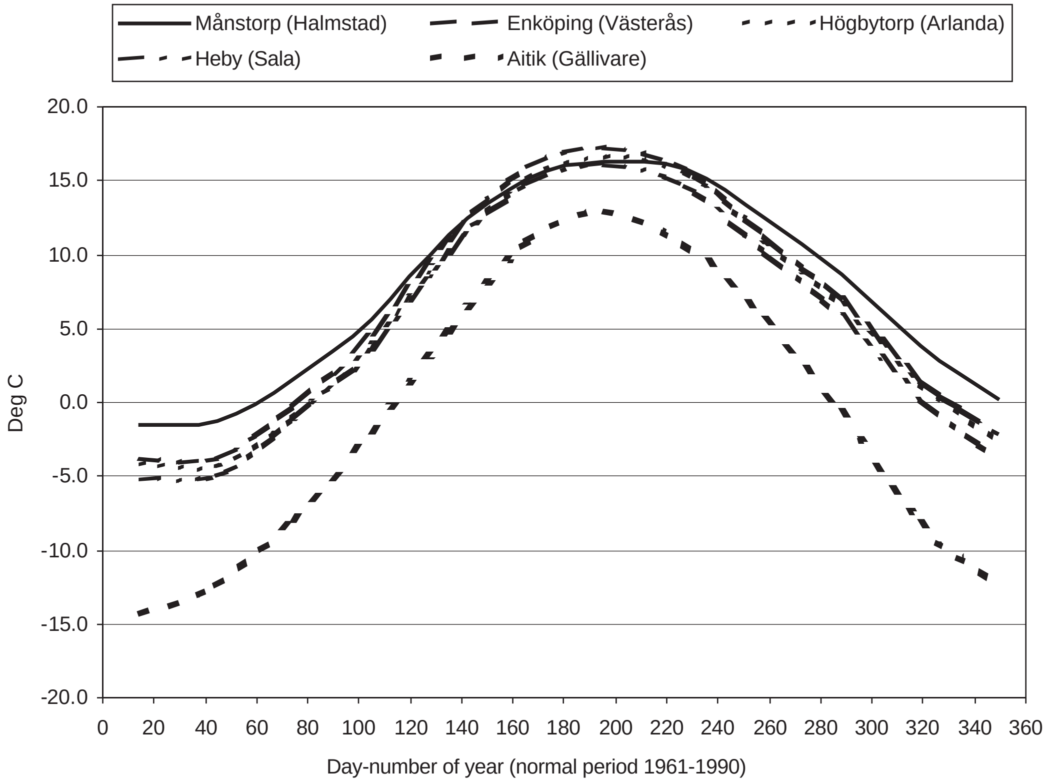


Fig. 2. Monthly normal temperatures from the most suitable nearby meteorological network station of the experimental sites concerned.

The drainage water origins from about 700 ha of fertilised farmland, mainly cropped with potatoes, rape, wheat and rye. The water contains high concentrations of NO_3-N, approximately 10–20 mg/l. For comparison, the upper limit of N in drinking water in Sweden is 10 mg N/l [11]. The water is collected and stored in a pond, situated at 300 m from the site, and applied to the willow vegetation filter without any further treatment.

Around the willow vegetation filter, 2.8 ha in size, drainage pipes were placed to prevent water from the surroundings from leaking into the willow plantations. The soil was sandy and mixed with clay and organic material. At a depth of 1 m there was a more compact layer of clay.

Three clones of *Salix viminalis* (78021, 78195 and 85007) and two of *S. dasyclados* (79097 and 900001) were planted in the spring of 1993 in five plots. During the establishment phase in 1993 the plants were irrigated with fresh water only. The cuttings were planted in a double row system, with a stool density of about 20,000/ha.

The plants were cut back in the winter of 1993/94 to 5–7 cm stumps to stimulate growth.

During the growing season of 1994, the polluted drainage water was pumped from the storage pond into a shallow furrow system using a flooding technique. Furrows were adjusted manually to get a uniform irrigation of the field and to avoid stagnant water in the lower areas. Irrigation took place from May to November. The plantation was irrigated with about 11 mm/day, the amount being controlled by a flow meter. The mean evapotranspiration from the willows was estimated to 5 mm/day during the growing season. During the treatment no fertiliser was used, except for the nitrogen supplied by the drainage water. The total amount of nitrogen delivered to the stand in 1995 was 185 kg N/ha.

The willows were well supplied with nitrogen, leading to high nitrogen content in the leaves and to a biomass production of > 10 tonnes of dry matter per ha and year [11]. Groundwater analyses showed that the nitrate content was substantially reduced under the willow crop. Biomass production results and nutrient analyses indicated that more than 60% of the nitrogen was incorporated in the biomass while nitrogen also was lost from the system by denitrification. The willow stand functioned well as a vegetation filter and the surface flooding technique applied was cost efficient and easy to install and maintain.

3.2. *Enköping*

Near the village of Enköping (59° 40′N, 17° 05′E), in the eastern part of Sweden, a wood chips-fired district heating power plant is located. The power plant is primarily owned by ENA Kraft AB, and provides, in close cooperation with the municipal council of Enköping, service to the farmers who cultivate the willows for fuel, the inhabitants of the municipality, who receive heat and electricity, and the local authorities. A lease agreement has been established with individual landowners. The district heating power plant is fired with a mixture of forest residues, sawdust, wood chips and *Salix* (about 20%). During the summer period most of the heat is produced by wood powder compressed in pellets. As a result, Enköping is heated by biofuel all year round.

In the vicinity of Enköping, three large-scale applications are going on, in which willow is used as a vegetation filter. All fields have a double-row system with a density of about 13,000 stools (i.e. plants that have resprouted after harvest) per ha. On the fields several *S. viminalis* clones were established. In the first application, residual ash from the power plant is used, ca. 1500 tonnes/y, and mixed with an equal amount of treated sludge from the wastewater treatment plant in Enköping. The mixture of ash and sludge contains heavy metals, and in a representative sample the following concentrations can be found: Cd, 0.75; Cu, 194.5; Cr, 26.1; Hg, 0,33; Ni, 12.9; Pb, 15; Zn, 324 mg/l.

This mixture is delivered, free of charge, to the local farmers to put on their SRWC instead as a fertiliser. The second application is at Nynäs Manor Farm, where a willow vegetation filter of approximately 76 ha is irrigated with a combination of clean water and sludge. Average values of heavy metals added to the field (in g/ha/y) by means of irrigation are: Cd, < 1.1; Cu, 183; Cr, 13; Hg, 0.4; Ni, 25; Pb, 13; Zn, 341.

The third application is located at Lundby, Göksbo and Djurby farms, where two storage ponds for sludge were constructed during 2001. Each pond has a volume of approximately 3500 m^3. Sludge is put into the first basin until the end of June, where it is left for 1 y before it is used for irrigation on the SRWC. Meanwhile, the second pond is being filled.

In the above cases the ash/sludge mixture is spread by a solid manure-spreading device, while sludge and sludge/water is distribute on the fields by irrigation hoses. Each day approximately 3 mm of wastewater was applied on the field.

Within the municipal boundaries of Enköping a total of 1200 ha of SRWC is available. About 10% of this area is necessary for dispersal of ash and sludge every year. The dispersal of this combination of ash and sludge has been in use since 1999. The Nynäs Manor Farm has an annual average yield of 5 GWh, which is 2% of ENA Kraft's total requirements of biofuel.

The integrated solutions for water and nutrient management, organic waste handling and SRWC for energy provision at the community level comprise the core of a recycling system that is run successfully on a commercial basis.

3.3. *Höbytorp*

Near the village of Bro (59°33′N, 17°37′E, 30 m above sea level), in the eastern part of Sweden, the landfill Högbytorp is run by the company Ragn-Sells Avfallsbehandling AB. Ragn-Sells handles residue products and hazardous waste, building up recovery markets, and is able to offer qualified solutions within the environmental sector. Currently the goal is to decrease landfill of unsorted waste by separating out an increased number of fractions. Furthermore, there is an ongoing development to use resources like landfill gas, biological degradable materials, tyres, metals, wood and oil and find ways to remedy polluted soils.

The Högbytorp plant receives mainly construction, industrial, demolition and domestic wastes. Metals are picked out for recovery and polluted soils are sorted and temporarily stored. Large quantities of combustible waste are shredded and sold to a heating plant. The remaining waste is compacted and covered by a mixture of soil, straw, horse manure and sewage sludge. Edge banks are constructed to prevent spreading of the waste by wind and to form the basis for a final covering.

The landfill produces up to 100,000 m^3 of leachates annually. The leachates contain metals in moderate concentrations, including cadmium and mercury. However, the concentrations of organic substances, chloride and ammonium-nitrogen are rather high (N: 200–220 mg/l; Cl: 790–820 mg/l and NH_4-N: 110–180 mg/l.).

The leachates are treated in a 70,000 m^3 basin system by applying oxygen, to nitrify/denitrify nitrogen, to degrade some of the organic substances, and to promote bacterial degradation and sedimentation of particles. Purification occurs during the warm period of the year. After this first treatment, the leachates are used to irrigate and fertilise SRWC.

Close to the Högbytorp recycling plant, two fields with SRWC are used for irrigation with landfill leachates. Irrigation takes place from June until November. The total area of SRWC is about 11.5 ha and cultivated with the willow clone Tora (a hybrid of *S. viminalis* and *Salix schwerinii*) with a density of about 13,000 cuttings/ha. In the first field, sprinkling with landfill leachates started in 1999, after the first year of establishment. In the second field, the willow cuttings were planted in 2001 and irrigation started in the growing season of 2002. The plants of the second field were cut back to a stump height of 30 cm in the spring of 2002 in order to promote sprouting and to speed up canopy closure. The landfill leachates were applied to the willow vegetation filter by sprinklers. Each day approximately 3–5 mm of landfill leachates were applied.

Preliminary studies of this system indicate that the willow clones used here are relatively tolerant to the applied chlorine levels (a slight decrease in production was noted at chlorine levels of >500 mg/l), that they take up nitrogen in large amounts and that contaminant leaching from the landfill and irrigation site is effectively kept under control.

3.4. Heby

Near the village of Heby (59°57′N, 16°51′E, 80 m above sea level) in the eastern part of Sweden, the sawmill Heby Sågverk is situated. The sawmill processes only spruce (*Picea abies*) and the stored round wood is irrigated to prevent it from dehydration, which is known to influence the quality of the stored wood and its suitability as raw material for the saw and pulp industry [12,13]. Previously, the runoff water from the storage yard, with large amounts of organic compounds, was returned to the river and caused severe contamination. Willow vegetation filters have been introduced recently to remediate this sawmill wastewater. The sprinkling intensity used in the sawmill industry has been relatively high, but currently the goal is to decrease the amounts. The lowest sprinkling levels that acceptably maintain the moisture content and quality of softwood saw timber vary between 25 and 33 mm/day [14–16]. Higher intensities, 40–100 mm/day, have been reported in other studies [17,18]. At the Heby sawmill, the sprinkling level is about 850 m^3/day.

The runoff water is collected in two storage ponds, together with a volume of about 1600 m^3. This runoff water contains, according to analysis in 2001, a high amount of organic compounds (80–90 mg/l), some nitrate (0.5–0.9 mg/l) and phosphate (0.7–1.1 mg/l), and phenolic compounds (0.04–0.09 mg/l). Without any further treatment, the runoff water is pumped to a nearby willow vegetation filter, where it is used as a fertiliser and for irrigation.

The nearby willow vegetation filter has a surface area of about 2 ha. Stool density in the field is about 14,000 stools per ha. On this field at least two different *S. viminalis* clones were established in a double-row system. Irrigation by overhead sprinklers takes place from May to November. The willows were irrigated with about 15–20 mm of wastewater per day. As the average evapotranspiration from a willow cultivation is only 3.5 mm per day during the growing season [19], some parts of the field became temporarily flooded.

Although the leaves of the willow vegetation filter regularly turned brown due to organic deposition, the plants were growing well and did not seem to suffer much from the pollutants. While no complete water and contaminant flow has been quantified for the system yet, the water quality in the river has improved markedly, showing hardly any traces of organic contaminants.

3.5. Aitik

Near the town of Gällivare (67° 0.06′N, 20° 0.8′E), in the north of Sweden and about 100 km north of the Arctic circle, the Aitik mine, a large open cut copper mine, is settled. Aitik has a climate with cold winters and relatively warm summers (Fig. 2). The growing season (threshold value of 5 °C) is normally only 120 days, and therefore less suitable for biomass production. Boliden Mineral AB started the open cut mining in 1968, and operation is planned to continue in the mine at least until 2008. About 200,000 tonnes of concentrated copper per year are produced. Furthermore, 24 Mt of waste rock and 18 Mt of mill tailings are generated per year by the production process. Tailings are finely crushed bedrock left after mineral separation from the ore. The tailings are transported as a water solid effluent by pipeline and deposited in a pond situated in a valley, and covering an area of more than 1000 ha. The thickness of the deposit varies and ranges from some meters to over 30 m. Water is collected in a reservoir at the western part for reuse in the mineral separation process. The tailings lack the properties that are characteristic of natural soils, as they do not contain organic matter or nitrogen. The rock in the ore deposit consists of quartz, feldspar, plagioclase, biotite and muscovite.

As the ore is dominated by sulphides of iron and copper the oxidation of both waste rock and tailings results in a pH decrease. When pyrite (FeS_2) reacts with H_2O and O_2, acid is generated, and the same reaction occurs with $CuFeS_2$ and PbS_2. Consequently, metals remain as ions in the substrate solution. As the annual normal precipitation at the Aitik mine is about 520 mm/y and the net infiltration into waste rock dumps about 500 mm/y [20], metals may leak into the environment together with the drainage water.

To avoid oxidation and subsequent leaching, the waste rock and tailings should be covered. Leaching can be prevented with plant establishment, because plants may increase evapotranspiration. Plants on top of mine tailings and waste rock, with a nutrient addition in the form of sewage sludge, may be used to reduce downward water movement and thereby leaching of heavy metals such as Cd, Cu, Pb and Zn.

In mid-1999, a cover was placed on a 14 ha area of the rock dump at the Aitik mine. This cover consisted of 1 m of moraine, distributed in two 0.5 m layers, individually compacted, and a 0.2–0.3 m layer of topsoil. The surface was finally seeded with grass. The effectiveness of this cover in reducing both oxygen and water infiltration rates is currently being assessed [20].

If the tailing pond is no longer filled with new wet sand, the soil will dry out, thus resulting in a desert-like landscape exposed to wind erosion. To prevent the sand from eroding by wind and/or by water (rain), which would result in spreading of metals into the surroundings, a new vegetation cover must be established. This vegetation cover will not only reduce environmental problems, like leaching of heavy metals, but will also result in an attractive area for recreation or other uses. To improve fertility of the waste sand it ought to be treated with an amendment, e.g., in the form of chemical fertilisers or sewage sludge [21,22].

Since 1997, field research has been performed to develop a stable vegetation cover on the mill tailings. Many local herbaceous and woody plant species have been tested, including different species of willow well adapted to the climate and site. In combination with those species trials, different soil amendments were tested, using sewage sludge, moss peat and paper mill sludge [23].

