VANPORT STERILIZERS INC.

31 January 2007

ATTN. Dwayne Kalynchuk
General Manager, Environmental Services
Capital Regional District
PO Box 1000, 625 Fisgard Street
Victoria, B.C. V8W 2S6

Dear Sir,

Re; Letter Proposal in Response to Request for Expressions of Interest to Treat Victoria's Sewage

Vanport Sterilizers builds industrial sterilization plants that meet federal agriculture quarantine control standards for sterilizing infectious international garbage and soils. With this proposal, we propose to develop a sterilizing filter for municipal sewage based on the use of dry pulverized coal (DPC). The sterilized effluent that exits the DPC filter would then be recycled to fuel a pumped storage hydro plant (PSH) upgrade of the nearby Jordan River Hydroelectric Project.

Spent DPC filter would be converted into a coal-water-slurry (CWS). The CWS would then be burned to generate power in a cogen plant that is also equipped for carbon capture and storage. The CWS could also be bio-gasified to improve the efficiency of the CWS burn or, it could be employed as an ideal starter media for the production of syngas that could compete with natural gas and/or could be mixed with natural gas and hydrogen (hythane).

The combined CWS - PSH power plant is being considered by Vanport for inclusion in an upcoming BC Hydro Call for Power. The CWS plant would provide the baseload power needed to run the pumps. A PSH upgrade at Jordan River would also include both conventional recycle and hybrid ocean PSH plant designs. CWS-fueled power plants are a proven, ultra-low-Nox power generation technology.

The effectiveness of DPC as a sterilizing coal filter can be easily verified in a simple pilot plant. A full scale operational scenario could evolve whereby raw sewage would first be pumped to E. Sooke and up to an elevation necessary for achieving high speed descent and swirl to concentrate solids for removal by gravity in a large glory hole or spiral tunnel. The swirl concentrator could be built either atop or, inside, mountains alongside the pipeline in an area extending from behind Mt. Matheson to Mt. Macquire and Broom Hill and up to the upper watershed of the Jordan River. The geology of the E. Sooke area is sedimentary and would permit the rapid construction of tunnels (see attached route profile, CRD Eng. file # L-55-3).

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Concentrated solids and sludge would be discharged directly onto a bed of DPC that is contained in mechanized coal slot storage devices built into the mountains (see attached brochure). As the DPC/sludge mix is discharged from the bottom of the device, a supply of fresh coal is added at the top. The discharge is then conveyed to a CWS fuel manufacture scheme that employs enclosed ball mills and tanks equipped with slurry pumps that pipe it for injection into the power boiler.

Semi-clarified wastewater that exits the concentrator and the first filter would be distributed into a series of progressively-larger coal filters that are sized with sufficient capacity to ensure that effluent exiting the final filter is free of bacterial and viral pathogens (note; the primary goal is to employ the filter to absorb pathogens and hydrocarbons, it is not to employ coal as an ion exchange media to treat contaminants by adsorbtion (see attached Rand Corp coal filter design).

The logistics of importing dry coal and exporting the spent coal to/from the filters are dependent upon a final determination of the size of the power plant (e.g. 50 Mw – 500 Mw). It is recognized that it would not be desirable to rebuild the old CNR railway between Sooke and Leechtown. Alternatively, this section could accomodate a pneumatic freight capsule pipeline that could extend through to Crofton, and, the Jordan River watershed can also be accessed by proceeding west from Leechtown.

Coal could also be barged directly to Jordan River with the construction of a new breakwater harbour and barge port. Spent coal discharged from the filters could then be exported to the power plant by a small diameter CWS pipeline or, by a new railway built alongside the highway to Jordan River. This route could also include a pneumatic freight capsule pipeline or, a sealed pipe conveyor built into the existing hydroelectric transmission line corridor from Jordan River.

A thermal power plant at Jordan River could also employ recycled wastewater for plant cooling, as well as for capture of stack pollutants and greenhouse gases, with GHG/CO2 then piped or barged for storage/sequestering either in the bottom depths of Saanich Inlet or, in sealed mine tunnels at the abandoned Britannia Mine near Squamish. This GHG control technology could also be applied to the operation of a new cement plant at Bamberton that would source high quality limestone from deposits near Leechtown or Lake Cowichan in order to also provide carbon-neutral cement for the planned construction of a new water pipeline for the CRD, etc.

The upper watershed of the Jordan River is also rich in mineral resources, including sand and gravel, garnet and talc (recycled wastewater could be employed to wash gravel, export limestone slurry to Bamberton, etc.). Further, the upland topography of the watershed provides numerous opportunities for installing advanced-design phytoremediation and artificial wetland treatment processes for passive attentuation and treatment of pollutants.

PSH upgrades at Jordan River could also be supported by offshore wave and wind turbine generator plants that would be employed to trickle-charge' a series of super-conducting batteries that would then be discharged to run the pumps. Ultimately, given the availability of sufficient storage, it may also prove profitable to import wastewater collected from other municipalities and pulp mills, via pipelines connecting from Port Alberni and along the Nitanat to Lake Cowichan and down to Crofton, across to Salt Spring Island via Sansum Narrows (cable-stayed pipe bridge) where it would pick up a pipeline that would island-hop from Harmac and down Thetis Island to Saltspring, and then across to Sidney and up the Saanich Pennisula to connect with the pipeline from Victoria in Langford. An alternate route would be to cross at the head of Saanich Inlet, possibly in combination with a new swing railway bridge across the inlet to connect with the airport that could also result in the installation of tidal power plants in the structure.

In summary, it has long been established that the cost of installing a 37 mi. long pressure sewer pipeline to Jordan River is very competitive with the cost of building a conventional treatment plant. It should also be recognized that a PSH plant will generally achieve a very high return-on-investment because it produces firm energy that has a premium value on the open electricity market and, if the infrastructure is financed either in whole or in part by wastewater disposal fees, then the cost-effectiveness of PSH would be unassailable in comparison against other power generation options. While BC Hydro may not like this fact because of its potentially negative impact on its export markets and proposals to secure higher electricity rates and more subsidies to other so-called 'green energy' producers, your consultant should (again) not be dissuaded from considering pipeline designs that are specific to operating a PSH plant (e.g. staged development of a multi-pipeline corridor that begins with a single 36 in. dia. pipeline to cost-effectively handle the average daily flow, rather than to handle, upfront, all projected future peak flows).

(Note; this proposal does not exclude the addition of high speed centrifuges in place of a gravity swirl concentrator, nor does it exclude other conventional treatment technologies or industrial sterilization methods in place of the coal filters, nor does it exclude pumping sewage to a low-level ocean PSH plant with output recycled for low cost production of hydrogen to fuel existing internal combustion engine vehicles; use of nutrient-enriched effluent for offshore mariculture/aquaculture; production/distribution of high quality artificial forestry soils-from-wastes, etc.).

Thanks again for you consideration, sincerely,

Richard Tennant, President

Attachments
Cc, Bob Elton, CEO, BC Hydro

(d) Pumped Storage Hydro

A pumped storage hydro project can be regarded as a large electric storage battery, which generates power during peak load periods, and is recharged by pumping during low load periods. In the generation mode, this project operates as a conventional hydro project and water flows from the upper reservoir through the

powerplant to the lower reservoir. In the pumping mode, the generators and reversible pump-turbines of the powerplant are operated as pumps to pump water from the lower reservoir back into the upper reservoir.

The efficiency of the pumping-generating cycle is usually about 70 percent, i.e. for every kilowatt-hour of pumping power used, about 0.7 kilowatt-hour can be recovered in the generating cycle, and the remaining 0.3 kilowatt-hour is lost in pumping and turbine losses, hydraulic losses in the water conduits, generator losses and transformer losses. A pumped storage project usually contains enough water in the upper reservoir to operate the powerplant at full capacity for 10 to 20 hours. The upper reservoir must be refilled periodically through pumping, and the project usually operates on a daily or weekly cycle of full to near empty and then back to full again.

A pumped storage project does not generate any net energy; in fact it actually consumes net energy as a result of pumping-generating cycle losses. The benefit of a pumped storage project is that it provides relatively low cost and dependable generating capacity suitable for short duration peak load operation. It does not have the high fuel costs or long start-up times associated with gas turbines as a peaking alternative. For most power systems, the incremental cost of pumping energy during base load periods is relatively low, and even after recovery of only 70 percent of this energy, a pumped storage project can provide fuel cost savings by reducing high cost fuel requirements from gas turbine projects and thermal peaking plants during peak load periods.

in excess of 94%. Generators have efficiencies on the order of 98%. Thus the overall efficiency of the turbine-generator can range from 88 to 92%.

23.2 TYPE OF HYDRO PLANTS

Hydro plants can generally be classified as conventional, pump storage, and tidal plants.

Conventional Hydro Plants

Conventional hydro plants can be classified in several ways: head, the way water is used with time, on the relationship of the powerhouse to the intake, and on the way they are operated.

When classified by head, *low-head* plants have heads of less than 30 m, *medium-head* for heads of 30 to 200 m, and *high-head* for heads greater than 200 m.

If the powerhouse and intake are part of one single structure, the powerhouse is designated as an *integral powerhouse.* The *separate powerhouse* is connected to the intake by means of a water conveyance system. This system may be a canal, pipeline (penstock), or tunnel.

Plants are also classified by the way they use water with time. *Run-of-river plants* utilize the flow as it is available up to plant capacity without storage. A *regulating plant* stores water for a short term, such as daily or weekly. A storage project stores water during the rainy season for use in the dry period of each year and may also store water for drought years.

Plants may be designated as *baseload plants* if power can be produced continuously as needed. *Peaking plants* are utilized for short daily periods to meet system peak loads.

Pump Storage Hydro Plants

Pump storage hydro plants have been developed to provide peaking service through storing water by pumping it back to an upper reservoir using off-peak energy from the electric system. Water is recycled generally on either a daily or a weekly basis. The early plants utilized a separate turbine and pump mounted on a shaft connected to a motor/generator. Today most new plants utilize a single impeller to operate as a turbine in one direction and as a pump in the other, combined with a motor/generator. The pump storage project requires two reservoirs, an upper reservoir and a lower reservoir. For medium heads, an integral powerhouse may be used. At high heads, the separate powerhouse is most often used. The trend is also to place the powerhouse underground to achieve greater construction economy. In this case, it is connected to each reservoir by tunnels and shafts. A pump storage hydro plant returns approximately 2 kW of peaking power for each 3 kW consumed in the pumping cycle.

A new concept under current study and development is the high-head underground powerhouse and lower reservoir. Heads of 1000 to 3000 m are being discussed with total plants of up to 2000 MW. Such plants require relatively small volumes of water, operate at high rotation speeds, and do not have the surface terrain restraints of the conventional pump storage.

The compressed air energy storage system is a hybrid pump storage system. It may use a small surface water reservoir to equalize the pressure of the air in storage. These systems utilize gas turbines to store compressed air in the low-load portion of the system cycle. This air is then used during the peak period to achieve higher generating capacities.

23.3 APPURTENANT STRUCTURES

A hydro plant requires a combination of several major structures and equipment, to develop the necessary head, to transport the water, and to operate the plant beside the turbine and generator.

Reservoir

Head is developed by storing water in a reservoir. The reservoir may also operate to provide flow regulation or long-term water storage.

Dams

Dams are used to divert flow into water conveyance structures or to develop reservoirs. These structures are commonly built of concrete, earthfill, rockfill, or earth and rockfill.

Intakes

The inlet for water to be carried to the powerhouse may be a separate structure from either the dam or powerhouse. It may be integrated with a dam. The intake has trash racks, service gates, and emergency gates.

Get set for Goldisthal

Germany's VEAG power utility hopes to start building the Goldisthal pumped storage scheme later this year.

From Berlin, Patrick Reynolds reports the background to the long awaited scheme and its place in the energy market.

Barring any setbacks from this autumn's state and federal elections, eastern Germany's VEAG power utility should start construction of the 1060MW Goldisthal pumped storage scheme before winter takes a grip (IWP&DC April).

The DM1500M (US$880M) scheme, first mooted by the GDR, will be VEAG's main hydroelectric project for the next decade. Though a major investment, the proposed scheme represents only about 5% of the utility's planned expenditure in the same period.

Brown coal will continue to rule the roost in eastern Germany's energy market, underpinning jobs and the economy.

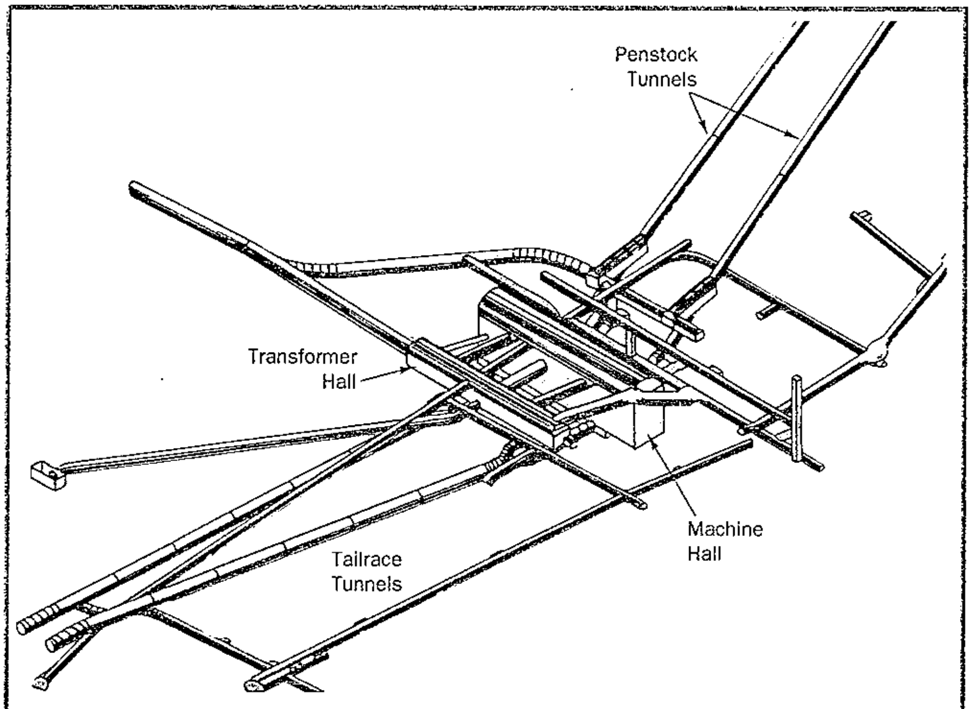
The region is suffering severe unemployment, and even VEAG - its purchase being negotiated by other utilities and the privatisation body, Treuhandanstalt - had to reduce its numbers considerably.

About 85% of the power in the year 2005 will be generated by lignite, supplemented by hard-coal, and some energy supply-only deals, especially with Danish utility Elkraft, allowing the phased upgrading of the brown coal plants. The market stability of power generation is being assured by an arrangement that eastern Germany's 12 regional utilities must buy 70% of their power from VEAG. The utilities transmit power at voltages up to 110kV, and VEAG mainly uses voltages of 220kV and 380kV.

Pumped storage is the dominant form of hydroelectricity in the region, satisfying peaks in power demand. VEAG has six main hydropower plants - Markersbach (1050MW), Hohenwarte II (320MW), Niederwartha (120MW), Bleiloch (80MW), Wendefurth (80MW), and Hohenwarte I (63MW).

The first, Hohenwarte, was built in the 1940s. Markersbach, finished in 1981, will the main pumped storage plant working with the new facility at Goldisthal, at the river Schwarza near Neuhaus in Thuringia.

Studies on the Goldisthal scheme were started in the 1960s by Hydroprojekt, the design arm of the GDR's VEB Spezialbaukombinat Wasserbau, 'especially geological studies,' says VEAG's hydropower manager Wolfgang Bogenrieder.



Schematic drawing of Goldisthal pumped storage scheme's underground works.

4.6 Other Factors

Energy benefits not quantified in the analysis include (a) strategic diversity of energy sources, (b) insurance against unpredictable increases in primary energy costs, (c) non-pollution of the environment, and (d) long operating life (perhaps 100 years). While benefit of long life cannot be easily quantified, its value in 1989 money would be in excess of £550 million annually provided that the debt had been fully discharged.

4.7 Mersey Barrage

A preliminary study has recently been completed on the proposed Mersey Barrage. The capacity of this development is approximately one tenth of that of the proposed Severn Cardiff-Western Scheme. The proposed development would appear to take prominence over the Cardiff-Western Barrage at this time. This is on account of greatly reduced investment that would be required.

A disadvantage of tidal power is that its availability is determined by the moon's position.

5. PUMPED STORAGE

During periods of low demand surplus capacity is used to pump water to an upper reservoir, and when the demand peaks the water is used to generate electricity. Because of the nature of pumped storage, schemes can only be developed in mountainous areas, but, unlike large-scale hydro, there are a number of sites which could be developed in the U.K. such as Craigroyston above Loch Lomond.

The economic case for pumped storage rests on low capital cost per installed kW in comparison with thermal plant and improved flexibility of operation. Savings are made by avoiding use of the more expensive plant except in exceptional demand or loss of generation. Installed pumped storage plant in the U.K. relative to installed generating capacity is much lower than in most industrial countries. This is on account of area where pumped storage can be located and transmission restrictions between generation and load demand. Pumped storage does not produce energy. It is an effective method of storing large amounts of electrical power. Conversion efficiency is typically 75% pumping to generating.

5.1 Craigroyston

Feasibility studies for a pumped storage plant at Craigroyston were undertaken by the NSHEB in the early 1970's. The development was for a 1600 MW scheme with a maximum storage capacity of 32 GWh and costing of the order of £330 per kW at January 1989 prices [5]. An alternative developemnt rated at 3200 MW was also considered. Construction time would be of the order of 10 years. Such a scheme is not required until at least the year 2000 on account of surplus generating capacity in Scotland together with transmission restrictions between the generation and load areas in England. The situation could change if a high-capacity HVDC line is constructed between Scotland and England as part of a HVDC power link between Iceland and the U.K.

5.2 Capacity

There is 1728 MW of pumped storage at Dinorwig, N. Wales which will be owned and operated by the Grid Company. There are 400 MW and 300 MW pumped storage plants at Cruachan and Foyers respectively in Scotland which at present, are owned and operated by the NSHEB. Under privatisation the 400 MW Cruachan plant will be transferred to the private electricity company which will succeed the SSEB.

6. SMALL-SCALE AND LOW-HEAD HYDRO

At present, installed capacity of hydro generation in continuous operation in the U.K. is of the order of 1762 MW, representing approximately 2% of U.K. generating capacity at this time. Up to 500 MW of additional capacity corresponding to 1.8 TWh/year could be developed by utilising small-scale and low-head schemes. This represents less than 1% of current electricity demand [1], [6].