The best plant establishment was obtained on a sewage sludge mixture, due to its pH-stabilising properties, water-holding capacity and nitrogen supply. Currently, sewage sludge from the city of Stockholm is used to improve the site conditions.

Considered as a multi-purpose system, the Aitik case presents an example where emphasis is placed put on waste handling, rather than on biomass production, which is severely limited by the short growing season. The reverse was the case at Månstorp, where a relatively long growing season—with the help of surface water nutrients—was employed to increase biomass production.

Both with regard to climatic conditions and purpose focus of the system (production/waste handling), Heby, Högbytorp and Enköping fall in between the Månstorp and Aitik situations.

Acknowledgements

We gratefully acknowledge Jan Holmlund and Eddie Johansson for information on the Enköping project, Pär Aronsson, Maria Jonsson, Kurth Perttu and Pär Wennman for their constructive comments, and Boliden Mineral AB, Mellanskog AB and Ragn-Sells AB for facility provision. Financial support was received from the Swedish National Energy Administration (to Theo Verwijst), from the Leonardo da Vinci foundation and from the Dutch energy company ENECO (to Jaconette Mirck).

References

[1] Sirén G, Perttu K, Eckersten H, Linder S, Christersson L, Sennerby Forsse L. Energiskogsodling. Nämnden för Energiproduktionsforskning (NE) 1983;11:242–5.

[2] Ledin S, Sennerby-Forsse L, Johansson H. Implementation of energy forestry on private farm land in Sweden. Proceedings IUFRO XIX world congress, 5–11 August, Montreal, Canada, 1990.

[3] Perttu KL, Kowalik PJ. *Salix* vegetation filters for purification of waters and soils. Biomass and Bioenergy 1997;12(1):9–19.

[4] Aronsson PG, Perttu K. Willow-vegetation filters for wastewater treatement and soil remediation combined with biomass production. The Forestry Chronicle 2001;77(2): 293–9.

[5] Verwijst T. Willows: an underestimated resource for environment and society. The Forestry Chronicle 2001; 77(2):281–5.

[6] US Environmental Protection Agency: a citizens guide to phytoremediation. US EPA, Office of Solid Waste and Emergency Response, Washington D.C; 1998.

[7] Isebrands JG, Karnosky DF. Environmental benefits of poplar culture. In: Dickman DI, et al. editors. Poplar Culture in North America. Ottawa Canada: NRC Research Press; 2001. p. 207–18.

[8] Von Fircks Y. Uptake and distribution of ^{137}Cs and ^{90}Sr in *Salix viminalis* plants. Journal of Environmental Radioactivity 2002;63:1–14.

[9] Perttu KL. Biomass production and nutrient removal from municipal wastes using willow-vegetation filters. Journal of Sustainable Forestry 1993;1(3):57–71.

[10] Gustafsson A. Leaching of nitrate from arable land into groundwater in Sweden. Environmental Geology 1983; 5:65–71.

[11] Elowson S. Willow as a vegetation filter for cleaning of polluted drainage water from agricultural land. Biomass and Bioenergy 1999;16:281–90.

[12] Liukko K. Climate-adapted wet storage of saw timber and pulpwood. An alternative method of sprinkling and its effect on freshness of roundwood and environment. Doctoral thesis. ISSN 1401-6230, ISBN 91-576-5335-6, 1997.

[13] Regnander J. Sprinkling of insect attacked pulpwood-an important part of the control of bark beatles. Sverige Skogvårdsförbunds Tidskrift 1976;74(5):497–505 (in Swedish).

[14] Johansson B. Intermitted sprinkling of sawlogs. Royal College of Forestry, Department of Forest Products, Stockholm, Sweden, Report No. 46, 1964 (in Swedish with English summary).

[15] Moltesen P, Dalgas KF, Herlow M. Lagring av stormfaeldet gran under overrisling. Dansk Skovforenings Tidskrift no 1974;59:253–95 (in Danish with English summary).

[16] Moltesen P. Dänische Erfarungen mit Nasslagerung van Rundholz. Forstarchiv 1977;48(3):45–50 (in German with English summary).

[17] Nylinder, P., 1976. Bevattning som virkesvård. Skogs- och virkesskydd. The Swedish University of Agricultural Sciences. Department of Forest Products, Uppsatser, No. 57 (in Swedish).

[18] Syme JH, Saucier JR. Effect of long-term storage of southern pine sawlogs under water sprinklers. Forest Products Journal 1995;45(1):47–50.

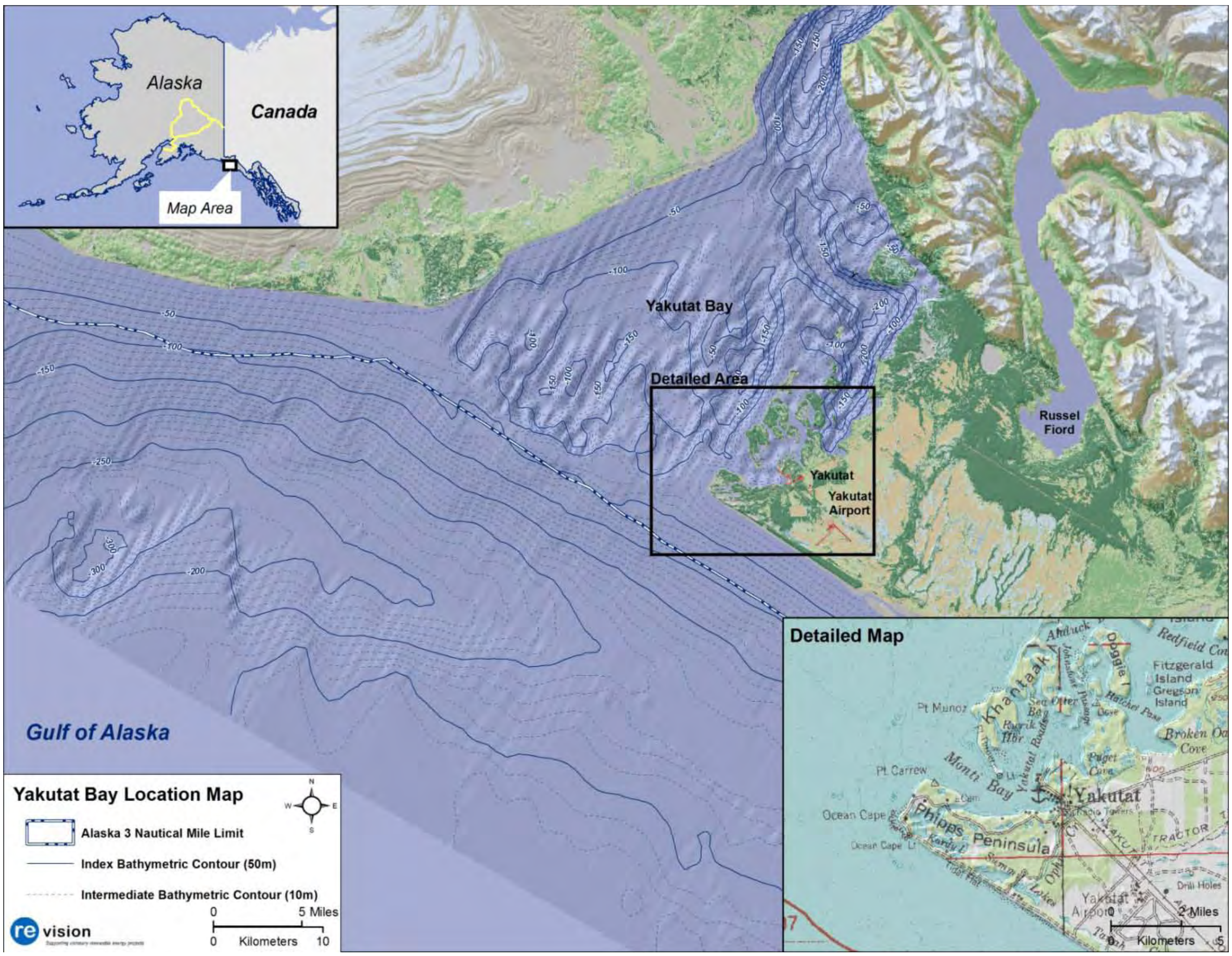
[19] Perttu KL. Purification of sludge and wastewater using willow vegetation filters. Proceedings seminar on sustainable utilisation of wastewater sludge, 1994.

[20] Timms G, Ritchie I, Lindvall M, Bennett J. A best practice approach to the closure of sulfidic waste rock dumps- Aitik mine as a case study. Securing the future. international conference on mining and the environment. June 25–July 1 Skellefteå 2001, p. 882–889.

[21] Bergholm J, Steen E. Vegetation establishment on a deposit of zinc mine wastes. Environmental pollution 1989;56:127–44.
[22] Borgegård S-O, Rydin H. Utilisation of waste products and inorganic fertiliser in the restoration of iron mine tailings. Journal of Applied Ecology 1989;26:1083–8.
[23] Stjernman L, Ledin S. Growth of Barley, red fescue and red clover in tailings mixed with different kinds of organic material. Securing the future. International conference on mining and the environment. June 25–July 1 Skellefteå 2001, p. 795–805.

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Yakutat Conceptual Design, Performance, Cost and Economic Wave Power Feasibility Study



Project	Yakutat Conceptual Wave Power Feasibility Study
Phase	Conceptual Design
Report	EPRI - WP- 006-Alaska
Author	Mirko Previsic
Coauthor	Roger Bedard
Date	November 30, 2009

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

Organization(s) that prepared this document:

Electric Power Research Institute

re vision consulting, LLC

Table of Contents

List of Figures

List of Tables

1. Introduction and Summary

A Phase I Reconnaissance and Phase II Feasibility Analysis Phase was completed in 2009 by the Electric Power Research Institute (EPRI) under Yakutat Power funding, which assessed the technical, cost and economic viability of a WEC project. This is the final report of this study phase.

An initial high-level scoping study showed that, given Yakutat's 500 kW to 1 MW electricity generation needs, it is unlikely that a deep-water wave power conversion plant would make economic sense. At the small scale proposed, the cost drivers are the subsea cable cost and installation and operation cost, which are dominated by offshore operational considerations. It was therefore decided to apply focus on near-shore technology.

The study scope included: (1) a shallow water wave energy resource assessment, (2) a conceptual design based on the Aquamarine Power Oyster shallow water wave energy conversion technology, (3) a cost assessment (capital and O&M), and (4) an economic analysis. The Aquamarine Oyster was chosen as representative of a shallow water wave energy conversion technology suitable for the deployment site. Oyster is a wave-actuated hydraulic pump that pumps fresh water to shore at a pressure level of about 120 bars, where it is converted into electricity using a conventional hydroelectric system and then returns it to the Oyster in a closed loop. The major project elements include: (1) the Oyster WEC device, (2) a high pressure (120-bar) supply sub sea pipeline and a low pressure (3-bar) return sub sea pipeline, (3) an onshore turbine generator power station, and (4) a distribution line extension to connect the power station to the city electrical grid network. The proposed deployment location and related project elements are shown in the following Figure 1.

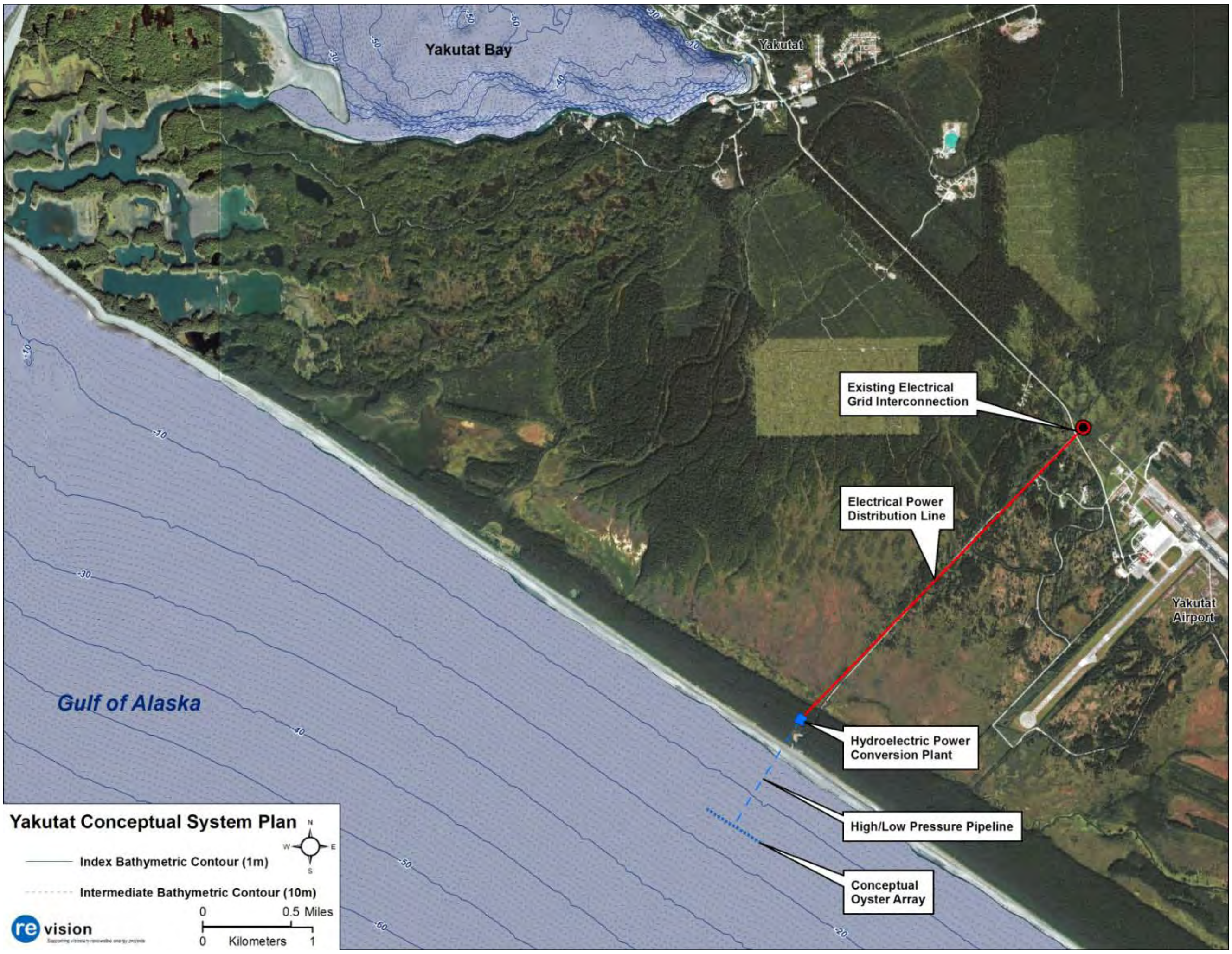


Figure 1 – Oyster II Conceptual Design Layout

Yakutat has an excellent wave climate for wave energy conversion. A shallow water wave transformation model (SWAN) was used to propagate a full year of wave data to the deployment location at 13m water depth. Shallow water power densities at the deployment site of interest were assessed at between 19kW/m and 22kW/m. Based on this wave energy resource data, the resulting capacity factor of the 650kW-rated Oyster machine was assessed at 48%. Cost elements, including: (1) device, (2) sub sea pipeline, (3) on-shore power station, (4) overland distribution line extension, (5) installation, and (6) operation and maintenance were assessed for the plant at four different sizes (1, 2, 4 and 8 units at 650 kW per unit), as summarized in Table 1 below. Cost of electricity was then computed using a Municipal Utility Ownership economic model. Cost of electricity is estimated to be about 45 cents/kWh (in constant Jan 1, 2010 dollars) for a 20-year plant-life. Cost and economic uncertainties at this early stage of project development are still quite substantial; based on EPRI's experience with similar projects at a conceptual stage of development, cost uncertainty is on the order of +/-30%.