Small-scale hydro is associated with a power range of up to 1MW and heads greater than about 3m. Factors such as compensation water and fisheries limits the potential which could be exploited in the U.K. However, the 1989 Water Bill which imposes only administrative costs of licencing stations smaller than 5 MW, U.K. small-scale, low-head schemes.

Drawbacks in economic terms are high capital investment and payback periods of up to 12 years. Specific schemes will be viable in the 1990's and water authorities have found it viable in specific cases to produce electricity themselves.

7. WIND POWER

The cost of electricity produced by wind power in the U.K. based on January 1989 prices is given as 3.0 ~ 5.0p/kWh [7]. This compares quite favourably with cost of energy from fossil and nuclear plant. Availability of existing wind farm power plant could be improved

In California, where 95% of current world wind power is generated, average availability of wind turbines is not high. New wind farm turbines achieve an availability which is significantly better. Current cost of wind turbines in the U.K. is £530/kW, but this cost would be expected to reduce considerably by bulk supply.

U.K. land-based wind turbines could, if developed, produce 45TWh/year equivalent to 17% of present U.K. demand. Theoretical studies suggest that up to 50% of generating capacity could be wind power plant before system operating problems would arise. Installing a thousand MWs or more of wind turbines should therefore have no adverse effect on power system operation in the U.K.

Estimates made recently by the Chairman of the CEGB intimate that wind energy could save burning 1 million tonnes of coal a year in the U.K. by the year 2000, and could supply 1000 MW of power by the year 2005, 1% of the country's electricity requirements. At present there are four experimental 1 MW wind turbines in operation at Carmarthen Bay (North Wales), and two more are expected to be erected at the same site. There is a 3 MW wind power plant in operation at Burgar Hill in Orkney (Scotland) at this time. 3 wind farms are at the planning stage. The first wind farm is expected to be constructed at Capel Cyon in S.Wales in 1990, with others to follow in 1991 (Cornwall) and 1992 (Durham). Each wind farm will comprise 25 machines with a total capacity per farm of 8 MW.

It should be noted that if wind power were to produce 20% of current needs some 20,000 machines similar to one of the 1 MW machines at Burgar Hill in Orkney would be required. There are 180,000 wind turbine sites on the U.K. landmass which would be suitable for wind turbines, but when national parks and areas of outstanding natural beauty are excluded this figure is reduced to 144,000 sites.

Wind farms are a prospect for producing a limited amount electrical energy in the U.K. at this time.

8. NORTH SEA GAS

A report in 1988 suggests that gas would increase its share of European power generation from 5% in 1988 to 16% by 2010. Most of this would come from combined cycle plant.

Until the early 1980's small-scale gas turbine units were used for peak lopping in electricity utilities and industrial plant. Developments in the aero engine sector in recent years have led to units rated at 200 MW or more becoming available. Gas turbine stations can be fitted with a waste heat boiler and a steam turbine-generator to increase output and thermal efficiency thus avoiding problems of siting new plant. In recent months, the NSHEB have entered into a contract with an oil company to supply natural gas at a sufficiently low price to make it economical to convert the 1320 MW Peterhead power station to gas. The station may operate base-load on North Sea Gas.

In addition, private consortia have suggested that a 1000 MW combined cycle gas turbine power plant located in the London area would be viable and save £2000m ~ £2500m at January 1989 prices within 40 years of commissioning based on cost of nuclear generation.

9. SMALL-SCALE COAL-FIRED PLANT

Privatisation of electricity supply could lead to a significant reduction in the number of new large coal-fired power stations (1800 MW or more) since initial costs of construction of large power plants are high and payback periods long. A recent debate in the House of Lords suggested that new coal-fired power stations would

Debut delayed

The future of hydropower will include distributed pumped storage systems to tackle local demand peaks and provide grid balancing services. However, US electricity market conditions have delayed their debut, though they could be a useful tool for economic Salmon protection, reports Patrick Reynolds.

Distributed, or modular, pumped storage systems developed in the US are virtual off-the-shelf economic packages designed for localised load balancing and meeting demand peaks in transmission grids - rather like wheel balancing using carefully positioned small weights.

However, with the US new power capacity market being dominated by gas-fired generation, coupled with depressed electricity prices and utilities playing the wait-and-see investment game over de-regulation, the project packages have remained not only on the shelf; in terms of convincing the market, they are effectively still on the drawing board.

Despite the current difficulties, Distributed/Modular Pumped Storage systems (DPS/MPS), like conventional pumped storage plants, offer marked benefits to overall power system performance. Particular dynamic operating benefits for a host grid using carefully located DPS plants can include peaking capacity, load following, operating and spinning reserve, voltage and power factor correction and frequency regulation.

On a wider, economic viewpoint, pumped storage plants offer many other benefits: they can help optimise energy transfer costs, the cheapest power sources on a utility system displacing the higher cost energy sources; thermal plant cycling can be reduced, with consequent operation and maintenance cost saving, plant life extension, and reduced air emissions with improved incremental plant efficiency.

Pumped storage's quick start capability qualifies as operating reserve, in the stand-still mode, and as spinning reserve; it can then help reduce thermal plant fuel costs and further reduce air emissions. Further, the closed cycle DPS plants rely only on groundwater, usually, so can help isolate a utility from possible fuel price hikes.

Away from thermal plants, in 'dry' years the closed-loop plants could even partially replace some conventional hydropower plants, which rely on surface waters, especially those used for peaking.

So, while offering much of the same benefits as conventional pumped storage plants, why is there a need for DPS plants? Quite simply, to save cost and so compete with gas-fired peaking plants through scale and positioning benefits.

As one engineer comments, pumped storage has typically been looked at from the point of view: 'if it ain't 1000MW it's not worth doing, but with DPS you can have a little 'ol' 200MW plant.' And, being usually independent of surface waters, the closer to a grid demand centre such a relatively small facility can be placed, the smaller it needs to be, setting the scene for 200MW plants or even smaller.

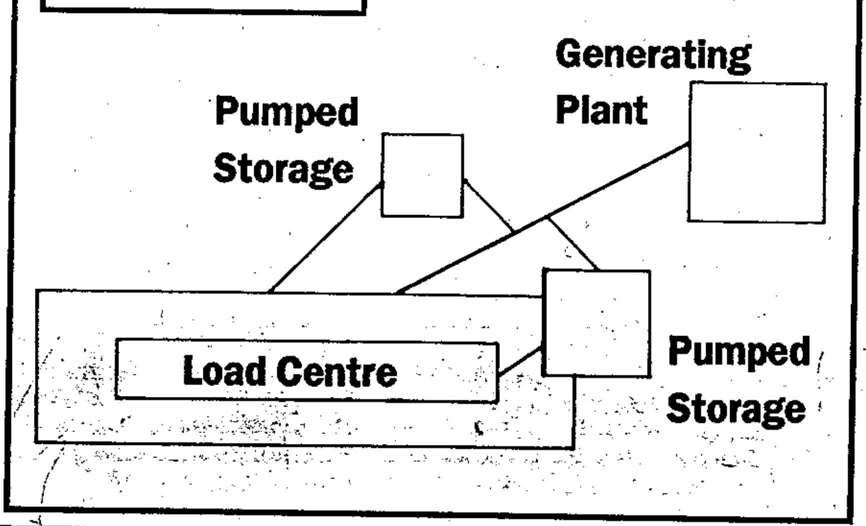
Prime mover behind the DPS concept development, Rick Koebbe, now Vice President with Energy Unlimited, has spent five years developing the concept with a small group of enthusiastic industry colleagues. 'We're partnering with people we have faith in, in a concept whose time will come,' says one associate, Herb Vernon, Vice President of sales & marketing with ABB Phoenix Controls. Vernon talks of investing time, money, engineering talent and pateience in the concept he is backing.

Koebbe explains that the development years have brought down the installation cost of DPS plants, from an initial US$1000/kW to about US$750/kW to compete with gas-fired plants. The current per kilowatt power cost beats that of gas-fired baseload plants by some US$50-150, though is still slightly more expensive than gas-fired peaking costs. However, the DPS cost is now in the same ballpark as the compe-

Table: Key project data for Brink PS

Business:	
• Cost (1995)	US$150M
• On-line target	May 2000
• Developer, Engineer	Energy Unlimited
Design data:	
• Gross head	305m
• Net head	262m
• Rate flow	90m³
• Motor gens	100MW/110MVA (2No)
• Pump-turbines	Vert. Francis
• Starting	Static Freq. Conv.
Powerhouse:	
• Type	Caisson, concrete
• Depth	76.2m
• Diameter	18.3m
• Penstock length	945m
• Penstock dia.	2.74-3.66m
Upper reservoir:	
• Area	38ha
• Total volume	3.454 million m³
• Embankment dam	152m by 19.2m high

Fig 1. Smaller, locally placed pumped storage plants could offer utilities system balancing benefits at investment rates comparable with gas-fired plants, but with extra environmental and strategic benefits.



tition and, argues Koebbe, the various economic and strategic benefits listed above could tilt the balance in his favour.

The technology, therefore, does have a place in the future of the troubled US hydropower sector at least, and probably will be implemented internationally.

In the meantime, though, the marketing push for power sales deals continues, despite utilities wavering on investments, with Koebbe going for greater DPS efficiencies and even lower cost of installed power. He is convinced that 200MW DPS projects are viable options, such as the proposed Brink project, Utah (see box).

Koebbe says that there are no new technological risks involved with the DPS concept, which is based on ten pumping-generating cycles per day to minimise maintenance costs - although this figure can be varied.

What would certainly be new would be the reduced environmental impact from a pumped storage scheme, even one so small. With a closed water circulation system, based on initial and top-up groundwater supplies, a DPS project would have no inflow or outflow needs, he says, unlike a conventional hydropower or pumped storage project.

Going a major step further along the environmental protection path, a modified DPS could help protect fisheries in the US Northwest - modified with an inflow/ outflow arrangement. The developers believe that DPS could store waters released to ensure minimum river flows for salmon but which is often not the best time for generation according to electricity market conditions. The 'lost revenue' could be recouped as water stored for generation at a more profitable market time.

Despite masterminding the development of the fast-track concept, though, Koebbe has competition. Having started off developing the concept when working with Peak Power - it was then called Modular Pumped Storage - he moved on to LB Industries two years ago when the company was bought by Magma Power, before joining Energy Unlimited. Magma Power was itself subsequently purchased by California Energy in February this year for more than US$900M.

California Energy, through Peak Power, is also seeking MPS licences and is keeping the applications to the Federal Energy Regulatory Commission valid on a quarterly basis. However, neither have any power purchase agreements so far, says Vince Fesmire, Vice President of Construction & Implementation.

One utility project which has been continually chased is the proposed 200MW Sheep Mountain MPS plant to help meet Nevada Power's need for extra capacity. The utility, though, recently stopped negotiations with all bidders in light of the changing electric power economic picture as prices continued to fall.

As the expanded California Energy company focuses primarily on geothermal energy, there is some industry speculation that Peak Power may be sold off or bid for in the near future. With a pretty bleak US generation construction market, California Energy is active in a number of projects in SE Asia. It does not intend, though, to push the MPS concept internationally in the near future, says Fesmire.

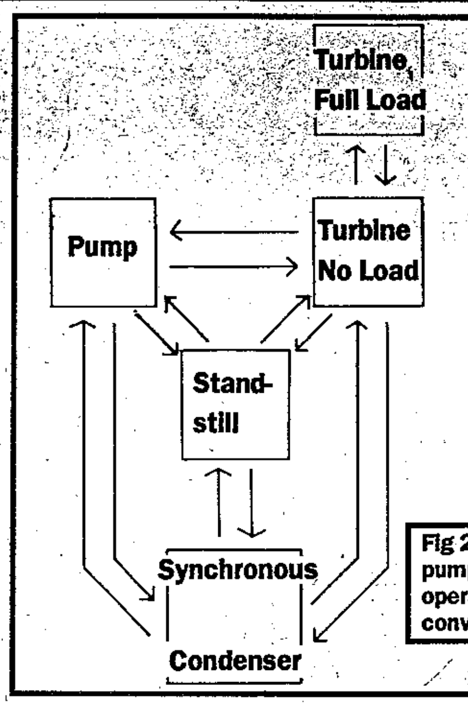


Fig 2. The small distributed/modular pumped storage (P.S) plants can operate in many modes, like conventional PS plants.

Taking hydro to the Brink

The 200MW Brink pumped storage project, with two single-stage reversible units, has been proposed for an undeveloped site in Sevier County, Utah, southeast of Richfield.

With the rights to the estimated US$150M project from his previous employer, Rick Koebbe proposes that the closed, distributed pumped storage system (DPS) be installed to meet a utility's power needs - including peaking power, load following, spinning reserve, voltage and frequency support - possibly that of PacifiCorp.

Koebbe's Brink design has the two reversible pump-turbine units operating under a gross head of about 1000ft (305m). With 10 hours running at full generating capacity, the DPS plant would have 2GWh of available total energy storage, he says.

Water to initially fill the DPS facility and replace evaporation losses would be tapped off a local aquifer in Bear Valley, says Koebbe. Subsequently, there should be no need for water from any river or existing reservoir, no reliance on rainfall trapping and consequently no inflow to the plant. Further, there will be no outflow.

The closed system's project's electrical and mechanical equipment are planned to be housed underground in a caisson-style powerhouse, to be excavated on the west side of the lower reservoir. The powerhouse silo would be topped of by a geodesic dome, removable for major maintenance work.

A 13.8kV powerhouse cable would be linked to an adjacent, surface switchyard for stepping up to the utility's 230kV grid voltage and connection to the grid at a nearby substation.

Herb Vernon says that modularisation is also the central philosophy for the control of the DPS projects. Such an approach allows best sensitivity and adaptability to a customer's proposed operating regime, he explains.

DPS plants would have a hierarchical control structure based on micro-processor based automatic controllers, he says, from wicket gate control level up to pump-turbine unit control level and then plant control. Unit controls would have the capability to link up with the owners EMS system, should that arrangement suit a client.

Further, the plant controller could be interrogated from various headquarters to process trending and performance data for analyses.

The automated control system would work within pre-programmed settings for flow, power or scheduled output, he says, based on signals from the utility despatcher. Headquarters could re-programme the micro-processor controls to optimise unit performance or change operating strategy over time. The proposed control package for Brink contains this arrangement.

Vernon also explains that the control system is standardised in three main ways: at the hardware, software platform and software control algorithm levels. The software and hardware platforms are off-the-shelf. SCADA-based software is modified to utility grade, he says. Standard, proven control algorithms ensure that the designers don't have to totally re-engineer the set up for each new project, 'so really keeping costs down and reliability up,' he says.

VANPORT STERILIZERS INC.

Jorvic Pumped Storage Project – Overview

Since 1988, VPS has proposed to BC Hydro and various government agencies various pumped storage plants to upgrade the Jordan River Hydroelectric Project (JRHP) including;

- Conventional Pumped Hydro (CPH) from the abandoned Forebay Reservoir to Bear Creek Reservoir and/or from Boneyard Lake up to a new summit reservoir located at the 500 M level;

- Ocean Pumped Hydro (OPH) from offshore to Forebay Reservoir;

- Compressed Air Pumped Storage (CAPS) to/from Sunro Mine tunnels;

- Hybrid Pumped Storage (HPS) from Victoria with municipal wastewater, possibly in combination with all of the above.

HPS has been the primary marketing focus as it was assumed that BC Hydro would be attracted by the economics of a new storage infrastructure that would be paid for by municipal taxpayers.

Finally, HPS assessment has mostly been on the basis of its waste treatment technology, rather than on the economics of merchant power, recycled water and artificial soils markets. BC Hydro has never made any reference to the competitive economics of such a 'peaker' plant versus the import or export of natural gas or electricity, it has never offered to review the impact of such a generic technology on its energy generation system, and, it has never offered to support a review of either the Jorvic or the proposed Britannia Mines pumped storage projects as possible catalysts for more cost-effective alternatives to the currently-proposed list of 'Gateway', 'P3" and 'Hydrogen Highway' projects.

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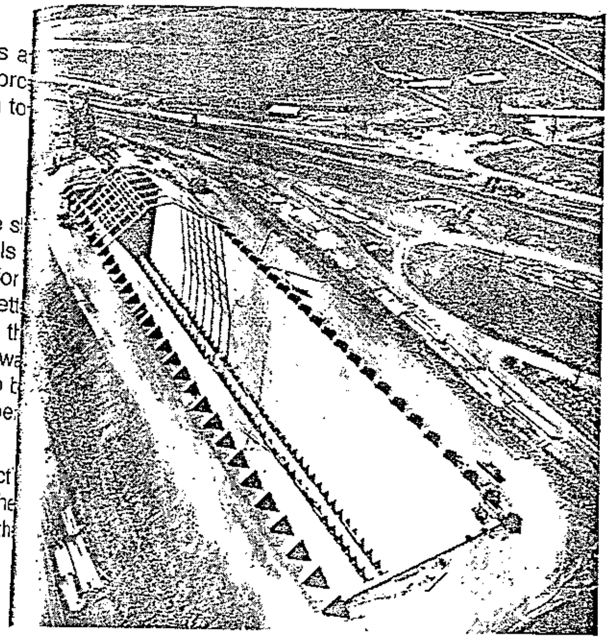


Fig. 2: Barn-covered slot built by SUNDECO fot its Cordero Mine at Gillette, Wyoming

of the vertical end-walls used Reinforced Earth, thus eliminating the delays of cast-in-place construction.

4.4 Great Plains Gasification Plant

The largest Reinforced Earth coal bunker to date will be completed this year for the Great Plains Coal Gasification Plant near Beulah, North Dakota (Fig. 3). The facility, which

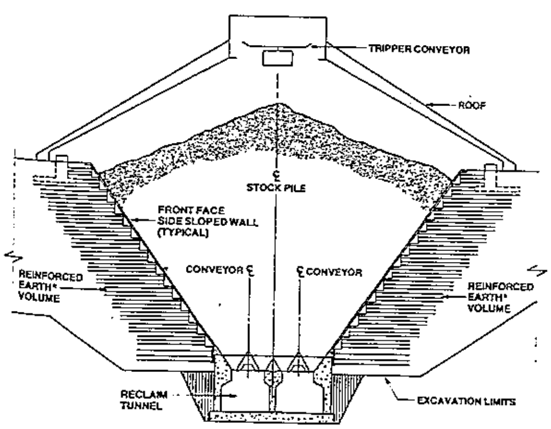


Fig. 3: Biggest barn-convered coal storage slot to date under construction at the Great Plains Coal Gasification Plant at Beulah, North Dakota

will store 113,500 tons of lignite for conversion to clean-burning gas, is 231 m long, 21 m deep and 38 m wide at the top. Partially set above ground, its width decreases to 10.5 m just above twin reclaim tunnels. An overhead conveyor suspended from an A-frame roof discharges coal into the slot. Rotary plows and conveyor belts in the reclaim tunnels move coal from storage to the plant.