Table 1 - Cost, Performance and Economic Summary

		1 Unit		2 Units		4 Units		8 Units	
Capital Cost		USD	$/kW	USD	$/kW	USD	$/kW	USD	$/kW
	Device Structure	$3,840,000	$4,923	$6,912,000	$4,431	$12,441,600	$3,988	$22,394,880	$3,589
	Water Pipeline	$1,344,000	$1,723	$2,419,200	$1,551	$4,354,560	$1,396	$7,838,208	$1,256
	Power House	$1,359,000	$1,742	$2,478,000	$1,588	$4,716,000	$1,512	$9,192,000	$1,473
	Installation Cost	$2,347,200	$3,009	$3,288,000	$2,108	$4,724,400	$1,514	$6,945,000	$1,113
	Total Cost	$8,890,200	$13,677	$15,097,200	$11,613	$26,236,560	$10,091	$46,370,088	$8,917
Annualized OPEX		$330,000	$508	$510,000	$392	$810,000	$312	$1,400,000	$269
Performance									
	Rated Power	650	kW	1300	kW	2600	kW	5200	kW
	Capacity Factor	48.00%		48.00%		48.00%		48.00%	
	Availability	95%		95%		95%		95%	
	Annual Energy Output	2596	MWh	5193	MWh	10386	MWh	20772	MWh
Cost of electricity (constant $)		45.1	cents/kWh	38.0	cents/kWh	32.3	cents/kWh	28.4	cents/kWh

The cost at this relatively small scale (compared with sizes of utility power plants in the lower 48) is clearly dominated by infrastructure and operational considerations related to the installation of the device in this somewhat remote location. However, present busbar cost of electricity from the existing diesel-based generation facility comes in at about 27 cents/kWh and will only increase in the future. This is comparable to Oyster at an 8 unit scale plant and removes the issue of price volatility of diesel fuel generation. Diesel fuel cost has dramatically increased since the year 2000 and is only temporarily lower at present because the global recession has reduced the demand on fossil fuels, temporarily creating a more attractive pricing structure. In the long term, energy costs are expected to increase, which creates an additional economic burden to small communities like Yakutat that are heavily reliant on diesel fuel.

A key result of the feasibility study is that the level of cost-reduction potential that could come from optimization is substantial. These cost reductions can only be quantified through detailed design and engineering analysis because most cost elements are driven by site-specific considerations. A key part of the proposed next phase, the final design and permitting phase, is to investigate some of the identified alternate design options and detail the "optimal" solution for the site of interest. Many cost reductions could come from improved installation and operational procedures, economies of scale and the potential to locate the plant closer to shore.

2. Site Description

Yakutat is located along the rugged Alaskan Gulf Coast between Sitka and Cordova. Bounded by the Gulf of Alaska on the South, nearly impenetrable mountains to the North and coastal glaciers to the East and West, Yakutat is undeniably remote. There are no roads leading into or out of Yakutat. All commerce and access must occur via air or sea. The City and Borough of Yakutat has a population of 631 and is located at the mouth of Yakutat Bay along the Gulf of Alaska, 225 miles northwest of Juneau and 220 miles southeast of Cordova. Yakutat receives monthly barge service during the winter and more frequent service during summer. Yakutat is equipped with two jet-certified runways and receives jet service daily. The U.S. Forest Service and the National Park Service have offices in Yakutat.

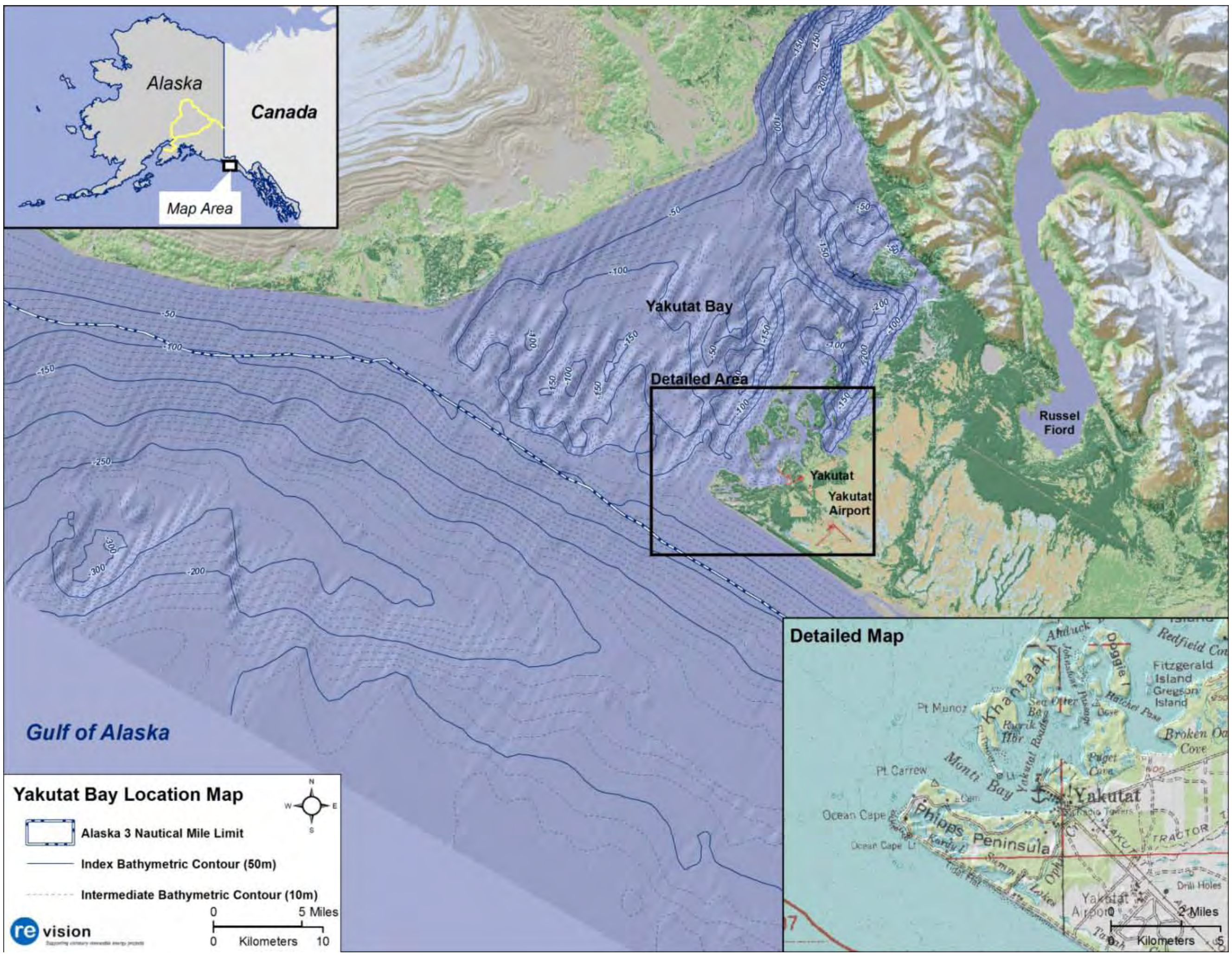


Figure 2 - Yakutat Overview Map

2.1. Bathymetry/Sediments

Little is know as to the exact nature of the sediments in the area. However, initial research indicates no rocky outcrops and a thick, soft sediment layer including sand and mud. The seabed is gently sloping, with the continental shelf extending about 60 miles off the coast. Figure 3 shows the bathymetry near Yakutat. Water depth contour lines are shown in 10m increments with the thicker lines, representing 50m increments.

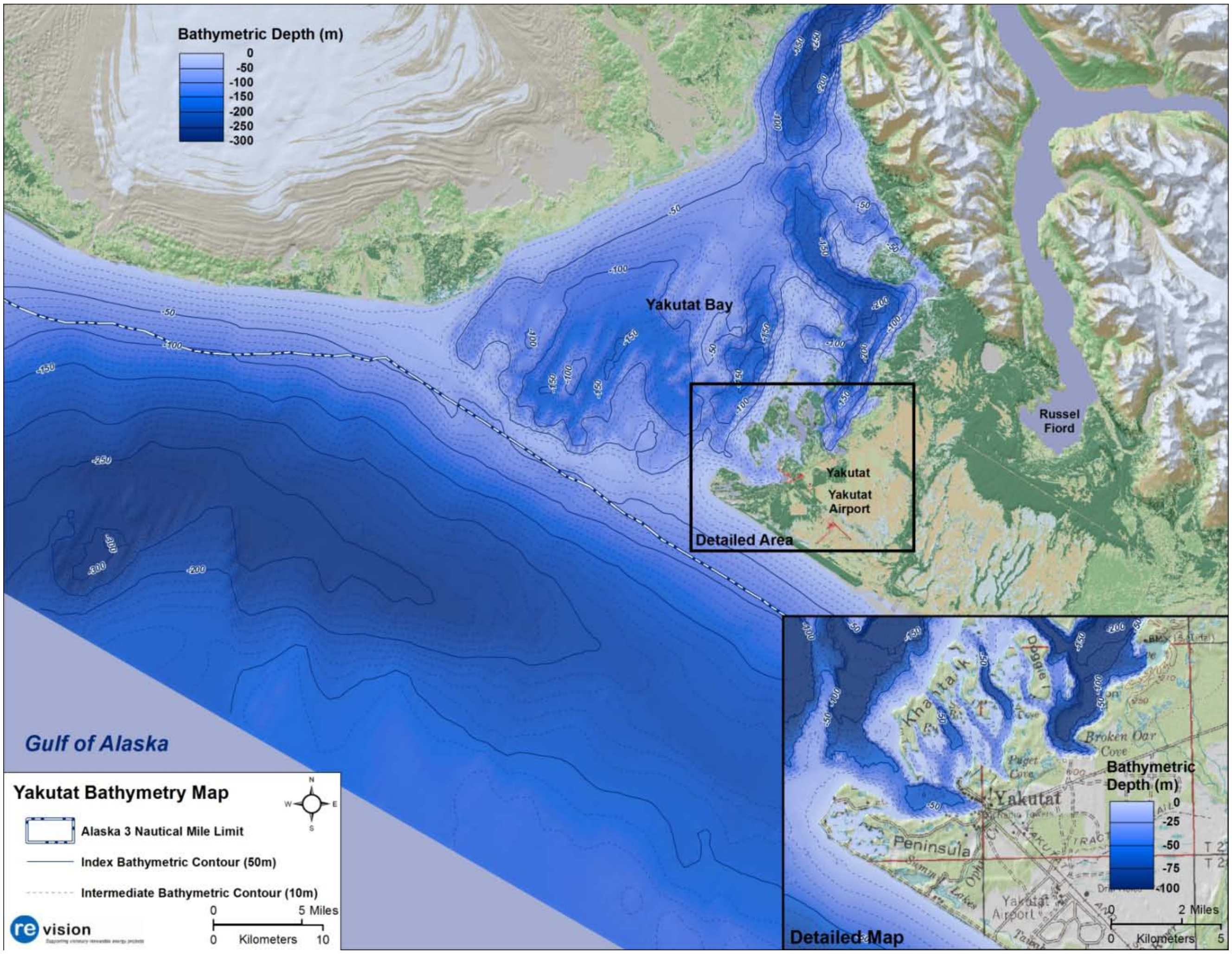


Figure 3 - Bathymetry near Yakutat. Water depth in meters. Thick contour lines in 50m increments.

2.2. Deep Water Wave Energy Resource

Yakutat has an excellent wave energy climate. Archival measurements are available from a number of sources, including National Oceanographic and Atmospheric Administration (NOAA), National Data Buoy Center (NDBC) and other wave measurement buoys. Preliminary analysis based on NDBC data from a prior assessment indicates the average annual deep water wave power density is about 34kW/m near Yakutat. The wave power densities are higher in the winter than in the summer due to seasonal storms, indicating a good match between higher winter electric loads and WEC device power output.

The Fairweather Grounds NOAA measurement buoy NDBC 46083 was chosen as representative of the deep water wave climate near Yakutat, Alaska. This measurement station is located 92Nm southeast of Yakutat in 136m water depth. The following illustration shows an overview map of the measurement buoy location.

Figure 4 - Location of Deep Water Measurement Buoy used for Analysis.

Monthly average power densities were computed from data of the time period 2001 through 2006. The following illustration shows the seasonal variations at the site of interest.

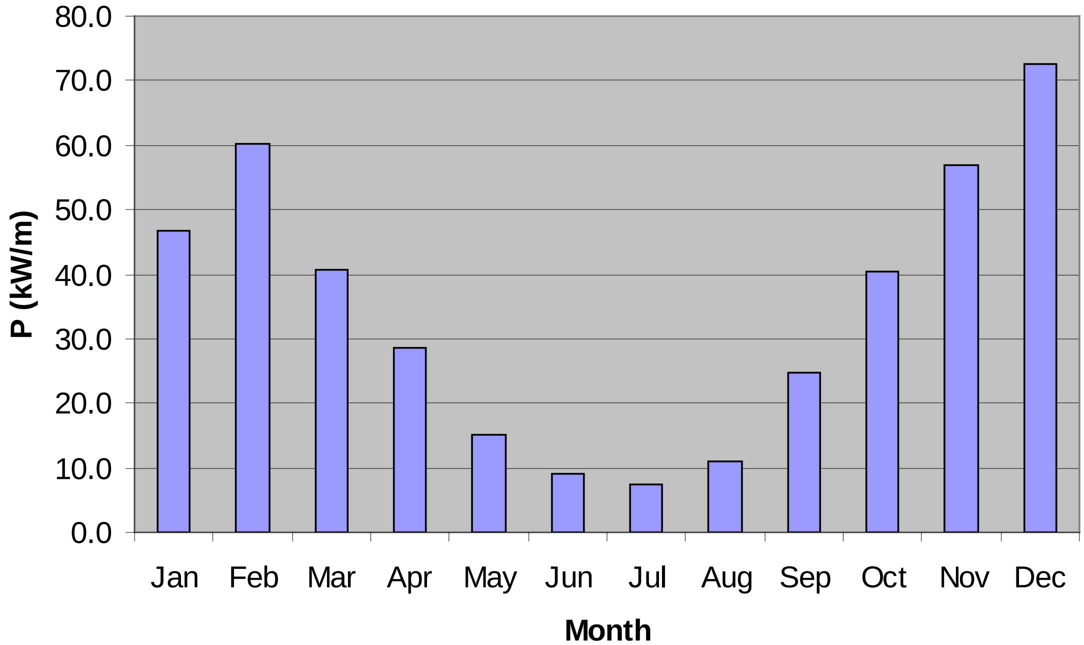


Figure 5 - Monthly Average Power Densities at NDBC 46083

2.3. Shallow Water Wave Energy Resource Assessment

SWAN is a third-generation wave model for obtaining realistic estimates of wave parameters in coastal areas, lakes and estuaries from given wind, bottom and current conditions. However, SWAN can be used on any scale relevant for wind-generated surface gravity waves. The model is based on the wave action balance equation with sources and sinks. Directional wave data from NOAA Wavewatch III was used to define the deep water offshore wave boundary condition. This boundary was about 50 miles from shore in sufficiently deep water. Bathymetry data obtained from NOAA was used to define the bathymetry. A total of 2920 SWAN runs were completed for the site, by propagating the deep water wave energy resource over the spatial domain in three-hour intervals. This corresponds to a full year of Wavewatch III data. The year 2008 was chosen as reference year.