4.5 Labadie Power Station

In a variant of the V-shaped bunker, Union Electric Compar constructed a *one-sided-slot* at its Labadie, Missouri, pow station as part of a facility for blending high- and low-sulf coal (Fig. 4). Low-sulfur coal unloaded from unit trains by

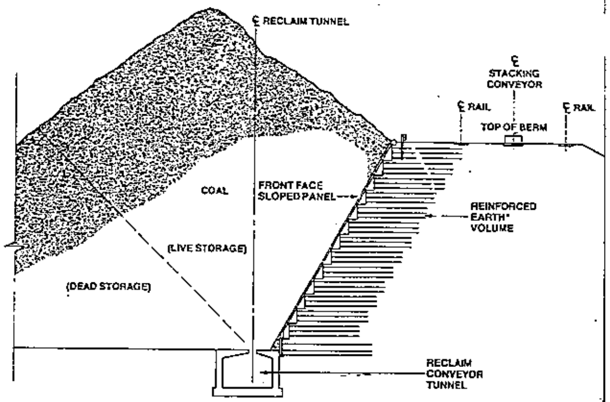


Fig. 4: Stacker-berm coal storage scheme for Union Electric Company Labadie Generating Station

rail-mounted traveling stacker is discharged from the top o an 18 m high, 158 m long Reinforced Earth berm. Co slides down the 60 degree incline to a 45,450 ton liv storage pile above the reclaim tunnel.

Coal either is shifted from live storage to a 1.36 million to dead storage pile alongside the reclaim tunnel or is ser directly to the 2,300 MW boilers. The dead storage pile sup ports the opposite side of the live storage sector. A conveyo in a second tunnel, below and perpendicular to the reclair tunnel, carries the coal to another conveyor where it i blended with high-sulfur coal before going to the boilers.

The berm sits on an old ash pond, which may cause th berm to settle up to 6.6 m. Reinforced Earth was chosen fo this site because it resists the stress of foundation settle ment.

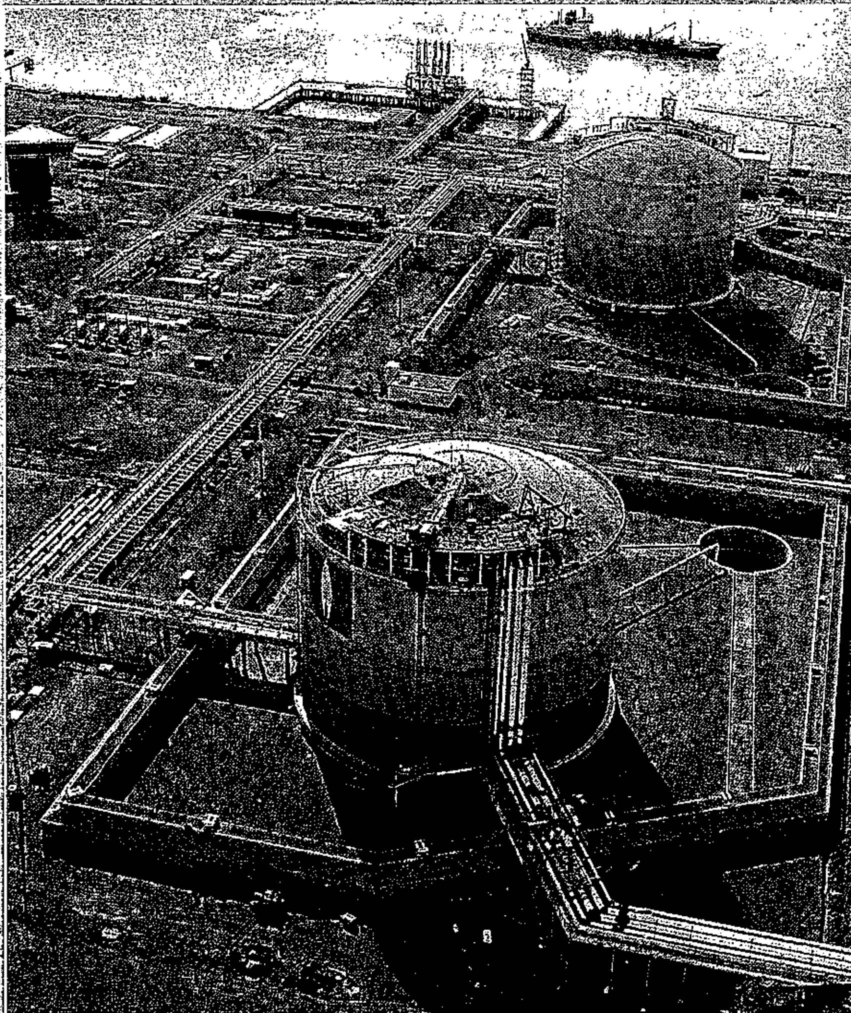
4.6 Glory Holes

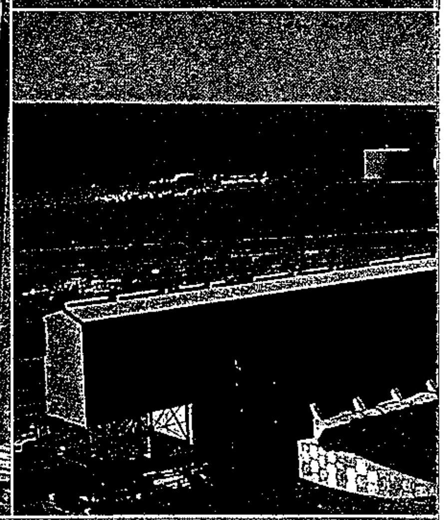
In an extension of its use in storage slots, sloping Reinforce Earth walls have been used to construct "glory hole"-typ storage facilities. These structures are inverted, conica polygons used for live coal storage. An overhead conveyo feeds coal into the center of the hole from which it is metere to a reclaim conveyor.

One such structure stores coal near Marissa, Illinois, wher material from several local mines travels by overland con veyor to an eight-sided glory hole, which acts as a surge pil to compensate for the differences between mining and pro cessing rates (Fig. 5). The 27,200 ton capacity hole tapers t a 9.15 m throat from a ground level diameter of 60 m. A vibrating feeder below the throat discharges coal onto a con veyor that goes to a processing plant.

A glory hole built by Coors Energy Company at its Keenes burg Mine in Colorado, provides 18,000 tons of live storag in the delivery system between the crushers and truck loac out. A 2.5 m diameter lowering well at the center minimize dust generation and supports a loading conveyor. A cast-in place buttressed parapet atop the structure increase storage volume and supports the roof.

Building Large-Scale Energy and Industrial Projects

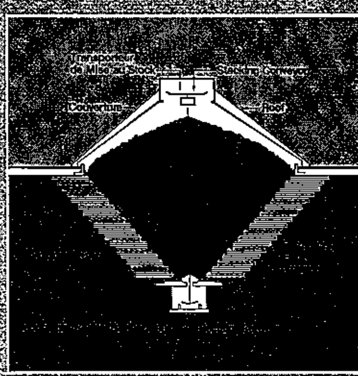




In the construction of large-scale industrial projects Reinforced Earth construction has economically solved a variety of technical, logistical, and scheduling problems.

An inclined wall technology has been developed for building barn-covered storage facilities. Called slots, these structures are well adapted to storing coal, minerals and other bulk materials. At mines and power generating stations, slot storage of large volumes of coal is economical and provides excellent operational characteristics including load-out rates of 4,000 tons per hour.

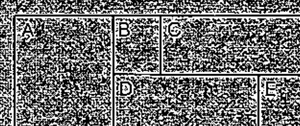
For secondary containment of liquefied natural gas (LNG), Reinforced Earth dikes offer a desirable structural geometry while fulfilling all safety requirements. In full-scale tests conducted by Gaz de France, Reinforced Earth dikes were subjected to the thermal extremes of a hypothetical accident. Chill-down and then burn-off tests verified that there would be no loss of containment and function in the event of a major spill.



Coupe type d'un ouvrage de stockage à parois inclinées en Terre Armée.

Typical section of a Reinforced Earth bulk storage slot.

Its speed of construction, flexibility of design in height and geometry, lower costs, and capacity to be dismantled and relocated have made Reinforced Earth a material of choice for many industrial applications.



A. Cuvettes de rétention autour des réservoirs de GNL du Terminal méthanier de Montoir-de-Bretagne (France).

B. Les murs des concasseurs sont conçus pour supporter des équipements lourds et de gros efforts dynamiques.

C. Dans les mines, les grands stockages inclinés, comme à Clovis Point (USA), permettent de charger rapidement les trains.

D. Les stockages couverts des centrales thermiques protègent le charbon des intempéries et permettent des manutentions faciles et rapides. (Maine USA)

E. Des ouvrages de stockage en forme de cône sont également réalisés avec des écailles inclinées.

A. Reinforced Earth containment dikes exceeded all safety requirements and reduced costs at the Montoir-de-Bretagne LNG Terminal, France.

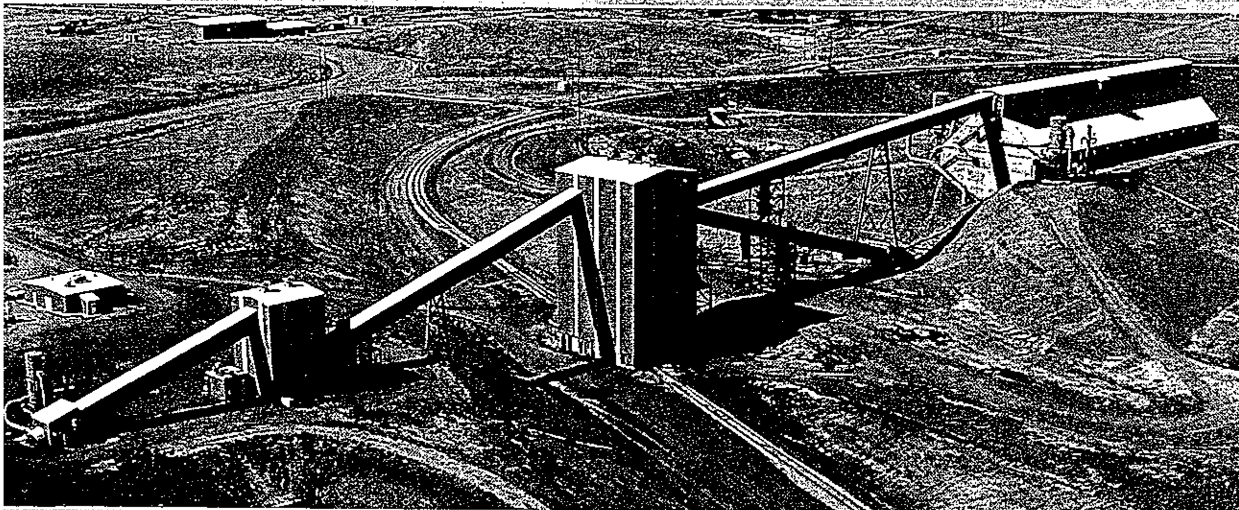
B. Crusher headwalls are designed to support heavy equipment and shifting loads.

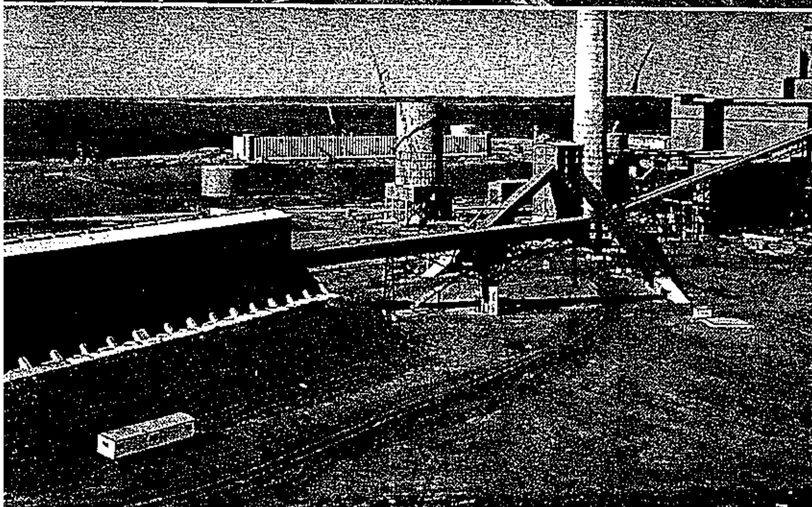
C. At mines like Clovis Point in the United States, coal storage slots provide rapid loading of unit trains.

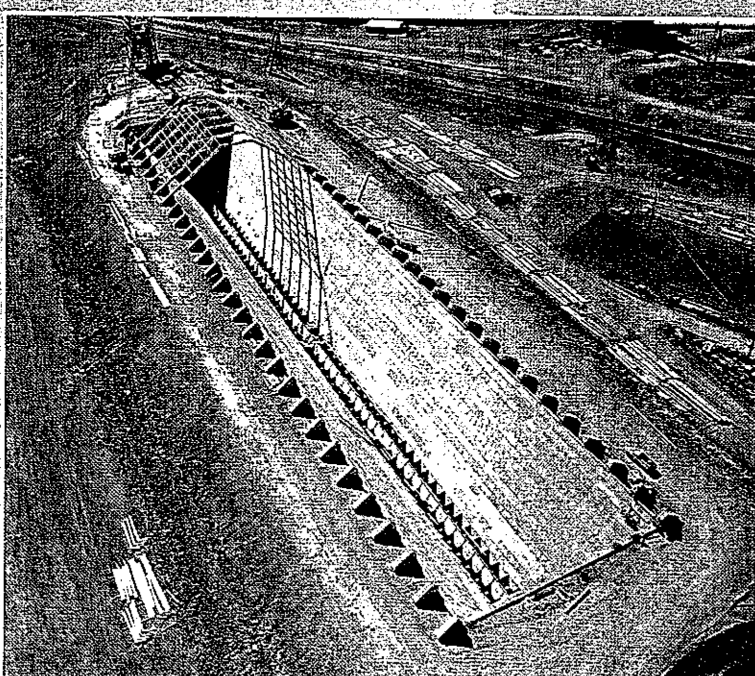
D. Barn-covered storage at power plants insures a weather protected fuel which is easily and economically drawn. This 23,000 ton structure is at the Coyote Station in the United States.

E. Conical storage structures, used as surge piles for surrounding mines, are built with inclined panel technology.

De Grands Aménagements pour l'Energie et l'Industrie







Grâce à la mise au point de ces murs inclinés, la construction de grands stockages de 100 000 T—comme à la mine de Cordero, USA—est devenue rentable et sûre.

An inclined wall technology made stable construction of large coal storage slots, like this 100,000-ton facility at the Cordero Mine in the United States, practical and economical.

La Terre Armée est largement utilisée dans les projets industriels, où elle résoud économiquement des problèmes techniques et logistiques très variés:

— les parois inclinées des grands stockages couverts bien adaptés au cas du charbon ou d'autres pondéreux. Près des mines ou des centrales thermiques, ces stockages offrent de gros avantages et notamment des cadences de manutention de l'ordre de 4 000 T/heure.

— les parois des cuvettes de rétention autour des réservoirs de gaz naturel liquéfié (GNL), conformément aux règles de sécurité. Les essais en vraie grandeur réalisés par Gaz de France (remplissage de GNL—incendie) confirment que la cuvette de rétention remplirait correctement son rôle en cas d'accident majeur.

Dans l'industrie, la Terre Armée est appreciée en raison de sa rapidité d'exécution, de sa souplesse et de la possibilité de démonter facilement les structures pour les adapter à l'évolution ultérieure des installations.

PERGAMON

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Use of bituminous coal for concentration of enteroviruses from sewage and effluent

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Abstract

A method has been developed for concentration of enteroviruses from untreated and treated domestic wastewater using bituminous coal bed as a virus adsorbent. A bed made from 1.5 g of 120 mesh coal powder was used for concentrating enteroviruses from 100 ml of clarified sewage at different pH values with and without addition of $AlCl_3$. To enhance the adsorption of viruses, requisite quantities of aluminium chloride were added so that a final concentration of 0.0005 M could be achieved. At pH 3.0 maximum adsorption (82.8%) of poliovirus type 1 from artificially contaminated clarified sewage was observed without addition of $AlCl_3$. However, at pH 5.0 maximum virus adsorption of 98.7% was achieved after addition of aluminium chloride. An average recovery of 86.9% of adsorbed viruses at pH 5.0 was achieved from coal bed with 3% flocculating beef extract at pH 9.5.

This method for concentration of enteroviruses incorporating use of coal was compared with that of Millipore membrane filter method applied to raw sewage and clarified sewage. The results obtained from the methodology using coal as adsorbent was subjected to Student's "*t*" test and it was observed that its efficiency is confirmed for recovery of enteroviruses from raw and nonclarified sewage. These results are also comparable with that obtained with MF method. The results presented in this paper are indicative of the potential of this method for both treated and raw sewage.

Keywords: Coal bed; Poliovirus; Raw sewage; Stabilization pond effluent; Adsorption; Elution; Flocculating beef extract; Beef extract in McIlvaine buffer

1. Introduction

In India, the per capita water requirement is increasing every year due to increase in population. This results in the generation of large quantities of domestic wastewater that contains bacterial pathogens and viruses. More than 100 types of enteroviruses are present in sewage. Among these, the most important waterborne viruses are infectious hepatitis viruses, rotaviruses and polioviruses which are responsible for causing epidemics of infectious hepatitis, gastroenteritis and poliomyelitis, respectively [1–3].

Enteroviruses detected in sewage are contributed not only by diseased persons but also by healthy children in the age group of 1–15 years [4]. These viruses are also detected in the ground, surface and sea water [5–9]. Faecal contamination of drinking water sources (ground and surface water) may cause viral outbreaks [10,11]. The concentration of enteroviruses in sewage varies depending upon the socio-economic and hygienic condition of the people in the community. Rao et al. [12] and Buras [13] detected 11,572 and 10,60,000 PFU/l in sewage from Nagpur (India) and Haifa (Israel), respectively.

Several methods were reported for concentration of viruses from sewage [12,14–16]. Microporous membrane filter (MF) method is widely used for concentrating enteroviruses from sewage and effluent. In this method, low recovery of viruses from sewage was reported [17,18]

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for average recovery of adsorbed viruses at pH 3.0, 4.0 and 5.0 were 73.1%, 74.1% and 86.9%, respectively. This showed that maximum virus recovery occurred at pH 5.0. It has been observed from the results that maximum adsorption of poliovirus occurred on a coal bed at pH 5.0 and their subsequent elution was effected with 3% BE at pH 9.5. Hence, these criteria were further used for concentration and detection of enteric viruses from sewage and stabilization pond effluents. The schematic of the method for concentration and reconcentration of viruses from domestic wastewater is depicted in Fig. 3.

4.4. Comparison of coal bed and MF protocols for recovery of virus

The coal bed and MF methods for concentration of enteric viruses were compared in terms of virus recovery. Sewage samples were collected according to a predetermined time schedule, blended for 2 min, centrifuged at 1800*g*, divided into two equal aliquots of 300 ml, and filtered through coal bed and MF separately. The adsorbed viruses were eluted with 6% BEMB at pH 7.1. The eluates obtained from both the procedures were assayed on the same batch of tissue culture. The comparative recovery of viruses using coal bed and MF method is presented in Table 5. The results indicated that the recovery of enteroviruses by coal bed and MF method ranged from 1040 to 7520 and 830 to 6580 PFU/l, respectively. The number of enteric viruses recovered by the coal bed method was more than that by the MF method. The comparison was made by applying Student's "*t*" test at 5% level of significance; the calculated "*t*" value was 3.03 as against (2.7%) reported in the literature for 12 degrees of freedom, indicating that the coal bed method is better than the MF method for recovery of enteroviruses from clarified sewage.

Enteric virus recovery from sewage is always far better than the MF method because the loss of viruses along with particulate matter due to centrifugation as it is an essential step in the MF method, is avoided resulting in higher virus recovery (Table 6).

The coal bed and MF protocols were used for concentration and detection of enteric viruses in raw sewage and effluent of stabilization pond treating domestic sewage. Both raw sewage and effluent samples were divided into two equal parts of 1000 ml after blending for 2 min. One part was processed using coal bed (110 mm dia.) and the other part was processed by MF (142 mm dia.) after clarification. Adsorbed viruses were eluted with 100 ml of 6% BEMB solution at pH 7.1 and reconcentrated by modified organic flocculation method. It could be seen that a higher percentage of enteric viruses were detected from raw and treated sewage by coal bed method compared to the MF method. The enteric viruses detected in sewage by the coal bed and MF methods ranged from 78 to 51,810 and 75 to 22,468 PFU/l, respectively (Table 7). Out of 21 effluent samples tested using both these techniques, enteric viruses could be detected in 20 samples by the coal bed method and in 18 samples by the MF method indicating the efficiency of the coal bed method.

5. Discussion

Bituminous coal has a great potential to adsorb enteric viruses hence it has been used in this study for adsorption of polioviruses from sewage. It has a cyclic structure and possesses carboxyl, hydroxyl, thioether and quinonic groups on its surface. The carbon content of the coal is 59.2%. The conductivity of the 0.5% suspension of coal was 0.014 mS/cm (at 20°C) and the zeta potential was −68.3 mV. This value suggests that the coal surface is negatively charged. Viruses behave as colloidal particles when suspended in an aquatic medium and are negatively charged at neutral pH. The surface of a virus particle is made of protein, therefore, the charges on virus particles are similar to those of protein. Amino acids have two major reactive groups i.e. amino ($-NH_2$) and carboxyl ($-COOH$). Therefore, charges on viruses are governed by acidic and alkaline

Table 4
Elution of viruses from coal bed

pH	Virus[a] input (PFU)	Virus recovery (%) Experiments					Average virus recovery (%)	SD
		1	2	3	4	5		
3.0	445	48.9	97.7	73.4	46.7	98.8	73.1	±25.2
4.0	445	90.0	70.5	65.4	60.6	83.8	74.1	±12.42
5.0	445	90.0	92.8	82.8	83.0	85.7	86.9	±4.41

SD = standard deviation; PFU = plaque forming unit.
[a] Virus added + indigenous viruses in the sample.

Table 5
Comparative recovery of viruses in clarified sewage by the coal bed and MF methods

Sr. no.	Coal method (PFU/l)	MF method (PFU/l)
1	1040	830
2	3780	3600
3	5330	3230
4	3380	3300
5	1940	1360
6	1900	1780
7	4430	3650
8	1322	1242
9	1514	1316
10	1304	1222
11	6610	6210
12	7520	6580
13	6520	6110
Mean	3583.8	3110.0

PFU = plaque forming unit; MF = membrane filter.

Table 6
Recovery of viruses from raw sewage using the coal bed and MF methods

Sr. no.	Coal bed method (PFU/l)	MF method[a] (PFU/l)
1	778	158
2	2808	997
3	845	592
4	976	288
5	9844	3478
6	32,444	7652
7	1668	798
8	49,450	12,051
9	32,400	6869
10	2360	1083
11	5593	683
12	676	638
13	258	172
14	849	263
15	1802	722
Mean	9516.7	2429.6

PFU = plaque forming unit; MF = membrane filter.
[a] Centrifuged at 1800*g*.

Table 7
Comparison of the coal bed method with the MF method for recovery of viruses from raw sewage and effluent of stabilization pond

Sr. no.	Coal bed method		MF method	
	Raw sewage (PFU/l)	Effluent (PFU/l)	Raw sewage (PFU/l)	Effluent (PFU/l)
1	976	318	600	260
2	13,454	1469	6821	264
3	51,810	1068	22,468	560
4	22,761	2842	7021	890
5	3724	368	2136	173
6	2682	550	701	328
7	1105	120	653	1206
8	504	46	105	ND
9	348	3	75	2
10	5047	105	190	76
11	1985	80	1887	8
12	346	3	148	41
13	1782	202	532	139
14	890	314	689	194
15	166	56	165	54
16	1081	192	736	ND
17	78	ND	76	ND
18	3476	378	2447	140
19	4100	172	4051	144
20	1770	135	1090	160
21	685	392	579	286

PFU = plaque forming unit; MF = membrane filter; ND = not detected.

increased. The percent adsorption of virus could be enhanced remarkably by amending the medium with $AlCl_3$. In this case, the percent adsorption ranged from 67% to 98.7%. In the presence of $AlCl_3$, the effect of pH is reversed in that the percent adsorption increased when the pH is raised to 4.0 and 5.0 from pH 3.0. This may be due to favoured $AlCl_3$ hydrolysis of higher pH. Hydrolysis of aluminium salt into oligomeric cationic species such as $[Al_6(OH)_{15}]^{3+}$, $[Al_8(OH)_{20}]^{4+}$, etc. is extensively documented [25]. It is believed that the negatively charged poliovirus 1 (at pH 5.0) easily adsorbs primarily onto oligomeric Al-cationic species, which in turn adsorb on to negatively charged coal particles. The composite Al^{n+}–virus bridges may be expected to possess a net positive charge and their adsorption on to negatively charged coal is facilitated. As a result, amendment-using $AlCl_3$ gave higher virus removal efficiency. This type of enhancement effect by $AlCl_3$. Persisted at all pH levels in the range of 3.0–6.0; however, pH 5.0 is found to be optimum. A somewhat lower enhancement found at pH 3.0 where $AlCl_3$ hydrolysis is either absent or less, indicates that both free Al^{3+} and corresponding hydrolyzed polymeric species are effective. However, the more pronounced enhancement found at pH 5.0 may be due to polymeric aluminium species with higher net positive charges.

6. Conclusions

- Bituminous coal has the potential to adsorb viruses from sewage and treated effluents.
- Maximum adsorption of viruses to the extent of 98.7% occurs at pH 5.0 in the presence of $AlCl_3$ (0.0005 M). This indicates that organic matter of

sewage does not interfere with virus adsorption to coal bed.

- Adsorbed viruses from sewage could be eluted with 3% flocculating BE (oxoid) and virus recovery ranged from 82.8% to 92.8% with an average of 86.9%.
- Prefilteration or centrifugation to clarify sewage is not required which is an essential step for the MF method. Hence, the loss of viruses that occurs during clarification of sewage is avoided in the coal bed method.
- More viruses were detected in sewage and effluent by the coal bed method than by the MF method.

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I SUMMARY

In 1963 the Rand Development Corporation of Cleveland, Ohio began a laboratory study to determine whether coal could be used advantageously in the treatment of sewage and industrial wastewaters. The work was supported by the Office of Coal Research, U. S. Department of the Interior, under Contract No. 14-01-0001-348, and was summarized in OCR Research and Development Contract No. 12, "Investigation of the Use of Coal for Treatment of Sewage and Wastewaters," issued in March, 1966.

Coal was found to be useful as a filter medium and settling aid, and as an agent for the partial removal of certain soluble pollutants by physical and chemical surface reactions. A single-step "coal-sewage process" evolved during this investigation, for which U. S. Patent No. 3,401,114 was issued; and in a continuing pilot plant program under a second OCR Contract, No. 14-01-0001-483, the process was refined and demonstrated to be feasible on a commercial scale. All of the pertinent material from both contract programs is included in this second and final report.

In its basic form the coal-sewage process is a deep-bed, gravity flow, consumable coal precoat filter which may be used in the treatment of wastewaters of nearly any type. Near-perfect removal of suspended solids is attained and variable proportions of dissolved organic matter and phosphates are removed as a function of the type of coal which is used. Process performance does not degrade with time, and there is no significant contamination of the water containing the sewage by the coal. Any type of coal which does not soften in water may be used, with consequent exclusion of only the lignites and some of the lower-rank sub-bituminous coals.

The process is a batch method, with long term continuity attained by alternation among filters at intervals of between one and three months as a function of the type of waste being treated. Continuity of flow rate during a filter run is achieved by the periodic removal of a thin layer of the filter surface by a traveling doctor blade, or scraper, which is the only item of special equipment required. The spent coal and sewage solids are discharged as a slurry which is de-watered by simple mechanical means and incinerated. Approximately ninety percent of the original heating value of the coal is recoverable as usable heat.

The coal-sewage process is the first practical large-scale sewage filter available to the industry: Quantities as high as ten million gallons per day can be treated in a single unit. In this respect the value of coal, as opposed to sand or other permanent media, is especially evident.

Particulate-bed filters must be cleaned periodically to remove the collected solids and to maintain filter flow. Simple removal of the filter cake alone is seldom satisfactory since soft or fibrous solids penetrate the filter surface and become enmeshed in the filter medium. When a permanent medium, such as sand, is used it must therefore be washed free of the solids with clear water so that it may be recovered for continued use.

The well-known rapid sand filter is used almost exclusively in the treatment of water supplies where the concentration of solids is low and where the collected solids can be washed from the sand with filtrate and returned to the receiving waters or to the sewers for treatment. These filters can be used for the polishing of secondary sewage-treatment effluents, but at the requirement of using a large portion of the filtrate for backwashing and of retreating the backwash water. They can not be used for raw sewage or similar high-solids wastes because of the high water requirements and the production of a second waste stream little different from the original.

Because coal is cheap and combustible it need not be washed or recovered; the only requirement is the removal of sufficient water from the waste mixture of coal and sewage solids to permit combustion. Experiments have indicated that a portion of the contained coal might be recovered to reduce process cost, but retrieval of all or any part of the medium is not integral to the process. Backwashing of the coal filter, or other interruption for rejuvenation, is therefore unnecessary, and the total recirculation of filtrate for in-plant use is less than two percent.

The coal filter may be of any shape adaptable to the scraping process. A special underdrain is required to support the coal and to prevent the accumulation of air in the filter bed, which may be chosen from a variety of commercial materials and installed independently of the tank structure.

The initial filter bed depth can be variable, with six feet suggested as a first specification. With allowance for two feet of supernatant water and one foot each for freeboard and for the underdrain a tank depth of ten feet is required. The width of a rectangular filter may be any dimension which can be conveniently bridged by the scraping mechanism. The length of a rectangular filter, or periphery of a round filter, is limited by the required frequency of scraping as determined by the type of waste to be treated, and ranges between approximately 100 and 250 feet.

The sized filter bed coal is mixed with plant filtrate and pumped to the filter tank for placement. No special attention is required, and when the slurry discharge is mounted on the traveling scraper mechanism a flat and level filter bed is deposited. The bed may then be flooded with water and held in readiness until needed.

A treatment run is started by introducing sewage into the filter and starting the scraping mechanism. Thereafter, the filter is gradually consumed; coal is not added during a run. The required frequency of scraping is determined by the type of waste to be treated, and varies between approximately 20 minutes and five hours. Only a thin cut is taken at each pass with 1/32-inch or less required for all cases. The sewage-treatment run requires virtually no attention, and can be automatically controlled. Experience in the 400,000 gallon-per-day pilot plant proved the process to be remarkably immune to misadventure such as the introduction of branches or solid objects into the filter by storms or accident, and to power failure, equipment failure or operator error.

A run may be continued to a terminal bed depth of 3.5 inches or less without decrease in the degree of treatment, and probably to one inch or less when the alternate filter is ready in case the effluent requires polishing. The residue is then washed from the filter as a slurry and added to the scraper sludge for incineration.

The filter bed coal is ground and sized within the limits of approximately 18 and 120-mesh, U. S. Standard designation, and as placed in the filter must contain less than approximately 1.5 percent as dust smaller than 270-mesh. The coal may be prepared by wet or dry procedures but the latter are preferred for flexibility. Conventional grinding and sizing equipment may be used, with special plant configuration and operating procedures recommended to attain the highest possible recovery of usable bed coal from raw coal. An overall recovery of 78 percent was attained in the pilot coal preparation plant -- a value which will probably be exceeded with further refinement.

Coal preparation is independent of the sewage-treatment process, and the coal plant may be located where desired. Coal of the required size can also be purchased in the market, so that small or first-generation plants need not be concerned with the separate activity of coal preparation. For certain applications of the coal-sewage process it also appears feasible to "borrow" sized coal from an existing user, such as a utility plant, and to return the waste solids to the fuel stream. In this application the coal cost to the sewage-treatment facility would be exceptionally low, and the method is especially recommended to industries which presently burn coal or which must select a future fuel on the basis of cost.

Laboratory work has indicated that the fines produced in coal preparation may be used in limited sewage-treatment applications. They may also be sold under certain circumstances. Neither of these alternatives will dependably exist in all cases, however, and the cost estimates derived for the process are based on the assumption that the material will initially be a waste by-product, to be burned for its fuel value only.

The coal-sewage sludge produced in the sewage-treatment operation can be de-watered by gravity-settling to a solids content of 50 weight percent, at which it can be burned in a conventional grate-type boiler. The composition of the stack gas is nearly identical to that when the original coal is burned. Air pollution control requirements are therefore the same as those for coal combustion and may be met by the use of conventional equipment. The use of wet-scrubbing is especially attractive in view of the availability of plant filtrate as clear water and of the plant itself for treatment of the scrubber effluent. Steam is produced in the combustion process and may be used for in-plant purposes or sold, as a means of defraying a portion of the plant cost.

The coal-sewage process was evaluated in the pilot plant for the treatment of raw municipal sewage and for the post, or so-called "tertiary," treatment of secondary sewage-treatment plant effluent. These wastes appear to typify the approximate extremes of process performance. Numerous variations were also examined in order to optimize the separate operations and to obtain an understanding of the process mechanism.

The average degree of treatment attained in these applications is listed in the accompanying table, along with that reported in the literature as attained in existing secondary treatment plants, and with that being recommended to meet the water quality standards established in 1969 under the provisions of the Federal Water Pollution Control Act, as amended.

The chemical treatment used to increase the phosphate removals in the coal-sewage process consisted of the addition of ferrous sulfate to the filter influent to form an insoluble iron phosphate which was then removed on the filter. Waste steel mill pickle liquor may be used. No other chemical additive is needed.

The average filter flow rate in the treatment of raw sewage is 0.35 gallons per square foot of filter per minute at 15 feet of head. At this flow rate, the tank area required for a given flow of sewage is approximately half that required for normal secondary treatment. The filter flow rate in the post-treatment of secondary treatment plant effluent is 1.0 gallon per square foot per minute at 16 feet of head.

In the treatment of raw sewage the consumption of sized filter bed coal, including the filter bed residue, is approximately 9.20 tons per million gallons. In the post-treatment of secondary effluent the coal consumption is approximately 1.32 tons per million gallons.

Process costs are calculated in this report for different plant sizes and coal sources. An example of each process application is given below, for a 100-MGD plant for which a captive on-site coal

The largest cost influence in coal process sewage-treatment is the rate of consumption of coal. Both the cost and coal consumption rates mentioned in this summary are based on actual pilot plant operation and are therefore conservative. Means are indicated in the body of the report by which the coal consumption might be reduced by half or more simply by varying the mode of process control. No alteration of equipment is necessary, and only a slight excess in filter capacity is required to perform the tests.

One of the most expensive and least satisfactory aspects of conventional sewage-treatment is the digestion, de-watering and disposal of the primary and secondary sludges. The cost estimates given in this report for coal-sewage post-treatment assume the redundancy of separate sludge-handling facilities, and therefore reflect the highest probable cost.

Laboratory tests have indicated that when the coal-sewage sludge is mixed with the raw primary and secondary sludges only a single de-watering operation is needed which can eliminate digestion and others of the present sludge-treatment steps. Because of the added heating value of the contained coal the mixed sludge can be burned at a higher water content and temperature with complete stabilization of the raw wastes. Only one sludge-handling facility is then needed and power is still recoverable which may be used, for example, to drive the compressors for secondary aeration. When sludge digestion is no longer needed, the separate step of grit removal can also be eliminated. In this case the waste fines from coal preparation can then be effectively used as a settling aid in the primary process while still retaining their fuel value.

Other refinements are also indicated if the coal-sewage post-treatment filter can be operated experimentally in conjunction with secondary processing. For example, a relatively large fraction of the land required for a secondary treatment plant must be devoted to the secondary clarifiers in order to attain reasonable removals of suspended solids. The extent of secondary clarification can probably be reduced when the coal filter is used for final polishing. In this respect the process should be especially valuable to relieve overloading in existing plants.

The coal-sewage process also offers an interesting opportunity to municipalities which must collect and incinerate garbage and solid refuse. These materials possess a high heating value and are already being used in some cases as fuels for power generation. When the coal process is used in a municipal plant all of the solid wastes could logically be burned in a single incinerator equipped for advanced air pollution control, with the production of significant amounts of power.

preparation facility and an incinerator are included. The cost of raw coal and freight is assumed at $12.00 per ton and interest is calculated at six percent for 25 years. A cost credit of $0.85 per thousand pounds of steam produced in the incineration step is taken. Costs are given in dollars per million gallons of sewage treated.