Figure 6 shows the annual average significant wave height over the computational domain. The significant wave height is a good indicator of power density and hence device performance. A single output point at the potential deployment site in 13m water depth was chosen, and a statistical analysis was carried out to quantify the resource in detail at the site of interest. The modeling indicated an annual average power density of 22kW/m wave front. Aquamarine Power (the developer of the Oyster) carried out an independent analysis processing eight years of data and came to a similar conclusion with about 19kW/m. For a shallow water resource assessment, these results demonstrated excellent agreement, providing confidence in the resource data available. However, it is important to note that both analyses used the same bathymetry data, which may or may not be accurate in such near shore locations. Data coverage is oftentimes sparse in near-shore locations, as it is difficult to operate in that environment with research vessels, and it may be that NOAA simply interpolated depth figures in the near-shore environment.

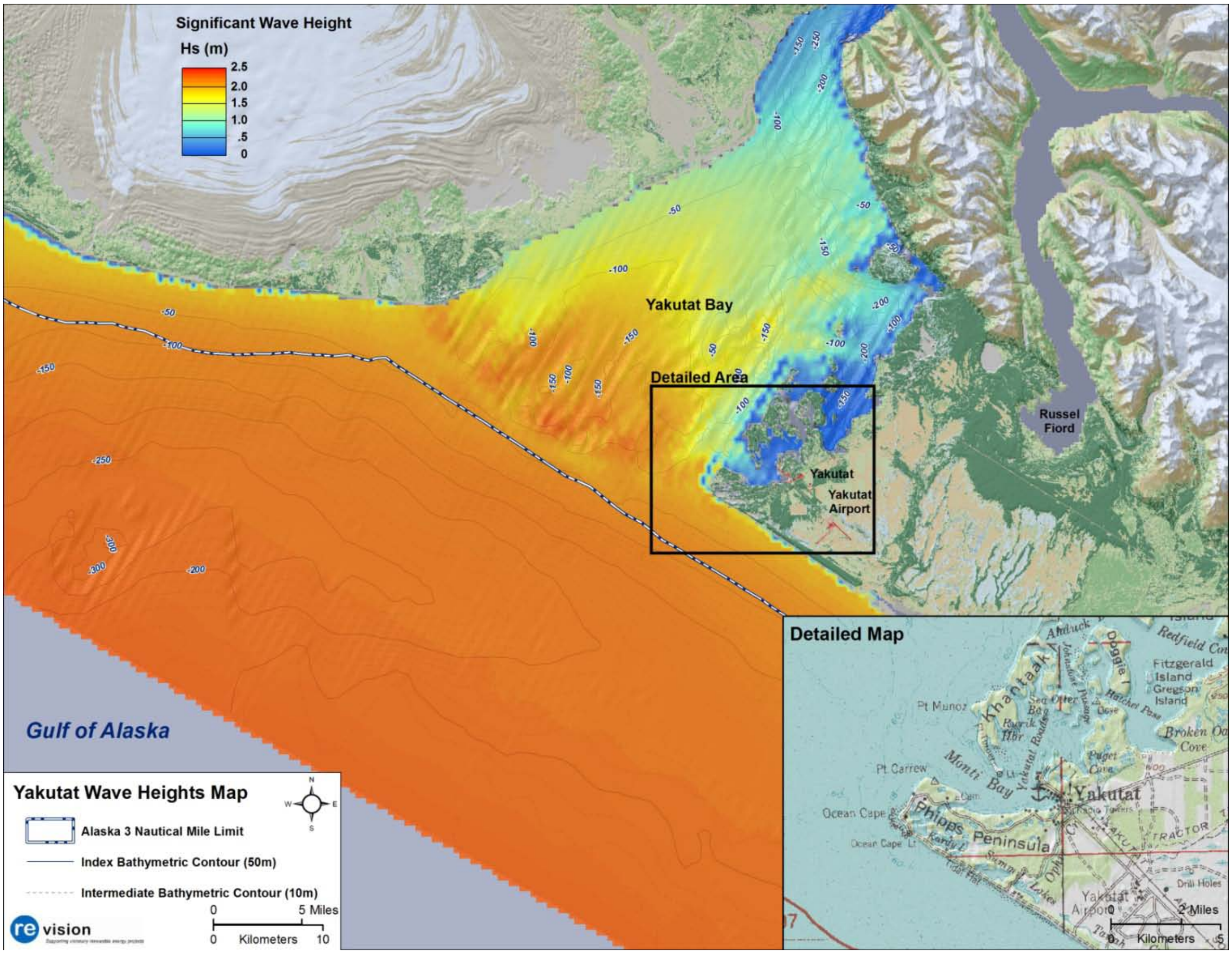


Figure 6 - Average Significant Wave Height (Hs) over the computational domain for the year 2008.

Table 2 shows a frequency distribution of sea-states defined as a function of significant wave height (Hs) and zero crossing period (Tz) at the deployment site.

Table 2 - Frequency Distribution of significant wave height (Hs) versus zero cross period (Tz) at the 13m deep deployment site computed from SWAN model outputs.

		Tz (s)											
		3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5
Hs (m)	0.25	0	0	3	0	2	1	2	0	0	0	0	0
	0.75	14	87	147	98	69	47	23	4	0	2	0	0
	1.25	2	120	270	159	92	57	34	15	1	2	3	0
	1.75	0	37	224	133	33	37	29	10	10	7	0	0
	2.25	0	0	81	177	68	23	22	18	2	7	0	0
	2.75	0	0	11	103	110	32	15	7	6	1	1	0
	3.25	0	0	0	35	87	62	14	9	5	2	2	0
	3.75	0	0	0	1	32	81	19	12	1	1	1	2
	4.25	0	0	0	0	0	31	36	6	2	0	0	1
	4.75	0	0	0	0	0	0	6	13	5	0	0	0
	5.25	0	0	0	0	0	0	0	5	5	2	0	0
	5.75	0	0	0	0	0	0	0	0	1	0	0	0

Using the Aquamarine Power Oyster performance table, which specifies the electrical machine output as a function of sea state, the annual energy output for the Oyster was calculated at the deployment site. The results of this performance assessment are shown below.

- Rated Capacity 650kW
- Capacity Factor 48%
- Availability 95%
- Annual Output 2,596 MWh/year

2.4. Existing Generation System

The existing resource is diesel fuel. Fuel is delivered to Yakutat via barge year-round and stored in bulk at the Delta Western tank farm. Fuel is delivered by truck to Yakutat Power, local businesses and residents. Yakutat Power made a major investment in 2007 to replace an antiquated CAT 3412 with the new 3516B, in order to increase the plant's rated kW capacity. A heat recovery system was installed in the early 1990s and provides heat to the Yakutat school complex nearby. Virtually all heating of the school complex is provided by the Yakutat power plant heat recovery system.

The existing Yakutat Power plant generation equipment consists of four diesel generator sets (gensets) with a total generation capacity of 4,000 kW. The generation system is a 4160-volt three-phase system. All generators operate at 1200 RPM.

- Genset #1 a new CAT 3516B rated at 1322 kW
- Genset #2 is a CAT 3512B rated at 880 kW
- Genset #3 is a CAT 3508B rated at 600 kW
- Genset #4 is a CAT 3516 rated at 1200 kW

The new 3516B is the primary genset. The 3512B and 3508B gensets operate on an as-needed basis when the electric load exceeds the 3516B capacity and when the 3516B is down for maintenance. The 3516 is nearing the end of its useful life and is thus used sparingly. The power plant has two separate cooling systems, both with heat recovery capability. The 3516B and 3512B are on one common cooling loop, and the 3508B and the 3516 are on a separate cooling loop. Both cooling loops are 5-inch diameter welded steel piping with flanged butterfly valves, an AMONT valve, plate heat exchanger and a single radiator.

2.5. Existing Demand/Market for Electricity and Cost

Figure 7 shows the daily electrical generation in Yakutat for 2007. The average electrical load during that year was 794kW.

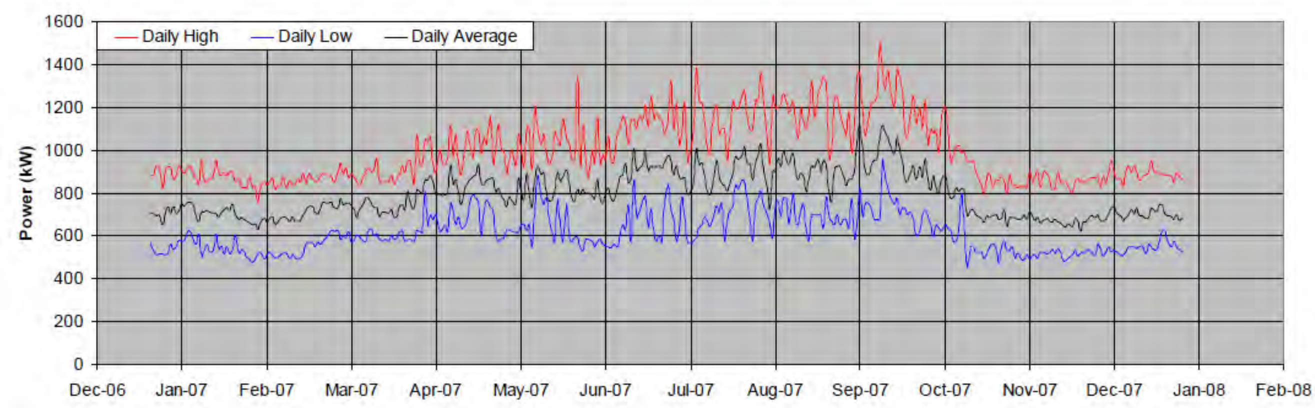


Figure 7 - Daily Average, Low and Peak Load for Yakutat

The amount of electricity that could be displaced is largely dependent on how well the generation matches demand. From the chart above, reporting daily average, low and peak generation, it becomes apparent that short-term storage could greatly increase the renewable capacity that could be added to the electrical system in the village. As daily load profiles for Yakutat were not available, Figure 8 and Figure 9 show examples of daily load fluctuations for other remote villages in Alaska for a winter and a summer month. These are presented as representative of the load profiles expected in Yakutat.

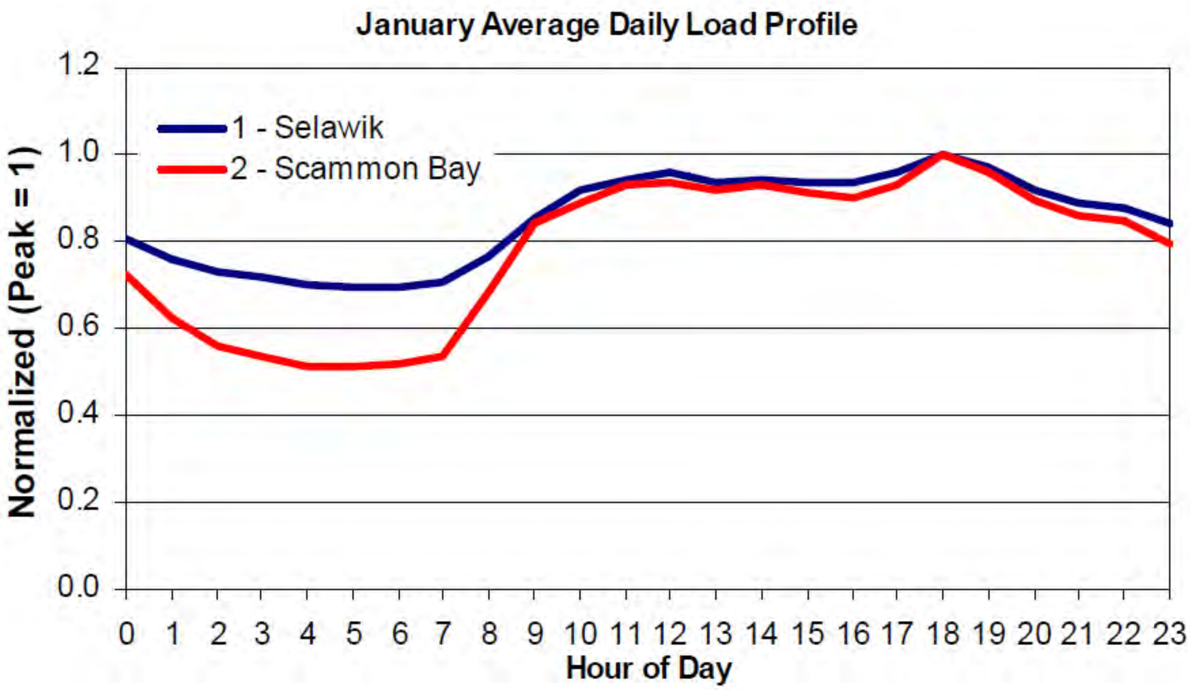


Figure 8 - January Average Load Profile for Selawik and Scammon Bay

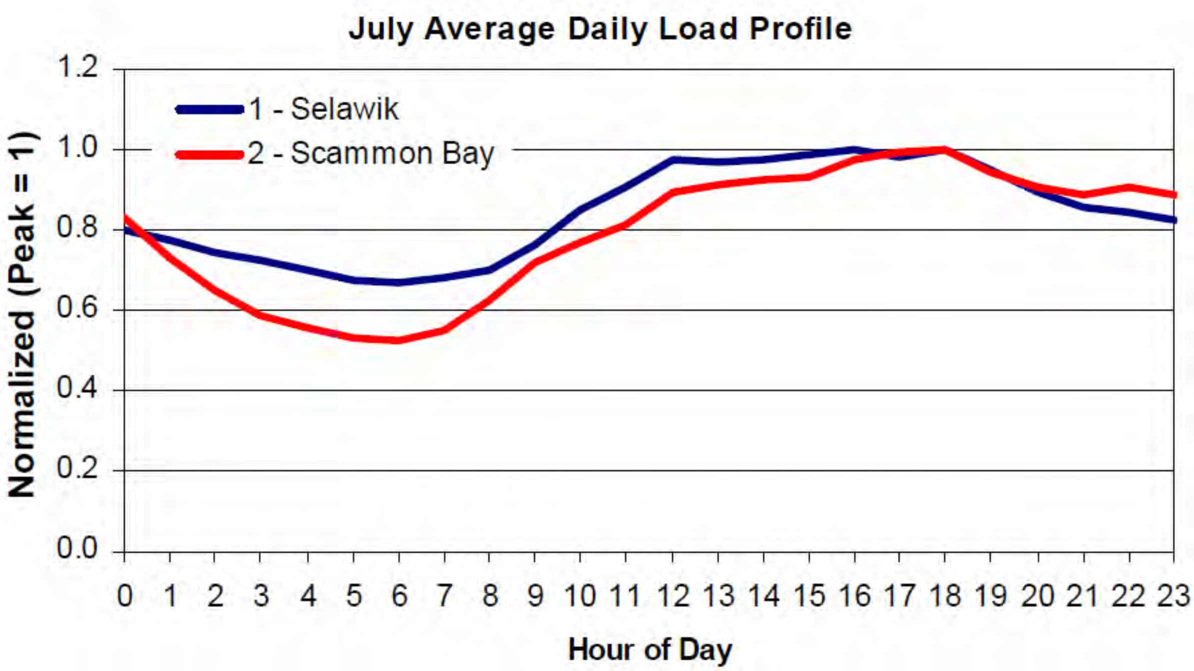


Figure 9 - July Average Daily Load Profile for Selawik and Scammon Bay

The load profile shows that the lowest load during the daily load cycle is almost half of the peak load. If there was no storage in the electrical system, the renewable generation system would have to be sized at a capacity that would not exceed the minimum load. This would insure that none of the electrical energy from a renewable power plant would get wasted. For Yakutat, this lower limit is at about 450kW.