	Coal Process Treatment of Raw Sewage	Coal Process Appended to Secondary Plant
Total treatment cost	$209.06	$ 46.10
Credit for power	166.60	23.72
Net Cost	$ 42.46	$ 22.38

The coal-sewage process was originally investigated as a new method for the complete treatment of raw sewage. At that time there were no uniform standards for treatment and the performance of new processes was judged mainly in comparison with that of established plants. On this basis the process rated favorably with secondary treatment, and in the case of suspended solids greatly exceeded it. These methods, however, can barely meet the new standards for raw sewage treatment, and will clearly be unsuitable in the future without augmentation as the standards inevitably become more stringent.

The coal-sewage process is therefore not recommended for the routine treatment of raw sewage. When a credit can be taken for the by-product power the cost is exceptionally favorable, however, and the process should be considered for special applications. Industrial uses would be particularly attractive where the steam could be used within the plant and the cost of the coal shared between production and waste-treatment.

When the coal precoat filter is used for the post-treatment of secondary effluent an extremely high degree of treatment is attained at a relatively low additional cost. Design and engineering data have been prepared for a plant of this type, and the process is considered to be entirely feasible and ready for commercial installation.

The process has been designed to be operable as an independent entity, so that it may be appended to existing plants with no interference in their design or operation. The process is modular, with increased capacity acquired by the addition of units. A first-generation plant can therefore be installed and operated experimentally on a small scale, if desired, in the treatment of only a portion of the effluent of the associated secondary plant and later increased without loss of the initial investment. This approach is recommended for first consideration, especially if funds and facilities are available for continuing development, since an opportunity for additional improvement in cost and performance is indicated.

glass columns. Daily composite samples were collected and analyzed over an eight-day period. Results are listed in Table 2-L.

This behavior was observed in many column tests, including the pilot plant, where phosphate removals decreased rapidly with time. On nearly every occasion the rate of removal approached zero after about one week, and thereafter unaccountably increased again to average daily reductions in the order of 15 to 30 percent. At first it appeared that an adsorption-desorption process might be involved, or that biological action might be in part responsible, but neither of these could be confirmed.

The possibility of reaction with iron in the coal was then investigated. Each of two 2-inch coal column was filled with 200 grams of 35 by 120-mesh HVC coal; one was washed with water until no dissolved iron could be detected in the effluent. A solution of KH_2PO_4, containing 48.8 ppm as PO_4, was then pumped through both columns at a rate of 0.5 gallon per square foot per minute (41 milliliters per minute). Results are compared in Table 2-M.

The sample of washed coal can be seen to have approached equilibrium after a total flow of 4600 milliliters of solution; 66 percent of the removed phosphate had been taken up after only 1200 milliliters of flow. The unwashed coal attained only 78 percent of equilibrium after 4025 milliliters of flow, and at 1050 milliliters was still removing virtually 100 percent of the dissolved phosphate.

Discussion

It is evident that substantial quantities of phosphates can be removed from water solution by reaction with coal and that most, if not all, of the reaction is one of chemical precipitation by iron compounds produced from the coal. It was observed in brief tests, and is logical to presume, that this property varies with iron content of the coal.

The reaction is similar to adsorption in that it is controlled by surface area of the coal. It is evident that high phosphate removals are attained on first exposure when large areas are available, and that the reaction then proceeds slowly but for apparently long periods as the surface iron is exhausted and diffusion within the pores of the coal becomes dominant. Application of the coal in the smallest feasible particle size would therefore be the most economical form of use.

It is not clear whether or not the precipitated iron phosphates remain attached to the coal. The initial decrease in removal observed in column tests, followed by an increase, suggests that a portion of the precipitate first formed is released, but that the rate of removal then exceeds the rate of release as the reaction proceeds within the body of the coal particle. Further investigation of this reaction would appear to be warranted.

C. BACTERIA

Except for one series of tests performed in another laboratory the effect of coal on the growth and removal of bacteria was observed mainly in connection with other experiments.

The special test was based on removals of Escherichia Coli, the common E. Coli whose presence in water is generally regarded as an indication of pollution by human wastes.

Two hundred and fifty milliliters of nutrient broth were innoculated with 0.1 ml. of an 18-hour culture of E. Coli, incubated for an additional 18 hours, and diluted to 10 liters. This suspension was determined to contain 6,900,000 E. Coli per milliliter, and was used as feed in a standard adsorption column packed with high-volatile-C coal. The column effluent was sampled periodically and analyzed immediately after each sampling.

For the evaluation of water specimens the bacterial count at the time of collection is not the only criterion; further development of the bacteria depends also on the content of organic nutrients in the water. For this reason a portion of each sample was set aside for ten days, after which a second analysis was performed to determine the rate of re-growth after treatment.

The experiment was also performed with tap water having an initial concentration of approximately 1 organism per milliliter. Results are listed in Table 2-O.

Virtually complete removals of E. Coli were observed until about 2 liters of the inoculated test solution had passed through the column, after which the concentration rose rapidly. Yet, while the concentration of E. Coli in the untreated sample increased by a factor of over 5,000 in ten days, the increase factor in the case of the treated sample after 6 liters had passed was only 250.

Likewise in the case of tap water the bacterial count in the untreated sample increased by a factor of more than 334,000 after ten days, while the count in the treated sample increased by a factor of only 690.

In the case of this one experiment coal was found to be exceptionally effective in removing E. Coli from water, at least in the early phase of the test. Of possibly greater significance is the fact that the concentration of bacteria in treated test media -- both water and the special culture -- increased much more slowly than did that of the untreated sample after ten days' storage. This occurrence was possible due to the fact that the coal removed not only a significant number of bacteria but also a portion of the nutrients required for them to multiply.

VII EXAMPLES OF TREATMENT BY COAL: INDUSTRIAL WASTES

In addition to the basic development work performed with raw sewage, several brief tests were conducted to investigate the use of coal in the treatment of industrial wastes. Most of these were performed early in the program by means of simple column tests without particular regard to flow rate, head or frequency of surface removal.

A number of general conclusions were drawn which appear to remain valid in the light of the subsequent pilot plant study, and are summarized here as an illustration of several different applications of coal in waste-treatment. One series of field tests was performed on the black water effluent from a coal benefication plant, and is also included.

A. SUMMARY AND CONCLUSIONS

With the solitary exception of a caustic black liquor waste from the manufacture of paper pulp, near-perfect removal of non-colloidal suspended matter of all types was attained by coal filtration. An increase was observed in the case of the black liquor, evidently as a result of attack on the coal. Inorganic matter, such as flue dust from a stack gas scrubber and mill scale, and organic matter such as meat solids and cellulose fiber were removed with equal effectiveness.

The removal of dissolved organic matter with respect to COD, BOD, color and odor was variable according to the type and concentration of the waste, but was generally similar to that observed in the case of raw sewage. When HVA and HVC coals were both used the removal of dissolved organics was invariably higher in the latter case, tending to confirm the results of the more basic adsorption studies. Certain materials, notably a mixture of fatty acids in water, were removed almost quantitatively by coal, suggesting that a high degree of chemisorption can take place.

Purely ionic inorganic matter was not removed by coal and, with exception of the caustic black liquor, did not appear to attack the coal.

The use of coal as a means of treating industrial wastes can be considered by the same criteria as those used for municipal sewage, providing that simple laboratory screening tests are performed to measure the probable degree of treatment attainable and to insure that attack of the coal will not ensue. Filter flow rate and coal consumption will be variable as these are discussed in Part Four in connection with a unified process, but these factors are apparently also responsive to the criteria used to judge mixed sewage.

Tests

Imhoff cone settling (no coal)
Filtration of 2.0 liters through 4-inch bed of High-Volatile-C coal, 60 by 250-mesh

Results

	Raw Waste	After Test	Reduction
Imhoff settling	0.6 ml/l	Slightly turbid	-
COD	120 ppm	77 ppm	36 percent
Coal Filtration			
COD	120 ppm	23 ppm	81 percent
Color	As above	Water-clear	Complete
Odor	As above	Absent	Complete

Discussion

The coal filter was effective in removing the suspended solids. The difference between the 36 percent reduction in COD obtained after settling and the 77 percent reduction after filtration was probably due in part to the adsorption of dissolved matter from the water. Odor-reduction was significant.

e. Summary

With the exception of coke plant wastes steel mill wastes are mainly soluble ionic inorganic compounds and comparatively inert materials such as scale and dust.

The use of coal is ineffective for the removal of dissolved inorganics; but is obviously suitable as a filter which exhibits the added properties of adsorbing quantities of organic matter. Primary settling of such wastes as mill scale or scrubber effluent would probably always be advantageous for the removal of dense solids. Subsequent coal-filtration would then appear to be an effective means of removing residual solids and color and odor, particularly if the fine coal could then be used elsewhere in the operation.

2. Meat Packing

Samples were provided by a medium-size beef packing company which slaughters an average of 250 head of cattle per day, using an average of 1,000 gallons of water per animal. Fresh water is first used in the cleaning of carcasses and in the general preparation of meat. This waste is settled for one hour for the separation and recovery of grease, and a portion of the effluent is then recirculated as a medium for handling the "paunch manure", or undigested food, which

VI SUMMARY AND RECOMMENDATIONS

The coal preparation pilot plant was designed and operated on a production scale according to data discussed in the foregoing sections. Modifications were made where possible, and information was obtained during operation which suggested further changes. The following recommendations are based on both the experimental data and on modifications indicated by the data.

The scheme of coal preparation presumes the location of the coal preparation plant as a site remote from that of the sewage-treatment operation, although none of the following reasons excludes location at the sewage-treatment plant.

1. A single plant can serve any number of different waste-treatment plants without its own operation being influenced by schedules, personnel or operations specific to any one of them.

2. The disposal of waste fines does not become an operation inherent to that of a given sewage-treatment plant. Fines may be used or not as dictated by individual conditions.

3. Heavy freight handling facilities, such as railroad sidings, are not required as part of a sewage-treatment plant.

4. The economy of coal preparation is enhanced when a number of sewage-treatment plants can be served by a single large facility.

Ground coal is difficult to handle when wet, and special procedures would be necessary if wet-processing were used, especially where freezing could occur. Except for dedusting there is no basic need for wet-processing; and therefore the method of dry grinding and sizing is recommended.

There is no disadvantage in not performing the dedusting operations at the coal preparation plant; there are, however, advantages to dedusting at the sewage-treatment site:

1. The relatively low dust content of the sized coal can be readily accommodated in the sewage-treatment operation, and therfore no special methods for disposal are required.

2. The dedusting step is compatible with the method of filter loading, and when performed in conjunction with it can be conducted at virtually no cost.

3. It is possible, though not dependably so, to dedust the bed coal adequately at the coal preparation plant; however, the handling of sized coal produces fines, so that there would be no certainty

The matter was further complicated by the fact that ground coal contains incipient fractures and on handling continues to decrepitate with the formation of fines, the degree varying with the type of coal and grinding process. Thus, even when a stream of sized coal could be properly sized and analyzed there was no assurance that sufficient additional fines would not accumulate on further handling to exceed the filter bed specification. It was evident that a process based on dry-screening alone, with quality control performed by a sensitive analysis itself prone to error, would be precarious at best.

The use of a hydrocyclone as a final dust removal step immediately prior to placement of the filter bed was then incorporated as part of the filter preparation procedure. By this means dust levels as high as approximately five percent in the screened coal could be reduced to less than the specified one and one-half percent in the filter bed. The criticality of both the dry-screening operation and the method of size analysis was therefore eliminated, as was the risk of additional dusting of sized coal in handling between the screener and cyclone. This one form of coal-sizing and handling was therefore advanced in this program to a simple and practical commercial procedure. Dry-screening is subject to limitations, however, and the examination of other methods was continued.

The experimental work reported here was performed over most of the six-year period of the two programs. Some of it preceded the final determination of specifications for filter bed coal and some followed the selection of the pilot plant equipment. The subject is therefore presented in the light of what is now known, with no pretense of a logical evolution which did not always exist.

A. EVALUATION CRITERIA

It is characteristic of screen processes that a substantial portion of sizes immediately smaller than a given screen will remain on the screen and thus appear in the nominally larger size cut. This behavior is due in part to particle shape and occurs when a particle of near-screen size does not become oriented in its passage across a screen at such an attitude as to permit it to pass. The condition is considerably aggravated when the screen is flooded, or overloaded, and generally worsens at smaller sizes.

For the same reason the rescreening of a given size cut will indicate the presence of particles larger than the large end of the cut, which chanced to pass the screen in the first operation but which were not properly oriented to pass the same screen in the second.

This behavior can not be prevented when particles of irregular shape are involved, but is of little practical consequence since the particles are so close to nominal size. It was observed that nearly all of the particles so affected could be found within two mixer was mounted at the top of the tank. Coal slurry water could be obtained either as pilot plant effluent or city tap water and was metered into the tank with an appropriate air-break in the latter case, through a rotameter (3). Manual and float valve controls were used.

A five-horsepower, variable-speed positive displacement pump (Moyno Type CDR) was connected to the bottom of the slurry tank (4), discharging through a 1-1/2-inch steel pipe main to a point central to tank loading; a bypass return from the main to the slurry tank was useful for purposes of experimental control. From the end of the slurry feed main a 1-1/2-inch hose led to the filter tank being loaded, where it could be moved over the surface manually or mechanically by attachment to the filter surface removal mechanism (scraper). For most tests a hydrocyclone was introduced into the slurry line and was erected on the scraper.

The rate of coal slurry production was controlled by manual adjustment of the slurry pump speed and was dictated by the pressure and flow requirements of the de-sliming cyclone. In typical operations a slurry of eight volume percent of coal in water was delivered to the cyclone at a rate of 60 gallons per minute at a pressure of 12.5 psig. Concentration of the slurry was controlled by adjustment of the coal feeder, with makeup slurry water added by the float valve.

b. Filter Tanks

Each of the three filter tanks was 10 by 40 feet in plan, with a bottom slope of one inch in five feet (eight inches overall), and 18 feet, 7 inches deep at the deep end (5). A plan and sections of a typical filter tank and wet-well set (No. 3) are shown in Figures 4-5, 4-6, and 4-7.

Each tank drained through a six-inch valve into a wet-well, or sump, 19 feet deep and four by six feet in plan (7). A standpipe (8) upstream from the valve provided for introduction of filter makeup water, available as either pilot plant effluent or fresh water, through a rotameter (9). For underdrain tests an air-release standpipe (6) was provided at the upper end.

Each wet well was connected to a 15-horsepower centrifugal pump (10), which discharged through a pneumatically-operated throttle valve (11). To permit flexibility of operation and to eliminate the need for much heavy plumbing the feed and effluent lines were grouped in a common distribution center where any process stream could be directed to any receiver by means of movable hoses (Ref. Figure 4-2).

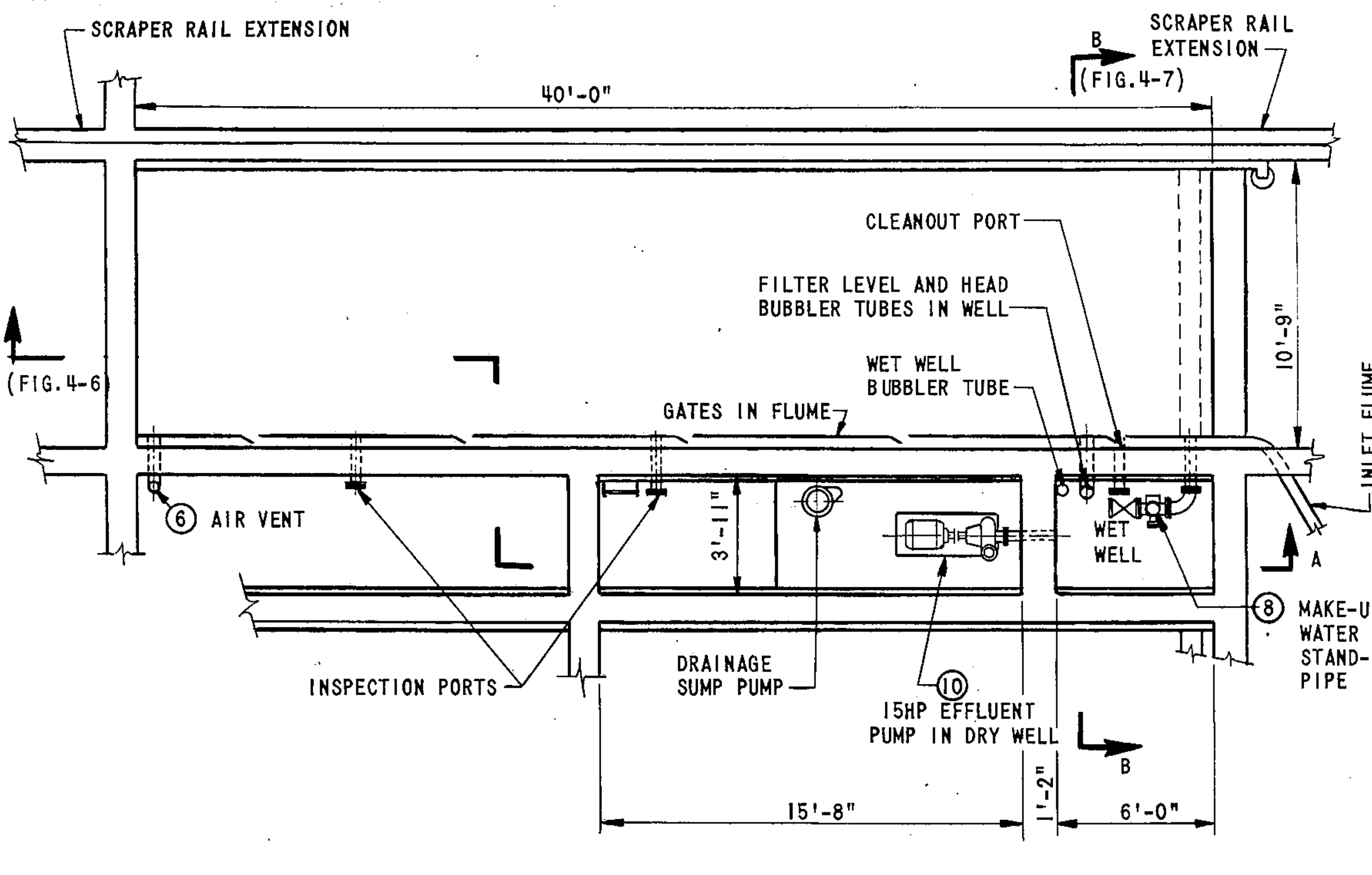


FIGURE 4-5
TYPICAL FILTER TANK AND
WET WELL SECTION (TANK 3)
COAL-SEWAGE PILOT PLANT

This mode of operation was found to be unnecessary and only two of the tanks were finally equipped with underdrains. The third was then available for special experiments involving chemical additions, sedimentation and the storage of large volumes of liquid.

2. Method of Filter Surface Removal

It had been learned in pre-pilot plant studies that the necessary removal of the surface layer of coal and sewage solids could be conveniently accomplished by hydraulic means, wherein a pump inlet was moved over the bed surface. The method was difficult to control, however, especially when gross solids such as rags were present, with the result that relatively large (1/8 to 1/2-inch) and uneven cuts frequently resulted. The necessary velocity of pumping also indicated that a large amount of water--perhaps as much as 25 percent of the process flow--might be required, and thus re-introduce the disadvantage of having to process a side-stream of waste water not greatly reduced in volume from that of the original sewage.

The pilot plant design was therefore based on the use of mechanical filter surface removal, where a thin surface layer could be separated from the filter by a positive cutting action, with the sludge stored in the removal apparatus for periodic transport from the tank. For the latter step pumping was selected as a more positive control of fines and flocculant solids.

3. Coal Preparation

The Easterly Pollution Control Center is located in a residential district and is noted for its park-like landscaping. To minimize disruption of the area for the experimental work and to have direct access to a railroad siding the coal preparation facility was located in an industrial area several miles away. Storage and transfer of the sized coal were required, and the investigation of means by which coal could be prepared either locally or at a remote site was therefore incorporated into the pilot plant plan.

Wet-sizing of coal had been found in the pre-pilot plant work to offer advantages in control of dust content. Special methods for storage, handling and transfer--especially in freezing climates--were indicated, however, as was a drawback in that the sewage-treatment plant operator would have no control of quality in cases where the coal was prepared at other locations. Dry-sizing was therefore selected, with final dust removal to be accomplished as part of the filter preparation procedure.

Various types of air classifier had been field-tested prior to the selection of equipment for the pilot plant. The method was found to be simple in operation and effective in maintaining a low dust content in the product coal but was not satisfactory in attaining the

7. Emphasis on practicality, dependability and cost of operation of any process steps as refined in the pilot plant

B. DESIGN OPTIONS

The design of the pilot plant was based wherever possible on data obtained in the earlier experimental work. Options were available in several cases, and are discussed below.

1. Filter Tank Shape and Size

Filter operation was based on a batch process in which a filter tank would be filled, operated to exhaustion and refilled, with continuous operation of a plant attained by alternation of process units. Continuous introduction of coal into the filter bottom was rejected on the basis of the large amount of equipment required for commercial-size plants and anticipated difficulty and cost of maintenance. The method of lowering the surface removal mechanism as the bed was consumed was therefore adopted as opposed to that of continuously raising the bed to a fixed-level scraper.

A period of one-to-two months was selected as a reasonable cycle of operation, and allowance was made for a ten-foot filter bed. A minimum of six feet of supernatant sewage was provided in order to gain head and to insure that the bed surface would not be disturbed by the incoming sewage. With allowance of one foot each for underdrain and freeboard a total tank depth of eighteen feet was therefore indicated. In order to preserve continuity of the tank floor the receiving wet wells were of the same depth, so that with allowance for piping a head of fifteen feet was available. This value was arbitrary; in commercial practice a great economic advantage would result from the use of a deeper wet-well since substantially higher flow rates can be attained in the same installed plant simply by increasing the filter head.

Filter design is independent of surface geometry, and either round or rectangular tanks appeared equally useful. Rectangular tanks were chosen to eliminate the necessarily variable scraper blade velocity which would obtain in round tanks, and also as being more nearly prototypal to large plants where increased capacity could be attained simply by extending the tank length. Round tanks would be equally effective in practice and, for small plants, cheaper to build.

The pilot plant was designed to permit the use of two treatment tanks operating in series, in the event of deterioration in the degree of treatment as one tank approached exhaustion. Thus, three tanks were installed so that one could be loaded while two were operating.

Secondary treatment plant effluent, when used as feed to the pilot plant, was obtained from the Easterly secondary clarifiers through an in-plant system.

The coal preparation pilot plant was located on industrial property approximately two miles from the Easterly site. Railroad siding and switching facilities and truck scales were available, as were watchmen services, heat and utilities.

Electric power was metered at both sites.

D. COAL PREPARATION FACILITY

The coal preparation pilot plant was designed and engineered to specification and erected under joint subcontract by The Jeffrey Manufacturing Company of Columbus, Ohio, and McDowell-Wellman Engineering Company of Cleveland, Ohio. Design conferences were held with the U. S. Bureau of Mines and with Cleveland Fire and Safety Officials to insure that the mill would meet the most advanced safety standards. The Penn-Rillton Company of Florham Park, New Jersey, and West Elizabeth, Pennsylvania, kindly contributed many valuable recommendations based on its own experience in the production of foundry facings from coal.

All construction and electrical work conformed to local and Federal Code. Class 1-D, explosion-proof electrical equipment was used throughout the plant. High temperature sensors were installed with central-station alarm reporting, and conventional protective devices were installed in the mill as described below.

The coal preparation and handling equipment was housed in a one-room metal-sheathed steel frame building 50 by 80 feet in dimension, to which access could be gained only from out-of-doors. Controls, office and sample-handling facilities, and a washroom occupied an addition to the building separated from the mill room by a concrete block wall. An explosion-proof diesel fork truck was used to handle the product coal.

Construction

Except for the receiving pit the coal crushing and sizing equipment, or mill, was erected as a free-standing steel-frame structure. The mill was 23 by 31 feet in plan, rising 39 feet above the floor and 50 feet above the bottom of the lowest elevator pit. Figure 4-1 is an isometric drawing of the mill, numbered with reference to the following description.

Coal was received by railroad hopper car. The car was positioned over a feed pit (1) from the bottom of which a variable-speed screw feeder (2) metered the raw coal to the No. 1 bucket elevator (3). The feeder sharpness of cut considered necessary at that time for the filter development investigation.

Dry-screening was recognized to have drawbacks in respect to cost and sensitivity of operation, with incomplete control of dust content in the product coal. The method was chosen for use in the pilot plant, however, because of the size-control which could be attained by it.

Dry-screening as a means to produce sized coal was the only process step which was recognized at the time of pilot plant design not be prototypal of large-scale plants. It was intended that the method would be used until the filter parameters were defined, after which an air-classifier could be chosen. This plan was accomplished, and an air-classifier was used with complete success for later pilot plant tests runs.

C. LOCATION AND FACILITIES

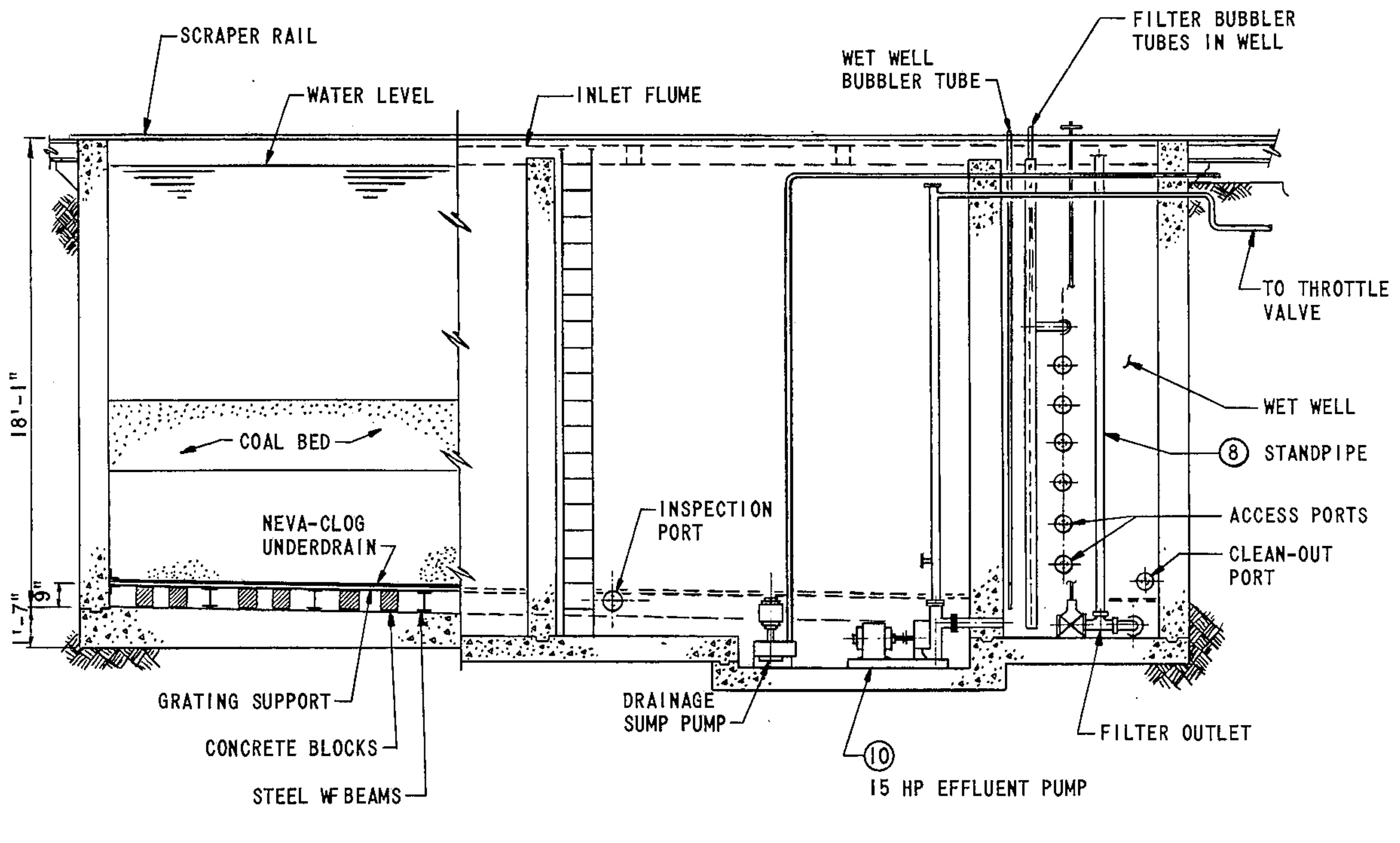
The hydraulics, or sewage-treatment, section of the pilot plant was installed on the site of the Easterly Water Pollution Center, 14001 Lake Shore Boulevard, Cleveland, Ohio. The Easterly plant is the largest of three sewage-treatment plants serving metropolitan Cleveland, and provides secondary activated sludge process treatment to a design flow of approximately 120,000,000 gallons per day of mixed domestic and industrial sewage.

The typical flow rate at Easterly during this program ranged from approximately 75 million gallons per day (three million gallons per hour) at night to 180 million gallons or more during the day in dry weather. During storm conditions the plant flow attained a maximum of 200 million gallons per day.

The Easterly plant is a complete treatment facility except for the disposal of the primary and secondary sludges. These are pumped to the Southerly Sewage Plant, a secondary treatment plant treating approximately 75,000,000 gallons per day of municipal sewage, where the sludge wastes from both plants are digested and incinerated.

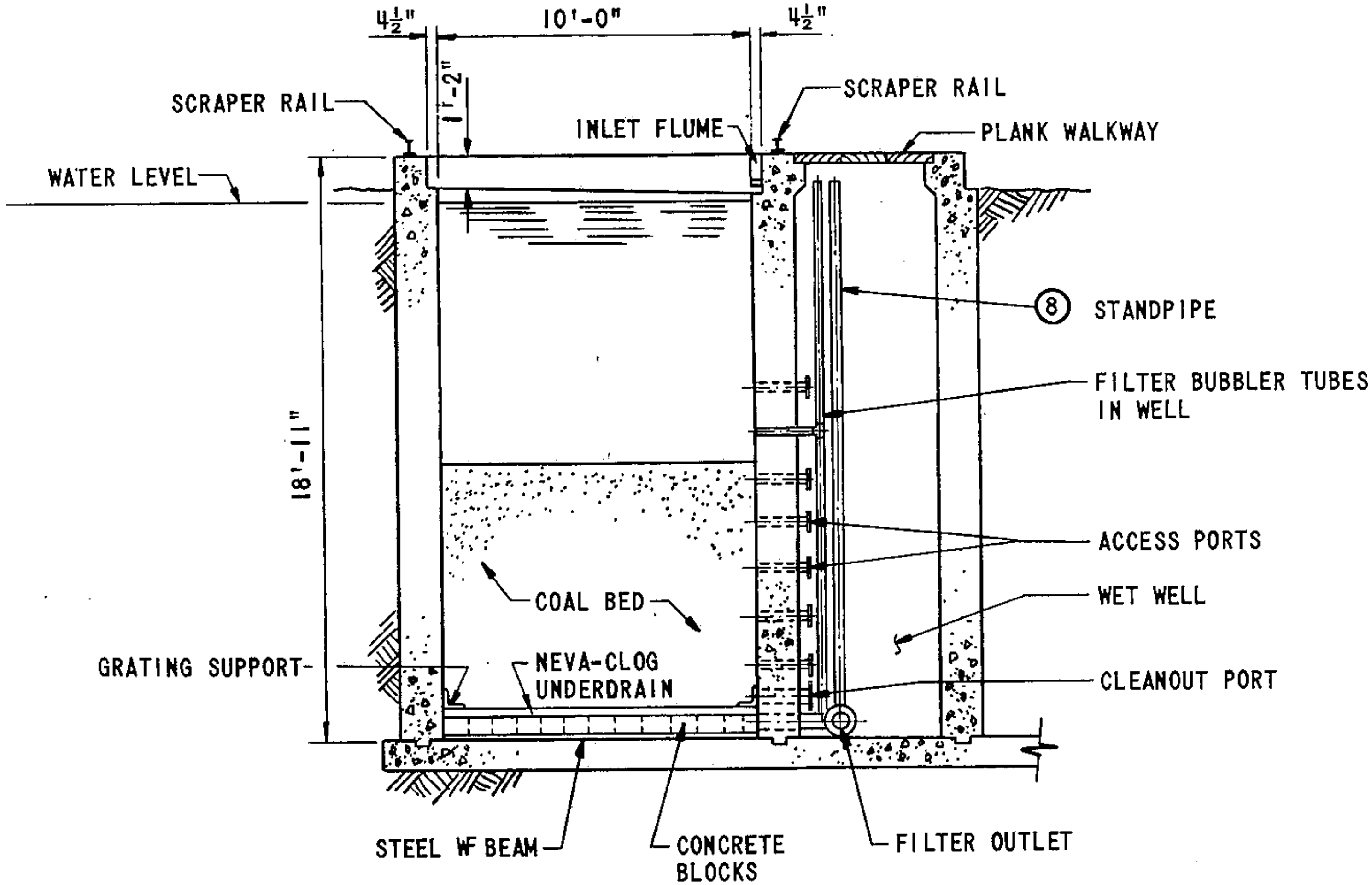
The Easterly plant does not pre-screen raw sewage. Coarse solids are comminuted, or shredded, as the first treatment step. Raw sewage for the pilot plant was drawn from the plant influent immediately downstream from the Comminutors, and therefore received no pre-treatment other than size-reduction of coarse matter.

The first treatment step at Easterly is the removal of grit by means of Dorr Detritors in which dense, mostly inorganic, solids settle and are removed. All pilot plant effluents were discharged into the plant flow upstream from the Detritors.



SECTION A-A
(FROM FIGURE 4-5)

FIGURE 4-6
TYPICAL FILTER TANK AND
WET WELL SECTION (TANK 3)
COAL SEWAGE PILOT PLANT



SECTION "B-B"
(FROM FIGURE 4-5)

FIGURE 4-7
TYPICAL FILTER TANK AND WET WELL SECTION (TANK 3)
COAL-SEWAGE PILOT PLANT

Filter bed preparation was normally a continuous operation, occasional interruptions occurred, but were found to cause no difficulty. The Tote-Bins of sized coal received from the preparation plant were placed on the discharge stations by use of a jib crane, with the coal fed continuously to the mixing tank at an average rate of one ton per hour. Fresh water was added to the mixing tank through a float valve, and the resulting slurry was pumped continuously into the dedusting device (Ty-Hukki classifier or hydrocyclone) which was mounted on the scraper mechanism over the filter. By continuously recycling the scraper and occasionally moving the cyclone discharge hose, it was possible to deposit a nearly level and uniform filter bed.

The operation was basically automatic, requiring an operator mainly to change the Tote-Bins and to adjust the location of the cyclone discharge.

In loading of the filter the slurry water drained through the bed as rapidly as introduced and was periodically removed by pumping. This operation was not automatic but could have been made so by changing the filter wet-well design. The cyclone overflow discharged into a gutter adjacent to the filter tank and was customarily discharged to waste. In several experiments the overflow water was collected in the non-operating center tank simply by extending the cyclone overflow outlet over the intervening walkway, without the need for the gutter or pumping. This method would be convenient in an operating raw sewage system for return of the overflow black water to the raw sewage inlet.

On completion of filter loading the bed surface was levelled if necessary, manually or by drawing the scraper blade backwards the length of the bed. Under projected conditions only the latter operation, if any, would be necessary.

The bed-loading procedure was normally straightforward. In extremely cold weather, at temperatures below approximately 10°F, the surface of the bed tended to freeze if the loading operation was in any manner delayed. Generally, the contained heat of the filter tank and the incoming slurry was sufficient to prevent freezing; however, the potential for freezing should be considered in future installations. No other cold-weather difficulties were encountered during bed preparation as long as the fluids were not allowed to stand for long periods in exposed piping. Nor were any cumulative freezing difficulties observed, such as the gradual formation of ice encrustations on the exposed cyclone which might alter its orifice size and operation.

In windy weather, especially if the makeup operation was interrupted, it was occasionally necessary to remove branches and other large wind-borne debris from the bed as it was placed. Leaves and other small objects created no difficulty.

On completion of bed loading the slurry and desliming equipment was simply drained, with no need for stand-by precautions except for the prevention of freezing in any water lines which could not be drained. Electrical heating tapes were useful for this purpose. In commercial practice the slurry equipment would logically be placed indoors.

Makeup water was introduced through a hose connected to the filter outlet standpipe (Figure 4-5). Fresh water was metered at rates of approximately 1/20 GF^2/M (20 GPM for a filter) until several feet of water had accumulated over the bed. No special depth was required as long as several feet of water were available to cushion the first inrush of sewage; usually the makeup operation was allowed to continue overnight unattended. Data listed for quantities of makeup water "used" must therefore be adjusted for what was otherwise a factor only of convenience.