Instead of using fuel for heating, electricity could be used. Because heat can be stored relatively easily using thermal mass, the time of the day during which energy is dissipated in heating elements does not need to directly coincide with the heating needs. To accomplish this, electrical boilers could be placed at the existing power plant and tied into the power plant’s heat recovery system. Further, electric boilers could be placed in large commercial/community buildings to absorb peak electric generation when demand is low. Yakutat is presently in the process of upgrading its entire electric distribution system. Potential future space heat electric loads will be considered in the design.

There also appears to be a natural correlation between the heating needs in the night/early morning hours and the lowest electrical energy needs in the village. This is the time during which there may be excess electricity coming from the wave power plant, and this energy could be dissipated in the form of heat. Total heating fuel used in 2007 was 343,000 Gallons. In order to calculate the equivalent number of kWh to meet that heating demand, the following assumptions are made:

- 1 Gallon of heating fuel = 140,000 btu
- Heating efficiency of oil = 80%
- 1kWh = 3,412 btu
- Electrical Heating efficiency = 99%

Based on these assumptions, 1 MWh of electricity could accomplish the same amount of heating as 30.2 gallons of heating fuel. In other words, the 343,000 gallons of heating fuel could be replaced with 11,357 MWh of electricity, which corresponds to an average electrical output of 1.3MW. Meeting all of the heating and electrical needs in the village may be impractical at present and would require additional work to create intelligent loads within the village. However, the total needs will set an upper limit on the potential for renewable generation within Yakutat. The total potential average load is 2.1MW (0.8MW electrical + 1.3MW heating). Given a capacity factor of the wave power plant of 48%, this would require an installed capacity of 4.3MW to meet all of the village electrical and heating needs. If no energy storage was present, the electrical generation from the wave power plant would have to be limited to the lowest electrical load in the system, which was 450kW in 2007. An intelligent grid design and integration with electrical heating has the potential to significantly increase the amount of energy that could come from a renewable (i.e. variable) resource.

A second consideration is the cost of electricity. Over the past decade, fuel prices have continually increased and have led to significant increases in the cost of electricity. The following chart shows the fuel prices between 1999 and 2008.

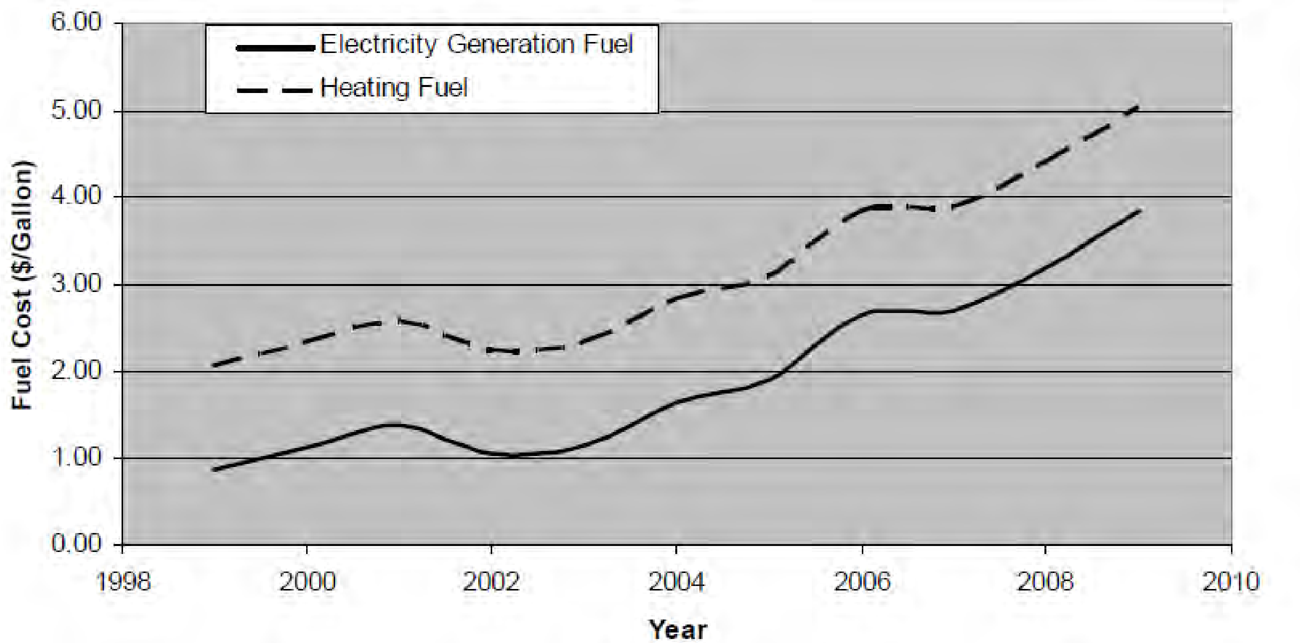


Figure 10 - Diesel and Heating Fuel Cost in Yakutat between 1999 and 2008.

These fuel cost have translated directly into significant electricity cost increases. The following chart shows the electricity cost over the same time frame.

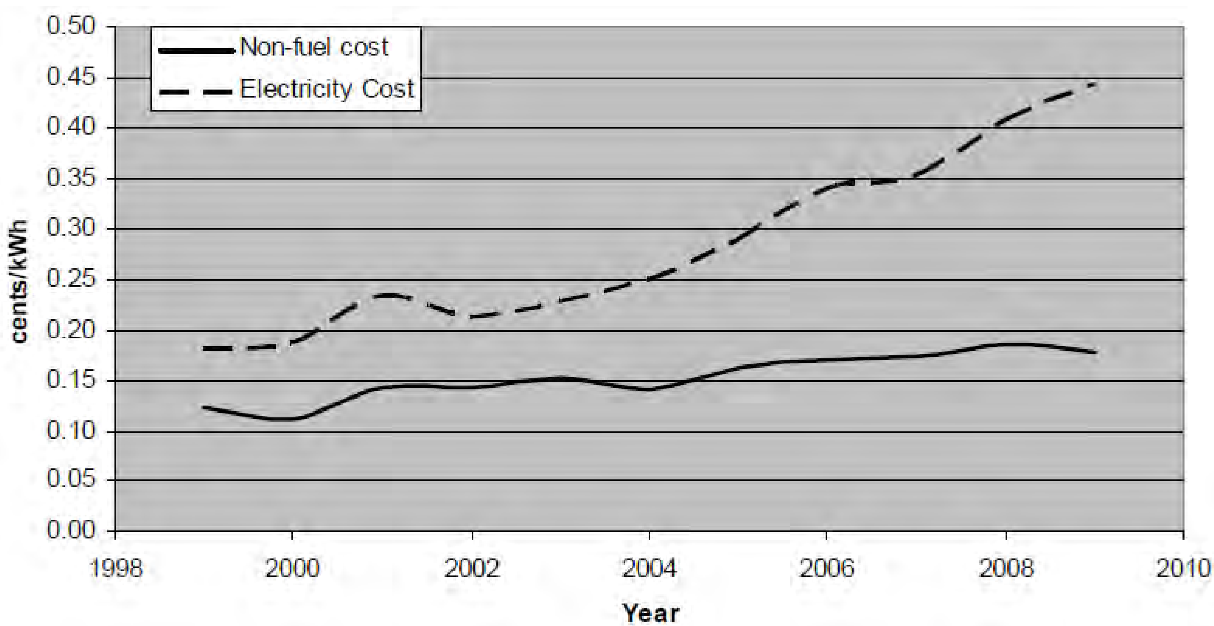


Figure 11 - Electricity Cost between 1999 and 2008

As shown in the above chart, electricity cost increases are largely driven by fuel cost increases. In 2008, the electricity cost in Yakutat reached 44 cents/kW (27 cents/kWh is directly related to fuel cost, and the remaining 17 cents/kWh is related to other cost of the electrical generation system). While fuel prices have lowered in 2009, this adjustment is largely believed to be of a temporary nature and is attributed to the global recession, which reduced pressure on fuel prices globally. In the long term, fuel prices will continue to climb and apply increased economic pressure on this remote community.

Clearly, the value of electricity for heating is not the same as the value for electricity. In addition, diesel generation systems can yield additional benefits such as district heating. Based on a heating fuel cost of $4.7 per gallon, the equivalent electricity value is 18 cents/kWh. In terms of present break-even points, the first 0.8 MW of average electricity (7,000MWh/year) has a value of 44 cents/kWh, while the next 3.5MW (31,000 MWh/year) has a value of 18 cents/kWh. As mentioned earlier, the real value of electricity from wave power would be less then the equivalent from a diesel generation system. However, because of the added value of long-term price stability from renewable resources, the above cost levels are good indicators of the value of electricity in Yakutat at the given generation levels and suggest that wave energy could provide cost-competitive renewable energy to the city.

3. Technology - Aquamarine Power Oyster

The Aquamarine Power Oyster is a near shore wave energy conversion device that was selected as representative of the technology most suitable to the Yakutat application.

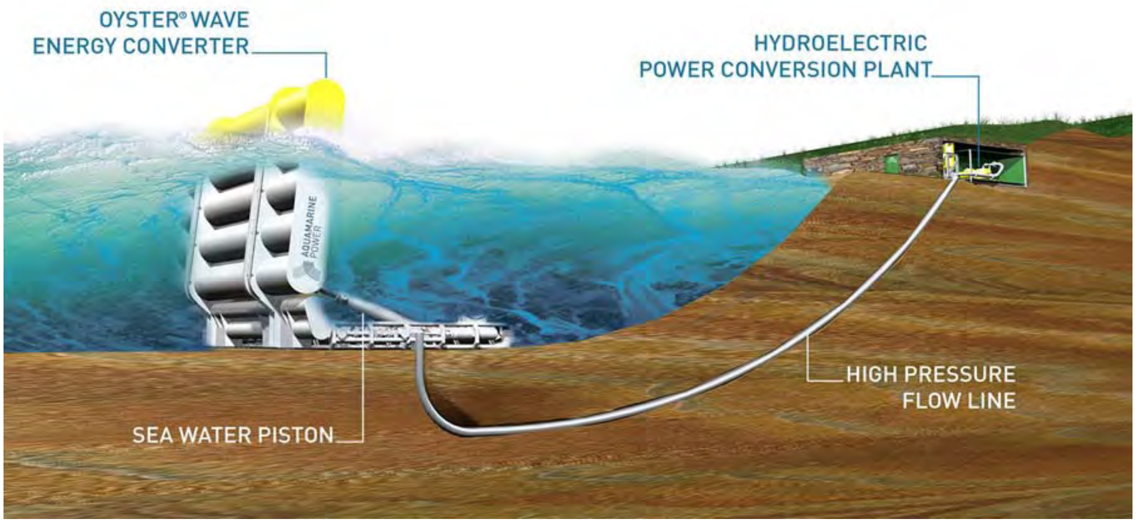


Figure 12 – Oyster 1 prototype illustration

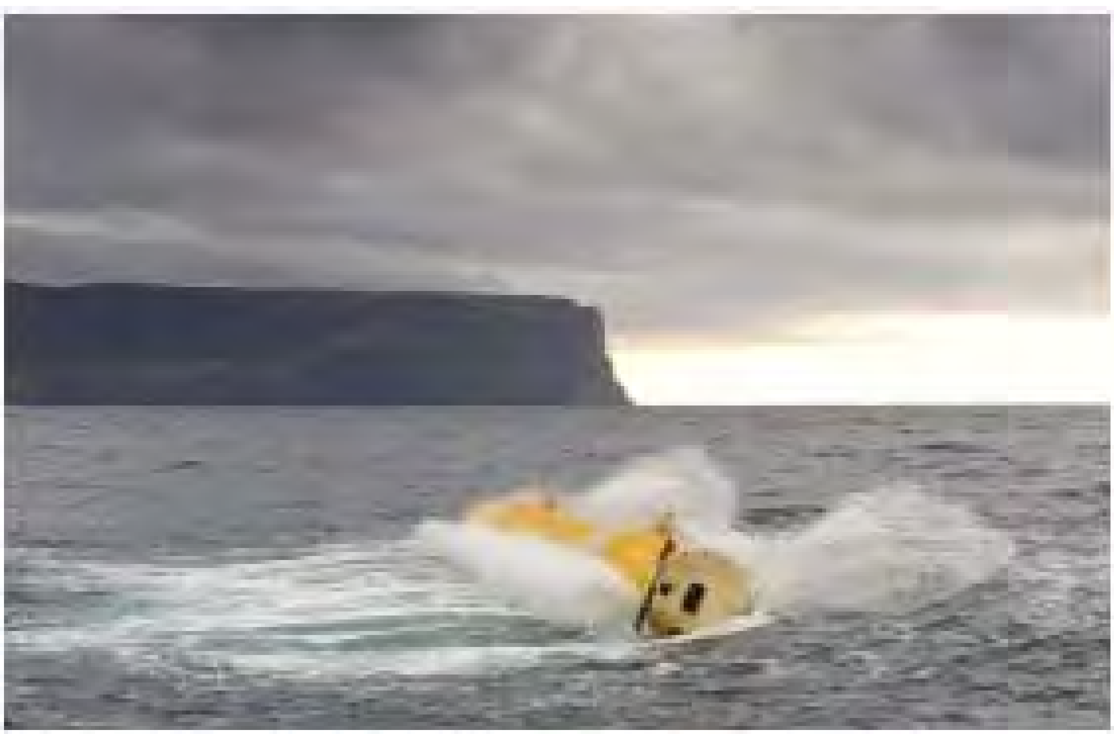


Figure 13 - Oyster Operating at EMEC in the Orkney islands, Scotland

Specifications (Oyster II commercial device)

Water Depth	12-16m typical, 10-20m possible
Flap Width	26m
Flap Depth	13m
Total Weight	about 450T, including foundations
Power Conversion	Water Hydraulics (closed loop)
Generator	3 phase Induction generator
Converter	step up transformer, to 11/33kV
Rated power output	about 700kW (depending on deployment site)
Anchor type	Site-specific, e.g. a novel tension anchor solution has been developed for hard rock substrates; other substrates such as deep sand will use conventional offshore foundation solutions such as suction cans.
Hydraulic fluid	Pressurized fresh water (closed loop system)

Company information

Company Name:	Aquamarine Power Limited
Website:	www.aquamarinepower.com

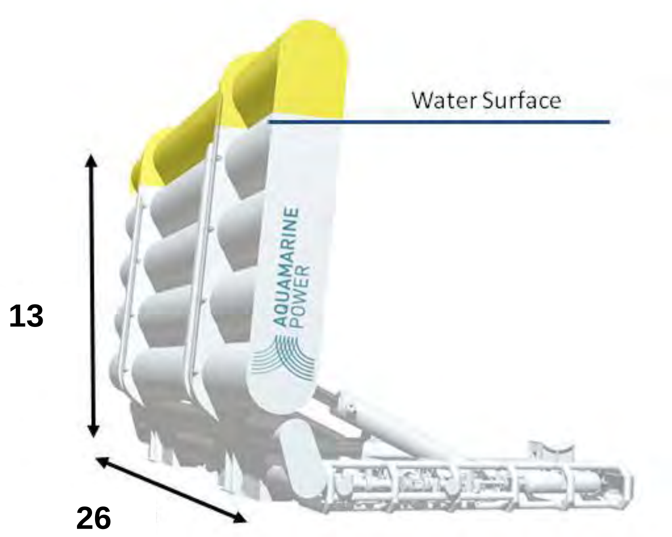


Figure 14 – Oyster II basic dimensions

3.1. Principle of Operation

The Oyster concept is a large buoyant oscillator that completely penetrates the water column from the water surface to the sea bed. It is a near shore device, typically deployed in 10 to 20 meter water depth, designed to capture the amplified surge forces found in these near shore waves. The surge component in the waves forces the bottom-hinged “flap” to oscillate, which in turn compresses and extends two hydraulic cylinders mounted between the flap and the sub-frame, pumping water at high pressure through a pipeline back to the beach.

Onshore is a modified hydro-electric plant consisting of a Pelton wheel turbine driving a variable speed electrical generator coupled to a flywheel. The Pelton turbine is an impulse turbine, commonly used in the hydropower industry. Impulse turbines are known to have high efficiencies at high pressure levels (typically >20 bars) and are considered proven technology. Power flow is regulated onshore using a combination of hydraulic accumulators, an adjustable spear valve, a flywheel in the mechanical power train and rectification and inversion of the electrical output. The low pressure return-water passes back to the device in a closed loop via a second pipeline. A key design philosophy is to keep the offshore components as few and as simple as possible. The Oyster device has no major electrical components or active control functions operating in the offshore environment.

3.2. Device Anchoring & Footprint

The Oyster wave power device differs from all other wave power devices in this project both because it is anchored directly to the sea floor and because it operates in relatively shallow water. An example array including device footprint size, pipeline layout and spacing between devices for a 5MW deployment is shown in Figure 15. An initial foundation concept has been developed for rocky substrates, using tension anchors to provide high friction between the device and the seabed. Other foundation solutions are under development for substrates, including deep sand and sand-over-rock.

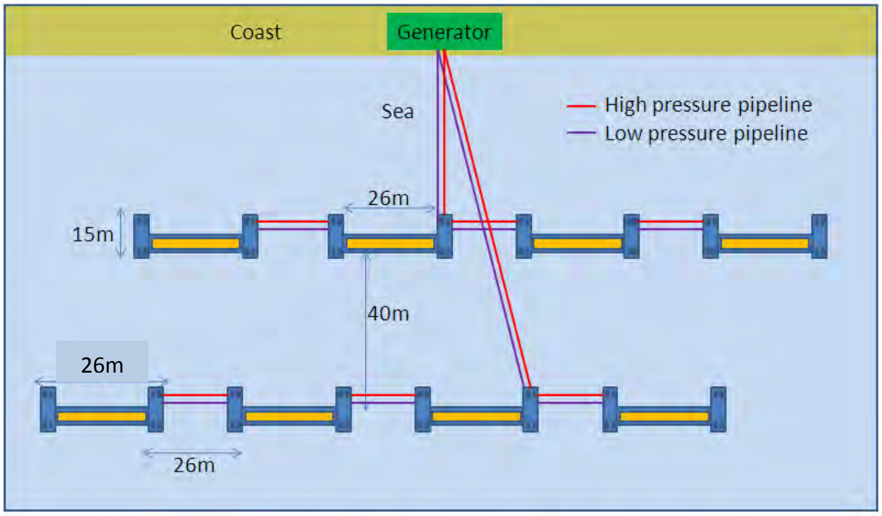


Figure 15 –Indicative device array and pipeline layout for a 5MW (peak) Oyster II farm

3.3. Operation & Maintenance

The offshore device units are designed with a minimal number of moving elements: two hinges, four non-return valves and an accumulator. Each moving part is designed for low-cost modular replacement using non-specialist marine vessels on a five-year preventative maintenance cycle. The fixed steel "flap" structure is designed for an operating lifetime of 20 years in high-energy sea environments, without replacement. This low level of complexity will likely result in extended periods of operation without the need for maintenance and/or repair. The Pelton wheel and turbine are located in a permanent onshore structure, and thus readily accessible on a 24/7 basis, in all weather conditions, for inspection and maintenance purposes.

3.4. Operating Procedures

The following operational activities and time frames are estimated for a deployment at three different scales. In absence of detailed design and engineering studies, the time frames and intervention intervals represent initial estimates and are to be used for illustrative purposes only. Time estimates refer to operational time within the general deployment area and includes mobilization time. Only offshore activities that are directly affecting the marine environment are outlined here to provide the reader with a better understanding of operational impacts on the environment.

The first set of operational activities are outlined for pre-construction activities that are used to support permitting, detailed design and subsequent construction activities at the site. Pre-installation activities will not differ significantly as a function of scale or technology choice.

Table 3 – Pre-installation resources and duration

Activity	Resources	Duration
Survey to map high-resolution bathymetry at deployment site and cable route	Survey vessel	< 1 week
Sub-bottom profiling to identify sedimentation layer thickness at deployment site	Survey vessel	< 1 week
Visual inspection of seabed in deployment area and along cable route. Soil Sampling where required.	Survey vessel ROV or diver	< 1 week
Wave Resource Characterization using ADCP or directional measurement buoy	Survey Vessel or RIB	1 year
Environmental baseline studies	Survey vessel Stand-alone instrumentation	1-2 years

The second set of activities represent project construction activities. These are activities that will have the most significant impacts over the project life and are compressed in a relatively short (one- to two-year) timeframe. While onshore construction and pipeline drilling works can take place during the winter months, offshore construction activities are dependent on weather windows at the site and would occur during times when there is a high likelihood of calm seas. Due to weather considerations, the offshore construction time period is likely constrained to the May through early September time period. It is likely that in reality the type of equipment mobilized would depend on project scale, since for larger projects, operational efficiencies become more important cost drivers in comparison to smaller projects, where mobilization cost tends to dominate. Addressing this equipment choice in detail is beyond the scope of this study.

Table 4 – Installation resources and duration

Activity	Resources	Duration	
		1-Unit	10-Units
Directional drilling to land high-pressure water pipeline to shore	Drill rig	< 2 months	< 2 months
Construction of onshore powerhouse	Standard excavation and construction equipment	< 3 months	< 3 months
Foundation Installation	2 Tugs, Barge, Supply boat	2 weeks (including weather downtime)	3 weeks
Connect High-pressure collector system	Supply boat & Diver	1 week (including weather risk)	2 weeks
Device Deployment and Commissioning	Barge, 2 Tugs, Supply boat	2 weeks (including weather downtime)	3 weeks

Operation and Maintenance activities can be divided into planned and unplanned activities. The majority of operational activities will occur during summer months, when relatively calm weather conditions allow these operations to be carried out safely. Some unplanned maintenance activities may need to be carried out during the winter season, as in the case of a failure that requires immediate attention.

Table 5 – Operational activity, resources and intervention frequency estimates

Activity	Resources	Frequency
Planned maintenance (offshore)	Standard mid-size boat	Every 5 years
Unplanned Maintenance (offshore)	Standard mid-size boat, diver	Every 4-5 years
Visual Inspection of underwater elements	Research Vessel, ROV	Every 2 years
Replacement/Refurbishment/Decommissioning of offshore Power Capture Unit and Foundation	Derrick Barge 2 Tugs Supply Boat	20 years

Decommissioning occurs at the end of the project life (typically 20 years). Decommissioning activities will probably be carried out over one to two summer seasons, depending on the project scale.

Table 6 – Decommissioning, resources and duration

Activity	Resources	1-Unit	10-Units
Recover Devices	Custom Vessel	1 week	2 weeks
Recover Device Foundation	2 x Tug Barge Supply Boat	1 week	2 weeks
Hydraulic Collector System Removal	2 x Tug Barge Supply Boat	1 week	2 weeks

4. Conceptual Design

Aquamarine Power's Oyster is a wave-actuated hydraulic pump that pumps fresh water to shore at a pressure level of about 120 bars, where it is converted into electricity using a conventional hydroelectric system and then returned to the Oyster in a closed loop. The major project elements include: (1) the Oyster WEC device, (2) a high-pressure supply sub sea pipeline and a low-pressure return sub sea pipeline, (3) an onshore turbine generator power station, and (4) a distribution line extension to connect the power station to the city electrical grid network. The proposed deployment location and related project elements are shown in the following figure.

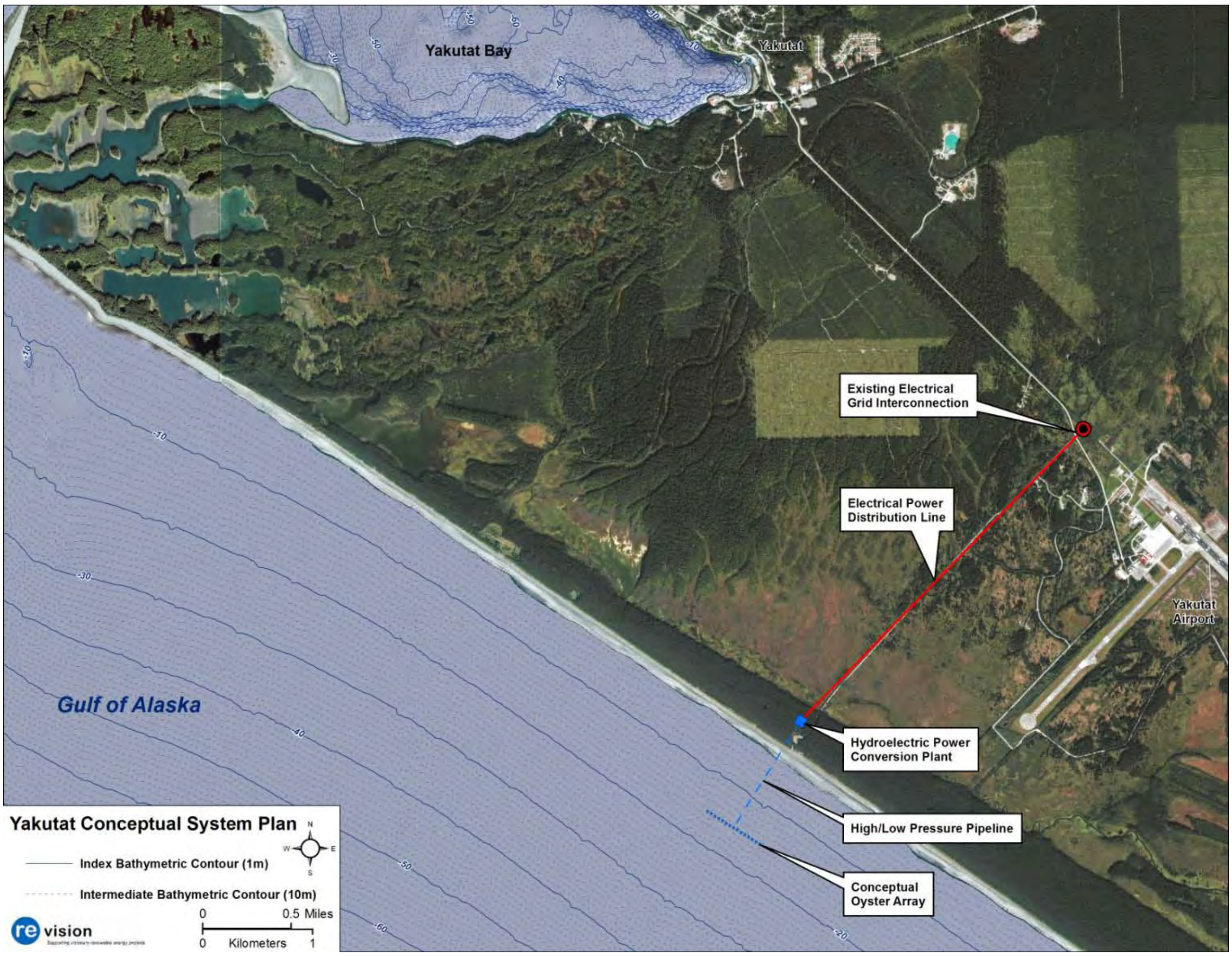


Figure 16 - Proposed Project Location and Design Elements. Thick contour lines in 10m increments.

A critical aspect of the plant design is the need to bring a set of pipelines from the deployment location back to the shore-based hydroelectric power plant. Such pipelines can be installed by directionally drilling from the shore to the site. A key cost reduction measure would entail only drilling for a portion of the distance and simply laying the pipeline onto the seabed for the remainder of the distance. The following illustration shows a cross-sectional profile of the anticipated pipeline path. The elevation profile extracted from a high-resolution GIS data set shows that about 1,150m of subsea pipeline would be needed to connect the offshore plant to the power station on-shore. However, it is likely that the near-shore bathymetry data is not accurate and further measurements should be carried out to properly characterize the bathymetry in the near-shore environment.