3. Filter Operation

Raw sewage or secondary treatment plant effluent was delivered to the pilot plant area and controlled as described in Section II. When the filter was operated with no pre-treatment steps, a run was begun simply by resetting the recorders and totalizers to zero and starting the pumps and scraper. The filter tank would fill at the maximum feed pump delivery rate of approximately 22,000 gallons per hour until the operating level was attained, after which the filter water level and influent flow were controlled automatically according to the demand of the filter.

At the start of a run the sewage was therefore diluted with residual makeup water and the filter flow rate was consequently initially high. The capacity of the wet-well pump was approximately 16,800 gallons per hour, or 280 gallons per minute, so that when the filter flow exceeded this rate the wet-well water level would rise and thereby decrease the filter head until the flow rate matched the capacity of the pump.

Most runs were therefore started at decreased heads of two to eight feet, since the flow rate at higher heads exceeded the pump capacity. The filter generally attained equilibrium after approximately 20 to 40 hours of operation, during which time the head was gradually increased to the intended set value, usually 12 to 14 feet. Scraper operation was also begun toward the end of this initial period.

Equilibrium was denoted by a leveling of the flow rate at the set head with the scraper in operation. At this time the makeup water had been replaced by sewage and the penetration rate of sewage solids into the bed surface had decreased to the same rate as the rate of removal of the bed surface by the scraper.

The scraper extended to approximately 3.5 inches above the underdrain, so that a residue of coal always remained in a filter as completion of a run. Because of scheduling limitations, most of the runs were arbitrarily stopped at higher levels once the performance of a thin bed was established. Several hours from the anticipated end of a run the inlet flow was stopped and the filter allowed to drain with the scraper operating. The scraper was then stopped and the remainder of the water allowed to drain overnight.

In the pilot plant the remaining coal was removed and discarded, by opening a drain flange at the surface of the underdrain and flushing the remaining coal into the wet well, from which it was pumped as a slurry for discharge. Usually, one man operating a fire hose supplied by either fresh water or effluent from an operating filter would clean a tank in four to six hours. This crude operation was not refined; however, it appeared that the residual coal could be removed by the scraper if it were modified to approach closer to the underdrain and if provided with water jets to fluidize the coal. Brief tests, described elsewhere, indicated that a portion of this coal, as well as of the coal contained in the filter sludge, could be recovered for reuse; however, as a minimum the material could either be added to the scraper sludge for dewatering and incineration, or returned to the plant inlet or the inlet of another filter.

No tendency for an operating filter to freeze was observed, in spite of temperatures below zero and high winds. It was necessary to heat the pumps and piping during standby periods; however, the filter tanks could be filled with water and covered with planks with only a surface layer of ice collecting.

In a commercial operation it would be logical to contain the principal hydraulic equipment within a heated building, so that only the filter tank and scraper would be exposed. Many fewer difficulties than expected were encountered with freezing; and the need for housing the filters would appear to be determined by the form of operation and the climate at each installation. Certainly the working conditions for operating and maintenance personnel would be more salutary; however, in a plant where only the filter tank and scraper were exposed the equipment could be weatherproofed to a degree by such as a heated housing on the scraper.

No special attention was given the system between runs except for a cursory washing of sewage and coal from the equipment. In several cases the filter residue was allowed to remain in a tank for several months, but was readily removed with no apparent damage to the underdrain having resulted. Mainly for the safety of personnel and visitors, the tanks were covered with planks when not in use.

Unless experimental changes were made the run then proceeded automatically, with the scraper operating according to a pre-set program. The filter level and head were maintained by the automatic controls as long as the total flow rate did not exceed 280 gallons per minute, or approximately 0.7 gallon per square foot per minute. This condition did not occur in the pilot plant except in the startup of all runs and in the post-treatment of secondary treatment plant effluent. The behavior in the latter case is described in the summary of Run No. 11 in Section D.

Characteristically, the surface of a filter bed was soft at the end of the makeup operation, prior to the start of a run; a 1/2-inch rod could be manually pushed into the surface to a depth of one foot or more. The surface hardened only slightly during the first hours of filtration when the supernatant was relatively clear water; but as a layer of sewage solids accumulated the surface became quite hard and could barely be penetrated by the 1/2-inch rod. During this initial period the bed surface also subsided several inches, probably by compression of the supernatant water against the surface layer of sewage solids. After a run had attained equilibrium the bed surface remained hard and flat, with no tendency to settle or swell, and was not altered in this respect by operation of the scraper. When a run was interrupted for periods of more than a few hours the bed surface would soften slightly, but on resumption of flow return to its previous condition without apparent harm.

The method of introducing sewage into the filter through the gated flume on one side of the tank appeared to be effective, although the design of the gates was such that rags and string tended to gather on them. These were removed periodically and discarded into the tank without apparent effect by the clumps of soft matter on the scraping operation.

The probability of large objects being inadvertently dropped into an operating filter was considered and often demonstrated. Objects ranging in size from nails to 4-inch pipe fittings, as well as tools of various sizes and shapes were occasionally lost in the opaque supernatant sewage. At first these were carefully removed by fishing with a magnet; however, when the scraper sludge-collection trough was modified with the center-discharge auger it was found that such objects were collected by the scraper and, if too large or heavy to be pumped out with the sludge, simply retained at the center of the trough until the run was completed. It was never necessary to drain a filter to retrieve lost objects.

In the same respect the Neva-Clog underdrain was found to be resistant to damage by objects dropped onto it when the tank was empty. In any event the material is readily patched by brazing or welding.

The phosphate precipitants are also flocculents, forming, in the case of iron, a hydroxide floc which is effective in entrapping colloids and fine solids which could otherwise penetrate the filter. By their use the fine solids are agglomerated into masses of such size as to be retained on the filter.

The differences among the solids removals listed in the first five columns of Table 4-CC are probably not significant in view of the comparative shortness of some of the tests. It was observed during the phosphate removal tests that when ferrous sulfate was carefully added at such a rate as to react with the available phosphates with no appreciable excess the degree of removal reflected by the composite samples was generally higher. The use of lime to enhance the formation of iron floc in the influent produced the same results. Apparently when an excess of soluble iron was present the increased formation of hydroxide floc in the composite effluent sample was responsible for the lower apparent degree of solids removal.

The value of polyelectrolyte as a means of improving solids removal in the filtration of raw sewage was not confirmed, although in visual observation the effluent generally appeared somewhat less turbid than when the material was not used. It does not appear likely that the added cost could be justified for this purpose alone in the case of raw municipal sewage.

When the filter influent consisted of secondary (biological) treatment plant effluent, the filtrate was always water-clear and did not exhibit subsequent growth of solids in the analytical composites. Relatively few fine solids were present in these influents to penetrate the filter; and, since the soluble BOD was low as a result of the previous treatment, insufficient nutrients remained in the filtrate to sustain continued biological action in the composites.

Conclusions

1) As a means of treatment the coal-sewage filter as examined in this program appears capable of removing virtually all suspended solids except those in the colloidal and near-colloidal sizes. Typical solids removals range from 96 to 99 percent, varying according to the content of fine solids in the influent.

2) In the measurement of solids-removal by the coal-sewage filter allowance must be made -- as it must be in any other treatment process -- for the subsequent growth of solids in the effluent and effluent samples as a result of biological and hydrolytic reactions deriving from residual dissolved matter. Apparent errors of five or more percent in the apparent filtration efficiency can be introduced by these processes.

in all raw sewage runs at twelve feet of head. Only a suggestion of higher flow rate at lower solids concentrations is apparent.

The relationship was obviously not direct, and attempts to define it continued throughout the program. Certain repetitive patterns became apparent, which indicated that the rate and direction of change of influent solids concentration was more influential than was the actual solids level; and it also appeared that two design features of the pilot plant -- the configuration of the filter tank and of the scraper blade and collection trough -- were also involved.

Many graphical correlations of flow rate with independent variables were attempted, these including total contaminant level, time into the run, season, and suspended solids in both parts per million concentration and total pounds over fixed intervals for the same day and preceding two days and for the sums and averages of these in all combinations. No direct dependency was apparent, however, except as can be summarized as three general trends:

1) When the influent solids concentrations increased suddenly from a relatively low and uniform level, the flow rate would immediately decrease. If the solids concentration then decreased rapidly the flow rate would generally increase accordingly. A direct and reasonably prompt relationship therefore existed, but mainly in cases where abrupt and transitory changes in solids concentration followed a period of low solids concentration.

2) When the suspended solids level rose and remained high for several days the flow rate would first decrease but then gradually rise to a moderate level, indicating an ability of the system to attain equilibrium, though only gradually, in spite of a high overall influx of solids.

3) When the suspended solids level decreased abruptly following a period of generally high concentration, the flow rate would not normally respond for periods varying to as long as three days or more. Thus an element of lag was also apparent. This condition is well illustrated in Figure 4-17, where the influent solids concentration had remained exceptionally high from the fifth through ninth day of the run.

Normally, then, the solids concentration began to rise sharply on Monday following a period of low weekend concentrations, with a characteristic sharp decline in flow rate to a typical low on Tuesday or Wednesday. Although the solids concentrations usually remained high the flow rate would gradually rise later in the week, seldom changing appreciably with abrupt changes of short duration in solids concentration. The influent solids level then normally dropped on Saturday but the flow rate did not rise notably until the following day, during which it continued to rise steeply until the Monday influx

In a 5-MGD post-treatment plant, for example, the entire flow could be accommodated in a single filter, so that one extra filter would be required for alternation. Assuming two weeks for cleaning and bed preparation, the spare filter would be available eighty percent of the time, representing a plant overcapacity of 100 percent during that period.

This overlap period could be used to advantage for optimization in early plants. In subsequent installations it would be reasonable to divide the nominal flow between the two filters, thus halving the required flow rate. Since this reduced flow rate could be maintained by less frequent scraping the rate of coal consumption would then be considerably decreased, while the operating life of a filter would be extended in proportion. This important consideration and certain interesting ramifications of it are discussed further in subsequent Section VII.

The materials balances and design calculations presented in Section VII are based largely on the actual pilot plant operation, without optimization except in respect to the standardization of filter bed depth and scraper cut and frequency. The calculated values agree well with the pilot plant data, but are somewhat lower in the case of raw sewage where, in the pilot plant, most of the runs were performed at unnecessarily deep scraper cuts and at experimentally reduced filter heads.

2. <u>Coal Recovery</u>

An exceptionally attractive means by which coal consumption might be further reduced, by half or more, would be the recovery of a portion of the used filter bed coal from the scraper sludge, as well as from the filter residue.

One of the most important advantages of the consumable coal filter over sand filtration or fine straining is the fact that the filter medium need not be cleaned or otherwise separated from the sewage residues. These steps are normally costly for sewage-treatment, in the quantities of clear water required for rejuvenation, and are eliminated in the coal process where the mixture of coal and sewage solids is simply incinerated after removal of a portion of the contained water.

Coal is no less readily separable from sewage solids than is sand when considered on a quantitative basis. However, it was frequently observed in the pilot plant that when samples of the dilute (approximately five weight-percent) filter sludge were settled half or more of the contained coal settled almost immediately, with the remainder of the coal and the sewage solids then settling more slowly.

Coal consumption is a derived function which can be accurately calculated only after other process variables have been determined and fixed; it can not be controlled independently.

Six variables influence coal consumption:

1) Efficiency of recovery of sized filter bed coal in the coal preparation plant, the sized coal including the dust which can not be removed by dry-processing

2) Dust content of the sized filter bed coal, removed during the bed preparation step

3) Apparent density of the filter bed as placed

4) Quantity of coal remaining in the filter and not recovered or re-used at the end of a run, as a proportion of the quantity originally charged

5) Depth of scraper cut during the sewage-treatment run

6) Frequency of scraping.

For design and cost purposes coal consumption may be calculated from four viewpoints:

1) The quantity of coal removed from the filter bed during the sewage-treatment operation per million gallons of sewage treated. This function is most influential on coal consumption and is determined by the required depth of cut and frequency of scraping for each process application.

2) The total quantity of sized dedusted coal placed into a filter, including the unconsumed portion of the filter bed, prorated over the total quantity of sewage treated. Certain latitude is available in this respect, depending on the depth to which a filter can be operated (preceding Section C-2-b) and the possibility of recovering and reusing the residue coal.

3) The total quantity of sized, but not dedusted, coal received at the filter bed preparation operation, prorated over the quantity of sewage treated. Normally this rate is only slightly greater than that for No. 2 above, reflecting the added weight of dust in the feed coal, but is a useful calculation when coal is purchased to size.

4) The total quantity of raw coal required for a run, including waste fines and dust, prorated over the total quantity of sewage treated in the run. This rate is the maximum possible, and assumes waste of all fines and no recovery of used coal.

No operating abnormalities or hazards were encountered or are anticipated. In windy weather, especially if the bed placement operation was interrupted, it was occasionally necessary to remove branches or other large wind-borne debris from the bed as it was placed. Leaves and other small objects created no difficulty.

2. The Sewage-Treatment Operation

a. Filter-Adsorption Tank Design

The pilot plant filter-adsorption tanks were rectangular in plan, 10 feet wide and 40 feet long. The dimension parallel to the scraper blade (width) is modular and limited only by structural requirements of the scraper. Total filter flow varies directly with filter width.

Tank length is also approximately modular in respect to flow rate, but is limited by the required frequency of scraping and the maximum possible scraper speed.

Plan geometry is restricted only by the ability of the scraper to reach all of the filter bed area. Round filters were investigated on the four-foot diameter test rig scale, and would not possess any inherent drawbacks. The effect of the variable rate of blade travel over the surface could not be investigated, but from general observation was not concluded to recommend against the use of the design as long as other scraper requirements were maintained.

The two-inch clearance allowed in the pilot plant between the scraper blade and the side and end walls of the tank appeared reasonable. A shoulder of unscraped coal, amounting in the pilot plant to four percent of the surface area, accumulated as a result and in the early runs periodically sloughed onto the bed surface but to no apparent detriment. The later addition of stiff rubber wipers to the sides of the blade provided positive control and is recommended.

The pilot plant tank depth of approximately sixteen feet was unnecessarily great in all runs and detrimental in some, where the supernatant depth of over fifteen feet at times caused excessive detention and the concentration of suspended solids by settling. The depth need be only as great as the initial thickness of the filter bed plus the minimum supernatant to prevent scouring of the surface by the incoming sewage. A two-foot depth was found satisfactory for this purpose, so that for an operation starting with the recommended six-foot filter bed a tank would be approximately nine feet deep above the underdrain when one foot of freeboard is allowed.

The method of controlling filter head by throttling the output of the wet-well pump was simple and effective. As illustrated in the test runs with secondary effluent where the pump capacity was inadequate, an alternative method is to operate the pump at a fixed rate less than the maximum filter flow rate. In such a case the head becomes self-controlling, automatically adjusting itself to compensate for variations in filter flow. There does not appear to be any limitation regarding minimum head: The pilot plant filter was operated at heads of as low as two inches. The head could be reduced to zero during interruptions and then increased to flow conditions days later without apparent effect.

d. Sewage Supply and Control

The method of distributing the incoming sewage through a single channel on one side of the filter was satisfactory, although in the pilot plant the design of the gates was such that rags and string tended to gather on them. These were periodically removed and discarded into the tank with no apparent harm. It is likely that dense suspended matter tended to settle and thus concentrate on the inlet side; however, no evidence of effect on the process or on the scraper performance was observed. The only design requirement would be the conventional one of providing adequate velocity of the sewage to prevent the settling of grit in the channel.

It was necessary in the pilot plant to pump the process influent to the level of the filter and to throttle the flow for purposes of experimental control. Neither would be necessary in an operating plant assuming that the filters could be built at or below the level of the incoming sewage. In such a case the filter inlet would be connected directly with the inlet channel. The filter water level would then fluctuate with the level of the inlet, with variations in flow accommodated by control of the head. Except that the wet-well pump flow would need to be varied periodically with total inlet flow, the process would be self-controlling.

In the case of raw sewage the presence of grit was found beneficial to flow rate; and no grit-removal step would appear to be needed. Screening or comminution of large solids would be required with the necessary minimum size determined, as in the case of conventional plants, by the size capacity of the equipment for subsequent steps. Ordinarily, the limiting size would be that of the scraper sludge pump.

In commercial operation it would be logical to contain the principal hydraulic equipment within a heated building, so that only the filter tank and scraper would be exposed. Many fewer difficulties than expected were encountered with freezing; and the need for housing the filters would appear to be determined by the form of operation and the climate at each installation. Certainly runs in which it was necessary are not fully valid. These are noted in the operating summary table in Section III.

A hopper car was spotted over the receiving pit and sampled for analysis by a commercial firm. The car then served as raw coal storage during the mill run, slowly emptying into the pit as the coal was processed. When the coal was wet it was occasionally necessary to rod the load and otherwise insure that the feed pit remained full. In all cases the coal was specified to be non-treated, as by oil or anti-freeze agents. None of the cars was received solidly frozen, however, and little difficulty was encountered with such freezing as did occur.

The rate of feed to the mill was governed by adjustment of the screw feeder in the receiving pit. When operating equilibrium had been attained, in several minutes after startup, the scalped oversize coal from the screener was returned to the inlet end of the feeder, so that the remaining volume was made up by raw coal. The rate of feed of raw coal was thus self-controlling.

The feed coal was delivered by a bucket elevator to a metal-free rubber belt passing through a metal detector arranged to stop the feeder, elevator and belt when any metallic object in the coal was encountered. A magnet ahead of the belt removed tramp iron; however, occasional stoppages resulted from the presence of non-ferrous metals. The effectiveness of the metal detector was especially notable in the first mill run, as weld spatters and other construction debris were being removed.

The mill could not be restarted until the section of contaminated coal has been cleared from the belt. This was discarded, as the metallic objects were seldom large enough to be seen. Non-metallic objects such as wood and cloth were not removed unless casually observed but did not appear to influence the operation.

The coal was delivered from the belt to the impactor and thence through a second bucket elevator to the gyratory dry screener. The impactor operated uneventfully; the screener operation was strongly influenced by the impactor performance and by moisture and oil in the coal, and is discussed at length in Part Three.

The sized filter bed coal was collected in the storage bins and periodically loaded into Tote-Bins which were then trucked to the sewage-treatment pilot plant. Each Tote-Bin was sampled throughout its depth by a thief, and the sample was analyzed before shipment. Any loads which did not meet fines specifications were rescreened. It was found generally, however, that the product from a given carload of coal was either acceptable throughout a mill run or required re-screening in its entirety.