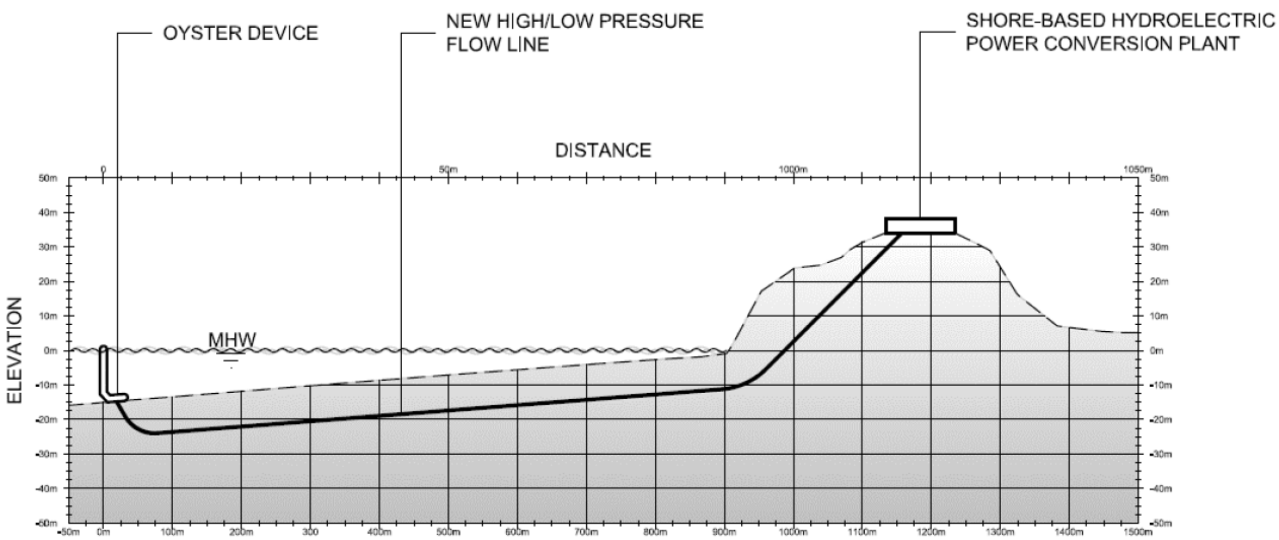


Figure 17 - Likely Pipeline Path at Deployment Site

A distribution line extension would need to be established to connect the powerhouse with the remainder of the electrical network. The planned upgrade of the powerhouse and related facilities would allow incorporating important changes to the electrical supply system in order to accommodate and integrate a wave power plant. Some of the key issues identified during the conceptual design phase that should be addressed during a detailed design study phase include:

Uncertainty in Bathymetry Accuracy – The bathymetry drives shallow water wave processes and therefore has a direct impact on the energy production from Oyster. It will also affect the placement location of the device, which has a key impact on the total cost of the system.

Directional Drilling Feasibility – A geotechnical assessment will be required to determine the feasibility of installing the subsea pipeline by means of directional drilling (or alternate method). Directional drilling cost is highly sensitive to the type of material that is being drilled through. Further, the cost in this conceptual feasibility study was calculated assuming that the pipeline would be placed by directional drilling for the whole distance of >1100m. Alternative placement methods for the outer subsea portion of the pipeline may result in significant cost savings.

Freezing Spray – Water spray will freeze if it comes in contact with protruding surfaces of the Oyster machine. Such ice build-up could add significant mass to the system and hence affect its tuning behavior. Attention should be paid during the detailed design phase to addressing this issue.

Foundation Design – The first Oyster was deployed on bedrock. An alternative foundation design will have to be used at this deployment site because the seabed at the deployment location likely consists of sand and mud.

Wave Resource Measurements – The presented performance estimates are based on modeling the wave energy resource. This introduces significant uncertainty into the process. Acoustic Doppler Current Profiler (ADCP) wave measurement device should be deployed at the likely deployment location for at least one year. This will allow for model calibration and an accurate assessment of the resource at the deployment site.

5. Cost Estimate

For emerging renewable energy technologies such as wave energy, the only method of estimating project costs (and underlying economics) is modeling technology-related parameters and estimating costs based on historical quotes and projects in related technology fields and projects. This approach introduces a significant amount of uncertainties, especially with technologies that have not yet been tested at full scale. Experience gained by EPRI and others in this field show that manufacturers typically underestimate cost in the early stages of development, and as the technologies progress towards commercial maturity, such cost-projections increase. The actual build and operational cost of a pilot device or a pilot tidal-farm, then, will reveal a complete cost picture and provide a solid starting point for further cost-studies.

Once a technology reaches commercial maturity, volume production will begin driving down cost. Figure 18 shows the typical cost projection as a function of design maturity.

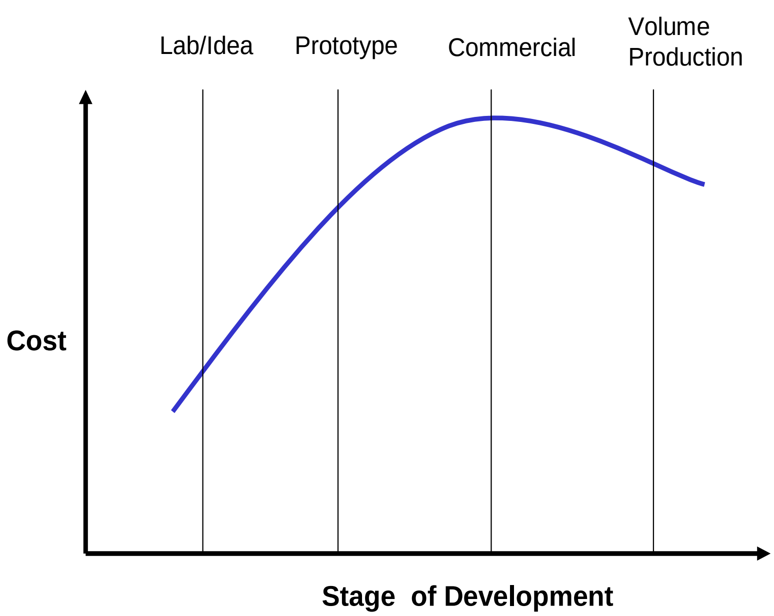


Figure 18 - Cost projection as a function of Development Status

Based on experience of estimating energy project cost, EPRI has developed a cost estimate rating table which assesses the likely range of uncertainty based on the technology's design maturity and the amount of detail going into the cost estimate. The cost estimate for a Yakutat wave power plant is placed in the simplified-preliminary level of detail and technology's stage of maturity at the pilot level, thereby yielding a likely cost uncertainty of – 30 to +30%.

Table 7 - EPRI cost estimate rating table

Cost Estimate Rating	A Mature	B Commercial	C Demonstration	D Pilot	E Conceptual (Idea or Lab)
A. Actual	0	-	-	-	-
B. Detailed	-5 to +5	-10 to +10	-15 to +20	-	-
C. Preliminary	-10 to +10	-15 to +15	-20 to +20	-25 to +30	-30 to +50
D. Simplified	-15 to +15	-20 to _20	-25 to +30	-30 to +30	-30 to +80
E. Goal	-	-30 to +70	-30 to +80	-30 to +100	-30 to +200

Likely Cost Uncertainty

In addition to technology-related cost uncertainties, the cost for raw materials such as steel and copper has increased significantly, and many relevant industries such as subsea cable manufacturers have limited additional capacity to meet global infrastructure expansions. As a direct result, end product costs are artificially inflated. A comparison of manufacturer quotes for subsea cables between 2004 and 2007 revealed a cost increase of over 200% for a similar cable. Other industries are affected by this trend as well. Wind energy reached an all-time low in the year 2000 when the cost of wind energy reached an all-time low of about $1100 per installed kW. Since then, cost has steadily increased and is now (2008) pushing $2000 per kW.

Many of these technologies were developed overseas in Europe (mainly the UK). Historical exchange rates make a direct correlation between building cost in the US and Europe difficult and requires independent cost-buildups for most projects. As a result of the above factors, significant uncertainties in the prediction of cost remain, and any cost and/or economic projections of these emerging technologies should be viewed with these factors in mind. The only way to reduce these uncertainties to an absolute minimum is to base cost projections on technology that is as mature as possible and use a consistent methodology to assess the technologies themselves.

Costs were estimated based on device data supplied by Aquamarine Power under non-disclosure agreement. An independent cost build-up was generated to independently evaluate the individual cost elements. Because most of this data is commercially sensitive, only high-level results are presented here.

Table 8 - Cost, Performance and Economic Summary ($2009)

		1 Unit		2 Units		4 Units		8 Units	
Capital Cost		USD	$/kW	USD	$/kW	USD	$/kW	USD	$/kW
	Device Structure	$3,840,000	$4,923	$6,912,000	$4,431	$12,441,600	$3,988	$22,394,880	$3,589
	Water Pipeline	$1,344,000	$1,723	$2,419,200	$1,551	$4,354,560	$1,396	$7,838,208	$1,256
	Power House	$1,359,000	$1,742	$2,478,000	$1,588	$4,716,000	$1,512	$9,192,000	$1,473
	Installation Cost	$2,347,200	$3,009	$3,288,000	$2,108	$4,724,400	$1,514	$6,945,000	$1,113
	Total Cost	$8,890,200	$13,677	$15,097,200	$11,613	$26,236,560	$10,091	$46,370,088	$8,917
Annualized OPEX		$330,000	$508	$510,000	$392	$810,000	$312	$1,400,000	$269
Performance									
	Rated Power	650	kW	1300	kW	2600	kW	5200	kW
	Capacity Factor	48.00%		48.00%		48.00%		48.00%	
	Availability	95%		95%		95%		95%	
	Annual Energy Output	2596	MWh	5193	MWh	10386	MWh	20772	MWh
Cost of electricity (constant $)		45.1	cents/kWh	38.0	cents/kWh	32.3	cents/kWh	28.4	cents/kWh

The above cost breakdown demonstrates that the device itself accounts for only about 1/3rd of the total project cost. At smaller scale, costs are clearly dominated by installation and pipeline cost. These cost items are highly dependent on the results of a detailed reconnaissance study, which will inform the detailed design of the system at deployment site of interest. Further, detailed resource assessments have proven to be of critical importance when evaluating the wave energy climate in the near-shore environment. As such, these detailed studies are critical to further the understanding of the real cost of the overall system.

Some of the main assumptions for this cost-estimate were:

Device Reliability and O&M procedures: The device component reliability directly impacts the operation and maintenance cost of a device. It is important to understand that it is not only the component that needs to be replaced; the actual operation required to recover the component can dominate the cost. Additional cost of the failure is incurred by the downtime of the device and its inability to generate revenues by producing electricity. In order to determine these operational costs, the failure rate on a per component basis was estimated. Operational procedures were then outlined to replace these components and carry out routine maintenance. The access arrangement has a critical influence in determining what kind of maintenance strategy is pursued and on the resulting total operation cost.

Insurance cost: The insurance cost can vary greatly depending on what the project risks are. While this is an area of uncertainty, especially considering the novelty of the technologies used and the likely lack of specific standards, it was assumed that a commercial farm will incur insurance costs similar to the costs of maturing an offshore oil and gas project, which is typically at about 1.5% of installed cost.

Device Cost: Device Cost was estimated by using a weight breakdown structure supplied by Aquamarine Power and using appropriate $/ton of manufactured steel figures.

Power Conversion System: The cost of the hydroelectric power plant on shore was estimated using cost data from hydroelectric power equipment.

Installation and Operation Cost: These costs are dominated by mobilization. Seattle is roughly 1000 miles and Anchorage 600 miles by boat. These costs could be significantly reduced if a vessel of opportunity could be used to install and recover the device (i.e. a tug delivering fuel to the village).

Pre-construction cost: Cost for permitting, detailed design and technical studies needed before construction are not included in the capital cost presented in Table 1, but are estimated at between $1.5M and $2M.

6. Economic Assessment

The cost of electricity (COE) was calculated for Yakutat Power, an Alaskan State Municipal Generator (MG). EPRI strongly recommends that Yakutat Power develop its own in-house economics capability. The potential large investment that Yakutat Power is considering making in wave power is a strong reason for developing an internal capability to estimate project economics.

Non-taxable municipal utilities set electricity rates that cover all operating costs. Generation projects are financed by issuing tax-exempt bonds, enabling municipal utility generators to access some of the lowest interest rates available

The EPRI-regulated MG methodology is based on a levelized cost approach using constant dollars (Jan 1, 2010 dollars) with plant start-up in January 2013 and a 20-year book life. The purpose of this methodology is to provide a consistent, verifiable and replicable basis for computing the LCOE of a wave power generation project (i.e., a project to procure, construct, operate and maintain a wave energy power plant – note that the cost to engineer the final design and permit the plant is NOT included).

The results of this economic evaluation are intended to help utility managers to determine the degree of financial incentives required to satisfy a business case. It will also help government policy makers to determine the public benefit of investing public funds into building the experience base of tidal energy, to transform the market to the point where private investment will take over and sustain it. Such technology support is typically done through funding R&D and through incentives for the deployment of targeted renewable technologies.

For this Yakutat wave energy study project, key project and financial assumptions are as follows:

- Total plant costs expressed in beginning of 2010 (Jan 1, 2010)
- All costs in current January 1, 2010 dollars
- Pre construction studies start date = January 1, 2011
- Construction begins Jan 1, 2012
- Construction period is 1 year
- Plant start up is Jan 1, 2013
- 20-year plant life

- Inflation rate of 3.0%, based on the U.S. Producer Price Index for 2003 [1]
- Projects 100% financed by the Bond Market
- Cost of capital = 4.75% nominal
- Not taxable
- No financial incentives

The yearly electrical energy produced and delivered to bus bar by the –single Oyster unit, 650 kW device with a 48% capacity plant described in this report is estimated to be 2,596 MWh/year The elements of cost and economics (again, in Jan 1 2019 constant $) are:

- Total Plant Cost = $8,890,200
- Annual O&M Cost = $330,000 (which includes the annualized cost of a 5-yearly reventive maintance cycle)
- Municipal Generator (MG) Levelized Cost of Electricity = 45.1 cents/kWh with no financial incentives

As the scale of the plant is increased from 1 to 2, 4 and 8 oyster units, the COE is lessened to 28.4 cents/kWhr at the 8 oyster unit size.

The detailed worksheets, including financial assumptions used to calculate these COE, are contained in Appendix A.

[1] Source: U.S. Bureau of Labor Statistics, 2004

7. Conclusions

This study presents the results of a conceptual system definition and feasibility study for a small wave power plant deployed in Yakutat, Alaska. An initial high-level scoping study showed that given the small generation capacity needed, it is unlikely that a deep-water wave power conversion plant would make economic sense. The cost drivers at the small scale proposed are the subsea cable cost and installation and operation cost, which are dominated by offshore operational considerations. It was therefore decided to focus on near-shore wave energy conversion technology.

The study scope included: (1) a shallow water wave energy resource assessment, (2) a conceptual design based on the Aquamarine Power Oyster shallow water wave energy conversion technology, (3) a cost assessment (capital and O&M), and (4) an economic analysis. Aquamarine Power's shallow water wave energy conversion technology Oyster is representative of the wave energy technology best suited for the deployment site. Oyster is a wave-actuated hydraulic pump that pumps fresh water to shore at a pressure level of about 120 bars, where it is converted into electricity using a conventional hydroelectric system and then returned to the Oyster in a closed loop. The major project elements include: (1) the Oyster WEC device, (2) a high pressure (120) bar pressure supply sub sea pipeline and a low pressure (3 bar) return sub sea pipeline, (4) an onshore turbine generator power station, and (5) a distribution line extension to connect the power station to the city electrical grid network. The proposed deployment location and related project elements are shown in the following figure.

The EPRI study showed that Yakutat has an excellent wave climate for wave energy conversion. A shallow water wave transformation model (SWAN) was used to propagate a full year of wave data to the deployment location at 13m water depth. Shallow water power densities at the deployment site of interest were assessed at between 19kW/m and 22kW/m. Based on this wave energy resource data, the resulting capacity factor of the 650 kW rated Oyster machine was assessed at 48%. Cost elements, including (1) device, (2) sub sea pipeline, (3) on-shore power station, (4) overland distribution line extension, (5) installation, and (6) operation and maintenance were assessed for the plant at four different sizes (1, 2, 4 and 8 units at 650 kW per unit), as summarized in Table 1 below. Cost of electricity was then computed using a Municipal Utility Ownership economic model. Cost of electricity is estimated to be about 45 cents/kWh (in constant Jan 1, 2010 dollars) for a 20-year plant-life. Cost and economic uncertainties at this early stage of project development are still quite substantial; based on EPRI's experience with similar projects at a conceptual stage of development, cost is estimated on the order of +/- 30%.

Table 9 - Cost, Performance and Economic Summary

	1 Unit		2 Units		4 Units		8 Units	
Capital Cost	USD	$/kW	USD	$/kW	USD	$/kW	USD	$/kW
Device Structure	$3,840,000	$4,923	$6,912,000	$4,431	$12,441,600	$3,988	$22,394,880	$3,589
Water Pipeline	$1,344,000	$1,723	$2,419,200	$1,551	$4,354,560	$1,396	$7,838,208	$1,256
Power House	$1,359,000	$1,742	$2,478,000	$1,588	$4,716,000	$1,512	$9,192,000	$1,473
Installation Cost	$2,347,200	$3,009	$3,288,000	$2,108	$4,724,400	$1,514	$6,945,000	$1,113
Total Cost	$8,890,200	$13,677	$15,097,200	$11,613	$26,236,560	$10,091	$46,370,088	$8,917
Annualized OPEX	$330,000	$508	$510,000	$392	$810,000	$312	$1,400,000	$269
Performance								
Rated Power	650	kW	1300	kW	2600	kW	5200	kW
Capacity Factor	48.00%		48.00%		48.00%		48.00%	
Availability	95%		95%		95%		95%	
Annual Energy Output	2596	MWh	5193	MWh	10386	MWh	20772	MWh
Cost of electricity (constant $)	45.1	cents/kWh	38.0	cents/kWh	32.3	cents/kWh	28.4	cents/kWh

The cost at this relatively small scale (in terms of sizes of utility power plants in the lower 48) is clearly dominated by infrastructure and operational considerations related to the installation of the device in this somewhat remote location. However, present bus bar cost of electricity from the existing diesel-based generation facility comes in at about 27 cents/kWh and will only increase in the future. It may be important to note that in 2008, cost of electricity was at over 40 cents/kWh. Diesel fuel cost has dramatically increased since the year 2000 and is only temporarily lower at present because the global recession has reduced the demand on fossil fuels, creating a more attractive yet transitory pricing structure. In the long-term, energy costs are expected to increase, which creates an additional economic burden to small communities like Yakutat that are heavily reliant on diesel fuel.

A key result of the EPRI feasibility study is that the level of cost-reduction potential that could come from optimization is substantial. These cost reductions can only be quantified through detailed design and engineering analysis because most cost elements are driven by site-specific considerations. A key part of the proposed next phase is to investigate some of the identified alternate design options and detail the “optimal” solution for the site of interest. Many cost reductions could come from improved installation and operational procedures, economies of scale and the potential to locate the plant closer to shore.

EPRI recommends that this project move forward with final design and permitting activities to further reduce uncertainties and perform techno-economic optimization.

Appendix A – COE Worksheets of Single Unit Oyster Case

EPRI Ocean Energy Utility Generator Cost of Electricity Calculator

Developed for: Yakutat Power

Although EPRI is proposing to use the economics assessment methodology report previously sent to Yakutat Power and this Excel worksheet, we strongly recommend that Yakutat Power develop its own in-house economics capability or hire an independent 3rd party economist consultant. The potential large investment that Yakutat Power is considering making in wave power is a strong reason for having an internal capability to estimate project economics. This is research-grade software and EPRI can provide no guarantee that it is bug-free nor can warranty this software

Developed By: Roger Bedard
EPRI
3420 Hillview Ave.
Palo Alto, CA 94304

INSTRUCTIONS

Indicates Input Cell (either input or use default values)

Indicates a Calculated Cell (do not input any values)

Strike outs indicate difference from Investor Owned Utility worksheet

Sheet 1. **TPC/TPI (Total Plant Cost/Total Plant Investment)**

a) Enter Component Unit Cost and No. of Units per System
b) Worksheet sums component costs to get TPC
c) Adds the value of the construction loan payments to get TPI
a) Enter Labor Hrs and and Parts Cost by O&M inc overhaul and refit
c) Worksheet Calculates Insurance and Total Annual O&M Cost

Sheet 3. **O&R (Overhaul and Replacement Cost)**

a) Enter Year of Cost and O&R Cost per Item
b) Worksheets calculates the present value of the O&R costs

Sheet 4. **Assumptions (Financial)**

a) Enter project and financial assumptions or leave default values

Sheet 5. **NPV (Net Present Value)**

A Gross Book Value = TPI
B Annual Book Depreciation = Gross Book Value/Book Life
C Cumulative Depreciation
F Net Book Value = Previous Year Net Book Value - Annual Book Depreciation - Deferred Tax for that Year

Sheet 6. **CRR (Capital Revenue Requirements)**

A Net Book Value for Column F of NPV Worksheet
B Common Equity = Net Book X Common Equity Financing Share X Common Equity Financing Rate
C Preferred Equity = Net Book X Preferred Equity Financing Share X Preferred Equity Financing Rate
D Debt = Net Book X Debt Financing Share X Debt Financing Rate
E Annual Book Depreciation = Gross Book Value/Book Life
G Property Taxes and Insurance Expense =
H Calculates Investment and ~~Production Tax Credit Revenues~~
I Capital Revenue Req'ts = Sum of Columns B through G

Sheet 7. **FCR (Fixed Charge Rate)**

A Nominal Rates Capital Revenue Req'ts from Columnn H of Previous Worksheet
B Nominal Rate Present Worth Factor = 1 / (1 + After Tax Discount Rate)
C Nominal Rate Product of Columns A and B = A * B
D Real Rates Capital Revenue Req'ts from Columnn H of Previous Worksheet
E Real Rates Present Worth Factor = 1 / (1 + After Tax Discount Rate - Inflation Rate)
F Real Rates Product of Columns A and B = A * B

Sheet 8. **Calculates COE (Cost of Electricity)**

COE = ((TPI * FCR) + AO&M + LO&R) / AEP

In other words…The Cost of Electricity =

The Sum of the Levelized Plant Investment + Annual O&M Cost including Levelized Overhaul and Replacement Cost Divided by the Annual Electric Energy Consumption

TOTAL PLANT COST (TPC) - Jan 1, 2010$

TPC Component	Unit	Unit Cost	Total Cost (Jan 1, 2010$)	
Device Structure	1	$3,840,000	$3,840,000	
Water Pipeline	1	$1,344,000	$1,344,000	
Powerhouse	1	$1,359,000	$1,359,000	
Installation	1	$2,347,200	$2,347,200	
			$0	
			$0	
TOTAL			$8,890,200	

TOTAL PLANT INVESTMENT (TPI) -Jan 1, 2010$

End of Year	Total Cash Expended TPC (Jan 1, 2010$)	Before Tax Construction Loan Cost at Debt Financing Rate	Jan 1, 2010 $ Value of Construction Loan Payments	TOTAL PLANT INVESTMENT - Jan 1, 2010
2010 -2011		$0	$0	$0
2012	$8,890,200	$955,697	$779,171	$9,669,371
Total	$8,890,200	$955,697	$779,171	$9,669,371

ANNUAL OPERATING AND MAINTENANCE COST (AO&M) - Jan 1, 2010$

Costs	Yrly Cost	Amount	
Labor and Parts	$88,000	$88,000	
Annualize cost 5 yearly overhaul	$107,430	$107,430	
Insurance (1.5% of TPC)	$133,353	$133,353	
Total		$328,783	

FINANCIAL ASSUMPTIONS

(default assumptions in pink background - without line numbers are calculated values)

1	Rated Plant Capacity ©	0.65	MW
2	Annual Electric Energy Production (AEP)	2,596	MWeh/yr
	Therefore, Capacity Factor	45.6	%
3	Year Constant Dollars	2010	Year
4	Federal Tax Rate	35	%
5	State	Alaska	
6	State Tax Rate	0	%
	Composite Tax Rate (t)	0.35	
	t/(1-t)	0.5385	
7	Book Life	20	Years
8	Construction Financing Rate	6.09	
9	Common Equity Financing Share	0	%
10	Preferred Equity Financing Share	0	%
11	Debt Financing Share	100	%
12	Common Equity Financing Rate	0	%
13	Preferred Equity Financing Rate	0	%
14	Debt Financing Rate	6.09	%
	Nominal Discount Rate Before-Tax	6.09	%
	Nominal Discount Rate After-Tax	3.96	%
15	Inflation Rate = 3%	3	%
	Real Discount Rate Before-Tax	3.00	%
	Real Discount Rate After-Tax	0.93	%
16	Federal Investment Tax Credit	0	
17	Federal REPI (1)		$/kWh
18	State Investment Tax Credit	0	% of TPI
19	State Investment Production Tax Credit	$0	Credit - 1st year only for ≥ $10M plant
20	Renewable Energy Certificate (2)	0	$/kWh
21	State Tax Depreciation	0	Installation Cost

Notes

1 $/kWh for 1st 10 years with escalation (assumed 3% per yr)

2 $/kWh for entire plant life with escalation (assumed 3% per yr)

NET PRESENT VALUE (NPV) - 2009 $

TPC $8,890,200

Year End	Gross Book Value	Book Depreciation Annual	Book Depreciation Accumulated	Renewable Resource MACRS Tax Depreciation Schedule	Deferred Taxes	Net Book Value
	A	B	C	D	E	F
2012	**8,890,200**					**8,890,200**
2013	8,890,200	444,510	444,510	0	0	8,445,690
2014	8,890,200	444,510	889,020	0	0	8,001,180
2015	8,890,200	444,510	1,333,530	0	0	7,556,670
2016	8,890,200	444,510	1,778,040	0	0	7,112,160
2017	8,890,200	444,510	2,222,550	0	0	6,667,650
2018	8,890,200	444,510	2,667,060	0	0	6,223,140
2019	8,890,200	444,510	3,111,570	0	0	5,778,630
2020	8,890,200	444,510	3,556,080	0	0	5,334,120
2021	8,890,200	444,510	4,000,590	0	0	4,889,610
2022	8,890,200	444,510	4,445,100	0	0	4,445,100
2023	8,890,200	444,510	4,889,610	0	0	4,000,590
2024	8,890,200	444,510	5,334,120	0	0	3,556,080
2025	8,890,200	444,510	5,778,630	0	0	3,111,570
2026	8,890,200	444,510	6,223,140	0	0	2,667,060
2027	8,890,200	444,510	6,667,650	0	0	2,222,550
2028	8,890,200	444,510	7,112,160	0	0	1,778,040
2029	8,890,200	444,510	7,556,670	0	0	1,333,530
2030	8,890,200	444,510	8,001,180	0	0	889,020
2031	8,890,200	444,510	8,445,690	0	0	444,510
2032	8,890,200	444,510	8,890,200	0	0	0

CAPITAL REVENUE REQUIREMENTS - 2009$

TPI = $9,669,371

End of Year	Net Book	Returns to Equity Common	Returns to Equity Pref	Interest on Debt	Book Dep	Income Tax on Equity Return	REPI	Capital Revenue Req'ts
	A	B	C	D	E	F	H	I
2012	**8,890,200**							
2013	8,445,690	0	0	541,413	444,510	0	0	985,923
2014	8,001,180	0	0	514,343	444,510	0	0	958,853
2015	7,556,670	0	0	487,272	444,510	0	0	931,782
2016	7,112,160	0	0	460,201	444,510	0	0	904,711
2017	6,667,650	0	0	433,131	444,510	0	0	877,641
2018	6,223,140	0	0	406,060	444,510	0	0	850,570
2019	5,778,630	0	0	378,989	444,510	0	0	823,499
2020	5,334,120	0	0	351,919	444,510	0	0	796,429
2021	4,889,610	0	0	324,848	444,510	0	0	769,358
2022	4,445,100	0	0	297,777	444,510	0	0	742,287
2023	4,000,590	0	0	270,707	444,510	0	0	715,217
2024	3,556,080	0	0	243,636	444,510	0	0	688,146
2025	3,111,570	0	0	216,565	444,510	0	0	661,075
2026	2,667,060	0	0	189,495	444,510	0	0	634,005
2027	2,222,550	0	0	162,424	444,510	0	0	606,934
2028	1,778,040	0	0	135,353	444,510	0	0	579,863
2029	1,333,530	0	0	108,283	444,510	0	0	552,793
2030	889,020	0	0	81,212	444,510	0	0	525,722
2031	444,510	0	0	54,141	444,510	0	0	498,651
2032	0	0	0	27,071	444,510	0	0	471,581
Sum of Annual Capital Revenue Requirements								14,575,038

FIXED CHARGE RATE (FCR) - NOMINAL AND REAL LEVELIZED - 2009$

TPI = $9,669,371

End of Year	Capital Revenue Req'ts Nominal A	Capital Revenue Req'ts Nominal A	Capital Revenue Req'ts Real D	Capital Revenue Req'ts Real D
2012				
2013	985,923	985,923	778,297	850,466
2014	958,853	958,853	734,881	803,024
2015	931,782	931,782	693,333	757,624
2016	904,711	904,711	653,583	714,187
2017	877,641	877,641	615,559	672,638
2018	850,570	850,570	579,197	632,904
2019	823,499	823,499	544,430	594,913
2020	796,429	796,429	511,197	558,599
2021	769,358	769,358	479,438	523,895
2022	742,287	742,287	449,096	490,739
2023	715,217	715,217	420,114	459,070
2024	688,146	688,146	392,440	428,830
2025	661,075	661,075	366,021	399,961
2026	634,005	634,005	340,809	372,411
2027	606,934	606,934	316,754	346,126
2028	579,863	579,863	293,812	321,056
2029	552,793	552,793	271,937	297,153
2030	525,722	525,722	251,088	274,370
2031	498,651	498,651	231,222	252,663
2032	471,581	471,581	212,300	231,986
2033	14,575,038	14,575,038	9,135,509	6,961,120

	Nominal $	**Real $**
1. The present value is at the beginning of 2009 and results from the sum of the products of the annual present value factors times the annual requirements	10,412,379	9,251,264
2. Escalation Rate	3%	3%
3. Discount Rate = i	6.09%	3.00%
4. Capital recovery factor value = $i(1+i)^n/(1+i)^n-1$ where book life = n and discount rate = i	0.08782263	0.067215708
5. The levelized annual charges (end of year) = Present Value (Item 1) * Capital Recovery Factor (Item 4)	914,442	621,830
6. Booked Cost	9,669,371	9,669,371
7. The levelized annual fixed charge rate (levelized annual charges divided by the booked cost)	**0.0946**	**0.0643**

LEVELIZED COST OF ELECTRICITY CALCULATION - MUNICIPAL GENERATOR – 2010$

COE = ((TPI * FCR) / AEP + (NPV (of O&M costs) * CRF) / AEP

In other words…

The Cost of Electricity =

The Sum of the Levelized Plant Investment + Annual O&M Cost + Levelized Overhaul and Replace
Cost

Divided by the Annual Electric Energy Consumption

CONSTANT DOLLARS

COE - Capital Cost	33.26
COE - O&M	11.88
COE TOTAL (cents/kWh)	45.1445