V DISCUSSION, COAL PREPARATION

Parameters of the coal grinding and sizing operations are discussed in Part Three of this report, along with recommendations for the selection of equipment type and processing scheme. Design of the coal preparation pilot plant was based largely on the conclusions derived from the basic equipment and processing studies, and is described in Section II of this part of the report.

This section is a discussion of the pilot plant coal preparation work. Emphasis is placed on the performance of the equipment as installed and operated; and recommendations are presented in regard to future plants.

While careful design and control are necessary in order to meet the size specifications of the product coal, the preparation procedure and equipment are otherwise similar to those employed in existing commercial plants. Many of the observations and recommendations presented here are standard practice in the industry; and the sewage-treatment plant designer should not infer that any extraordinary technology or hazard is involved.

A. GENERAL OPERATION

The coal used in ten of the twelve sewage-treatment runs was ground and sized in the pilot plant operation. A total of 423 tons of filter bed coal was prepared from 558 tons of raw coal obtained from three sources over a period of sixteen months.

All of the coal was received by rail. To eliminate the requirement for storage and mixing, the filter runs were based on carloads of coal, the quantity actually placed in the filter for a given run therefore varying with the weight received and the efficiency of processing. Two carloads were used for Runs 1 and 2; the remaining runs were based on one load each. As-received coal size varied between 1/4-inch by 1/2-millimeter and two-inch by zero (Table 4-Y).

Because of the sensitivity of the dry-screening method to high moisture content in the coal, an attempt was made to have the cars covered with tarpaulins at the mines; however, these invariably leaked and most of the cars shipped during rainy periods were received with water running from the bottoms. As a consequence the plant can be reported to have operated with as-shipped coal. In certain cases the dampness of the coal resulted in partial blinding of the sizing screen, so that rescreening -- for which provision had not been included in the design -- was necessary. This operation involved manual labor and was wasteful of product, so that operating data for those

VI SLUDGE DE-WATERING AND INCINERATION

A. INTRODUCTION

Disposal of the solid matter removed from sewage is one of the most cumbersome and expensive aspects of conventional sewage-treatment. The waste sludges are putrescible and voluminous, seldom containing less than 95 percent water, and must be stabilized and reduced in volume for ultimate disposal.

These sludges are commonly subjected to anaerobic digestion as a first step, in which process the total quantity of solids is reduced and the remainder is biologically stabilized. After subsequent conditioning the digested sludge can be filtered to remove the solids, which are then used as soil conditioners or disposed of by incineration. There is increasing interest in the direct filtration of the raw sludges for incineration, and in the disposal of digested sludge as a soil conditioner without filtration; but in either case large quantities of low-concentration sludge must be extensively handled.

One of the most valuable features of the coal-sewage process is the fact that the waste sludge is concentrated, representing less than one-half percent of the plant flow, and that the heating value of the sludge is so increased by the entrained coal as to permit high-temperature incineration with only minimum de-watering. Excess heat is also produced during incineration, which may be recovered in useful form as a means of reducing process cost.

The coal-sewage sludges are also putrescible, although the action is somewhat inhibited by the presence of the contained coal. In small operations it might be convenient to dispose of the solids by careful land-fill; however, incineration would be desirable, if not required, for most cases.

Portions of the experimental program were directed toward means by which the coal-sewage sludge can most suitably be burned, and to an evaluation of the combustion process. De-watering of the sludge, by the minimum methods necessary to meet the requirements of incineration, was also investigated in conjunction with the combustion.

When the coal-sewage process is used for the post-treatment of secondary biological treatment plant effluent, the sludges from the conventional plant must still be disposed of. The combination of these with the coal-sludge was also considered as a means of simplifying the conventional plant operations, and is discussed in this section.

The potential cost-saving by elimination of grit-removal, digestion and filtration in any of the plant stages might also justify the purchase of additional coal solely to enhance the sludge-disposal operation. For such a use the coal would need to be only ground without removal of undersize and oversize material.

The process specifications and cost estimates in Sections VII and VIII do not assume the combination of sludge-handling facilities in a combined plant, since the concept and methods have not been experimentally confirmed. It is strongly recommended that the approach be thoroughly investigated, since success would result in a substantial reduction in capital and operating costs.

G. DESALINIZATION OF SEA WATER WITH INCINERATION HEAT

In 1965 Pope and Deming published a study of the extent to which a community's fresh water needs could be supplied by the desalinization of sea water when only coal-sewage sludge and municipal solid refuse were used as fuel. A flow sheet is presented, with separate materials and flow balances for the coal-sewage sludge, municipal refuse and a combination of both.

The disposal of solid refuse, while not part of the coal-sewage investigation, deserves attention when the recovery of power from the spent coal wastes is assumed. Various sources report that quantities of from three to five pounds of garbage and refuse with an average heating value of 5,000 Btu per pound are produced per person per day; and the recovery of power from this immense source of free fuel is being increasingly exploited. It is reasonable that when a power-producing incinerator is operated at a sewage-treatment plant, the inclusion of solid refuse in the same furnace could result in the reduction in a municipality's waste-disposal costs while producing a significant amount of power. Pope and Deming's study is reviewed here as a practical example of the extent to which this power could serve a community's needs.

The authors assume a community of 100,000 persons, consuming an average of 150 gallons per person per day of fresh water, and producing 120 gallons of sewage and 4.4 pound of 5,000 Btu refuse per person per day. A 12-million GPD sewage-treatment plant is therefore required, for which the coal-sewage process is assumed. A coal consumption of 5.0 tons per million gallons, based on the pre-pilot plant data from this program, is used for calculation.

The proposed desalinization plant assumes combustion of the waste at 81 percent efficiency, to produce steam at 1,200 psig. The high pressure steam supplies a turbine generator, and is exhausted to a multiple stage flash evaporator. All surplus electrical energy not supplied to in-plant auxiliaries is used to produce additional fresh

It is not within the scope of this report to recommend specific combustion processes; the design engineer would be expected to solicit quotations from manufacturers of different process types. Certain general conclusions and recommendations may be presented, however.

1. When the coal-sewage process is used in the treatment of raw or settled sewage, or secondaary treatment plant effluent, the process waste consists by definition of a five weight-percent slurry of coal and sewage solids in water. On a moisture-free basis the composition of the dried sludge ranges between extremes of approximately 1.5 and 13 weight percent sewage solids and is more typically within the range of 6 to 11 percent.

2. The heating value of the dried coal-sewage sludges is the sum of the separate heating values of the coal and sewage solids, and is typically 12,500 to 13,500 Btu per pound depending on the type of coal used. The combustion properties of the coal-sewage sludges are predictable from analysis of sludge composition and water content, and conventional engineering techniques may be used in description of the combustion process.

3. The composition of the stack gases from the incineration of coal-sewage sludges is predictable from the composition of the sludge fuel. Except that the water vapor content is increased and that sludge odors can be produced when the incinerator is not properly designed or operated, the composition of the stack gas is similar to that produced in the burning of coal.

4. The addition of sulfur-suppressants, such as limestone, to the sludge fuel reduces the sulfur content of the stack gas in the same manner as in the case of normal coal. The use of lime with phosphate precipitants in the sewage-treatment process may provide all or portion of the requirement.

5. The required degree of sludge de-watering is determined by the type of firing equipment as recommended by the incinerator designer.

6. The sludge produced in operation of the coal-sewage filter can be de-watered by simple gravity-settling to contain approximately 50 percent solids; a filter press, with air-blowing, was shown to be capable of producing a cake of at least 67 percent solids. Centrifuging is expected to be the method ultimately adapted. There is some indication that a basket-type or disc-type centrifuge might be most effective.

Gravity-settling should be investigated further, possibly in conjunction with centrifuging as recommended by the designers of de-watering equipment.

In a large plant where several filters are operated together, the use of a settling-collection basin to receive all in-plant waste streams would be especially convenient as a means of stabilizing the sludge flow rate and of concentrating the sludge, with a substantial likelihood of being adequate at the same time to produce a sludge which could be burned without further mechanical or thermal de-watering.

7. In the grinding and sizing of filter bed coal a quantity of fines equivalent to approximately one-third the weight of filter bed coal used is produced. When these fines can not be more advantageously disposed of they may be added to the partially-de-watered sludge to increase the solids content and heating value.

8. A wide variety of furnaces and burners appear satisfactory for combustion of the de-watered coal-sewage sludge, subject to the following observations.

a. Combustion at high temperatures is necessary to insure destruction of odor. Water-cooled furnaces (boilers) are reported to more satisfactory for the purpose than simple refractory-lined furnaces. The use of a steam-generating incinerator is therefore recommended, even for situations where the steam is not used but is simply condensed for recycle.

b. De-watered coal-sewage sludges, at least within the range of 50 to 67 percent solids and probably beyond, are somewhat pasty in composition and tend to extrude in feeding equipment rather than to behave as granular solids. Care must therefore be exercised in the selection of conveying and feeding equipment.

The designers of materials-handling systems would be expected to have no difficulty in selecting suitable equipment. Commonly-used methods include conveyor or cage-mill pre-drying by use of steam jackets or furnace off-gas, and admixture with recirculated fly-ash or bottom ash.

c. Although the spreader stoker was used in two tests, a specially engineered design would be required for unmodified de-watered sludges. Effectiveness of the spreader stoker depends on its ability to throw a thin uniform layer of coal over the fire surface, and is diminished when the fuel is a cohesive mass.

Chain-conveyor fuel feeders, a guillotine-spiller, or a modified spreader stoker, preferably with pre-conditioning as described in "b" above, were recommended by the Detroit Stoker Co. engineers, and others would no doubt also serve.

d. In spite of the small particle size of the contained coal the coal-sewage sludge does not exhibit any greater tendency to fall through furnace grates than do the fines in normal coal; and it is expected that conventional grate designs would be satisfactory. The several types of moving grate developed for refuse incineration should also be considered.

e. No tests were performed on the burning of coal-sewage sludges by pulverized-fuel equipment as operated in large boilers. It is proabable that only small amounts of raw-sewage/coal sludge could be accommodated if mixed into the feed to a pulverizer because of the water and the large, soft and stringy sewage solids present. Post-treatment filter sludge would be more attractive because of the small and uniform particle size of the sewage solids.

It is improbable that the sludges, unless dried, could be fired directly in a pulverized-fuel burner without modification to improve handling and size-uniformity.

Cyclone-type burners, as sometimes used in large furnaces, are less sensitive to fuel size and water content. The operation of a utility boiler on a 70-percent coal slurry pumped directly to cyclone burners has been demonstrated to be feasible and should be considered when large quantities of coal-sewage sludge are available.

9. The quantity of steam which can be produced from sludge incineration can be determined by direct calculation. An overall incinerator-boiler efficiency of 75 to 80 percent, including furnace and stack losses and the vaporization of contained water, is estimated.

As a rule of thumb the heat loss in the vaporization of water from the de-watered sludge is approximately offset by the increase in heating value due to the contained sewage solids, so that the net quantity of recoverable heat is approximately equivalent to that available from the original as-received coal. On the basis of the weight of contained solids approximately 90 percent of the original heating value of the coal therefore appears as steam; on the basis of total weight of sludge, including water, approximately 75 to 80 percent of the as-received heating value of the sludge is recoverable.

According to general literature sources, from 16,000 to 18,400 pounds of low-pressure (500 psi) steam can be recovered per ton of contained sludge solids, depending on type of coal used and efficiency of the incinerator design.

10. In small plants the value of the steam produced would probably not be recovered, although experience has shown that when free steam is available a use is nearly always found for it. In larger plants the steam could definitely be used to supply all in-plant needs, including the supply of air for the biological secondary process.

The by-product steam would be used when the coal-sewage process is used in industry, and in many other cases could be sold to nearby consumers as an alternative to their operation of independent boiler plants. In certain situations large industries operate internal electrical-generation plants under reciprocal agreements with utilities to buy or sell electricity as needed or as available in excess. Such an installation might be especially attractive for a large sewage-treatment plant, where conventional electrical equipment could be used and supplied with power, and where a single market for all excess power would be available at all times.

11. As one example of the extent to which process steam could be used, approximately 40 percent of a community's fresh-water needs could be supplied by desalinization of sea water when only the coal-sludge from raw sewage treatment is used as fuel. In post-treatment applications the proportion would be approximately 5.5 percent.

12. An economy in the incineration of solid municipal garbage and trash would probably be realized when these wastes and the coal-sewage are burned together in a single incinerator equipped for heat recovery.

The heating value of this additional free fuel is substantial. Continuing the example of desalinization, the fresh-water production from a plant burning the combined sludge and refuse would meet approximately 70 percent of a community's needs when the coal process is used to treat the raw sewage from the community; 35 percent would be met when the process is used only for post-treatment.

13. Combination of the post-treatment coal-sewage sludge with the primary and secondary plant sludges was not investigated in the pilot plant, but appears feasible and is strongly recommended for continued study.

It is probable that the separate process steps of grit removal, sludge digestion and vacuum filtration as generally required for primary and secondary treatment could be eliminated as a result of the improved de-watering properties imparted to the sludges by coal. The mixture could be burned at a higher water content as a result of the added heating value of the coal. When solid refuse is also introduced to the partially de-watered sludge, along with waste fines from coal preparation, the burning properties could be expected to improve. The purchase of additional coal exclusively for this purpose might also be justified, especially when a use for the large amount of power available from an integrated municipal waste-disposal system is available.

consumption can be calculated. Typical flow and materials balance for the process when used for the treatment of raw sewage and secondary treatment plant are included as these generally typify the lower and upper limits of performance. These examples are the basis of cost estimates presented in Section VIII.

B. FLOW SHEET

Figure 4-31 is the general flow sheet for the coal-sewage filter process, and is based on the performance of one complete run as the minimum unit of operation which incorporates all process features. Performance of a run involves in-plant recycle streams which must be retreated and which therefore require that the filter capacity be increased slightly over that necessary to treat the nominal flow of sewage. Certain of these streams are intermittent, and the design of the plant depends on their quantity and the means by which they are apportioned over the length of a run. Certain assumptions must be made:

1. Filter Bed Preparation

The dry sized filter bed coal is prepared as a slurry with plant filtrate at a rate determined by the overall size of the operation, by the capacity of the coal preparation plant, and by other factors such as the most economical application of available labor. These characteristics will vary in all situations, and the quantity of filtrate recycled through the slurry operation is therefore an average daily flow determined by the quantity of water required for a filter of given area, prorated over the length of the run which can be conducted in the filter.

It is desirable that the filter bed be placed during a relatively short period to reduce acid-production and for substantial reasons of economy as discussed in Section V. The actual rate of diversion of filtrate and return of slimes to the influent would be greater for short intermittent periods than the average rate.

The bed coal as placed in the filter must contain less than approximately 1.5 percent as dust smaller than 270-mesh. This dust level is not dependably attainable by dry-sizing, and the use of a hydrocyclone desliming step is specified. When the filter is not preceded by a solids-removal step, such as settling, the slimes are returned to the filter inlet. When pre-treatment is used the slimes are returned to a location prior to the presettling step in order to reduce the load of fine solids in the filter influent. The quantity of suspended solids will vary widely with the dust content of the coal, the rate of addition and the total plant flow, but will normally range between 5 and 30 ppm during the placement period.

A. INTRODUCTION

Many applications of coal to sewage treatment have been considered in this report, but the central and novel feature of each is the consumable coal precoat filter. This basic "coal-sewage process" is described in this section as the minimum unit which can be operated as either a complete treatment facility where appropriate, or as a process supplement which can be installed and operated independently of the functions or equipment of the associated conventional secondary plant.

In respect to process design, the variations which have been investigated fall generally into two categories:

1. Improvements of the filter process by means which would not affect the flow sheet or structures of an installed plant. These are concerned mainly with increasing the flow rate and decreasing coal consumption by manipulation of process controls as recommended in Sections IV, V and VI. All of these refinements can be investigated and implemented within the basic design described here.

2. Improvement of a sewage-treatment system of which the coal-sewage filter is only a part, where changes in the flow sheet or equipment of any part might be altered by the combination. The removal of phosphates by chemical precipitation prior to secondary treatment where the coal process is used for post-filtration, and the elimination of grit-removal and sludge-digestion by combination of the primary and secondary sludges with the coal-sewage sludge for direct de-watering and incineration are examples. These are mainly variations in process application; and while they are recommended for continued investigation they are not as a whole reflected in the basic design.

The two important auxiliary operations of coal preparation and sludge incineration are also not integral to the basic process except as certain specifications are determined by the process requirements and performance. Both functions can be efficiently accomplished through the use of conventional equipment and established engineering practices; and there is no inherent requirement for either to be performed at the sewage-treatment site or under the supervision of the sewage-treatment operator. Sludge de-watering is included in the basic process, since the excess water must be returned to the plant inlet for re-treatment.

A single flow sheet is presented which represents the basic filter process for use in any application. The general requirements and performance of the separate steps are discussed, and a series of design equations is given by which filter size and overall coal

The flow sheet also assumes, for simplicity, that the clear-water fraction of the clean cyclone underflow, which drains through the filter bed as it is placed, will be combined with the slimes for return to the raw sewage inlet. Depending on the content of acid or iron, if any, this water can probably be returned to the plant effluent. The point of return of this combined stream is indicated in the materials balances for the two process applications.

2. Filter Makeup

After placement of the bed the filter is made up with plant filtrate, the required quantity depending on the depth and area of the filter and the depth of supernatant water. A standard bed depth of six feet is assumed in these specifications, with two feet of supernatant water. Other values may be substituted in the design equations in Section "C", however.

The makeup water constitutes a second recycle stream. As in the case of the slurry water the quantity is assumed to be prorated over an entire run.

3. Filter Operation

The largest process recycle stream is the removal of coal-sewage sludge by the scraper and the return of a portion of the contained water after de-watering of the sludge. Because this sludge is removed from the surface of the filter in a vehicle of supernatant water, the recirculation loop is independent of the filter process; and in fact the required area is reduced slightly by the amount of process influent withdrawn ahead of the filter and retained in the de-watered sludge. In the flow sheets the supernatant sewage and the filter are shown separately in order to emphasize this aspect.

The sludge de-watering step is assumed to proceed continuously, receiving sludge at a relatively constant average rate from one or more filters. The de-watered sludge is produced at a fixed water content determined by the type of incineration process used, and is here taken at the proven value of fifty weight percent. Other concentrations may be substituted, however.

4. Tank Cleaning

On completion of a filter run the bed residue must be removed. For this purpose the tank is cleaned with plant filtrate. The resulting slurry is assumed here to be de-watered for incineration of the solids.

The de-watering step is shown in the flow sheets as a separate operation because it is intermittent, as opposed to the continuous de-watering of the process sludge. In practice the two materials would probably be combined for treatment in one operation, producing single

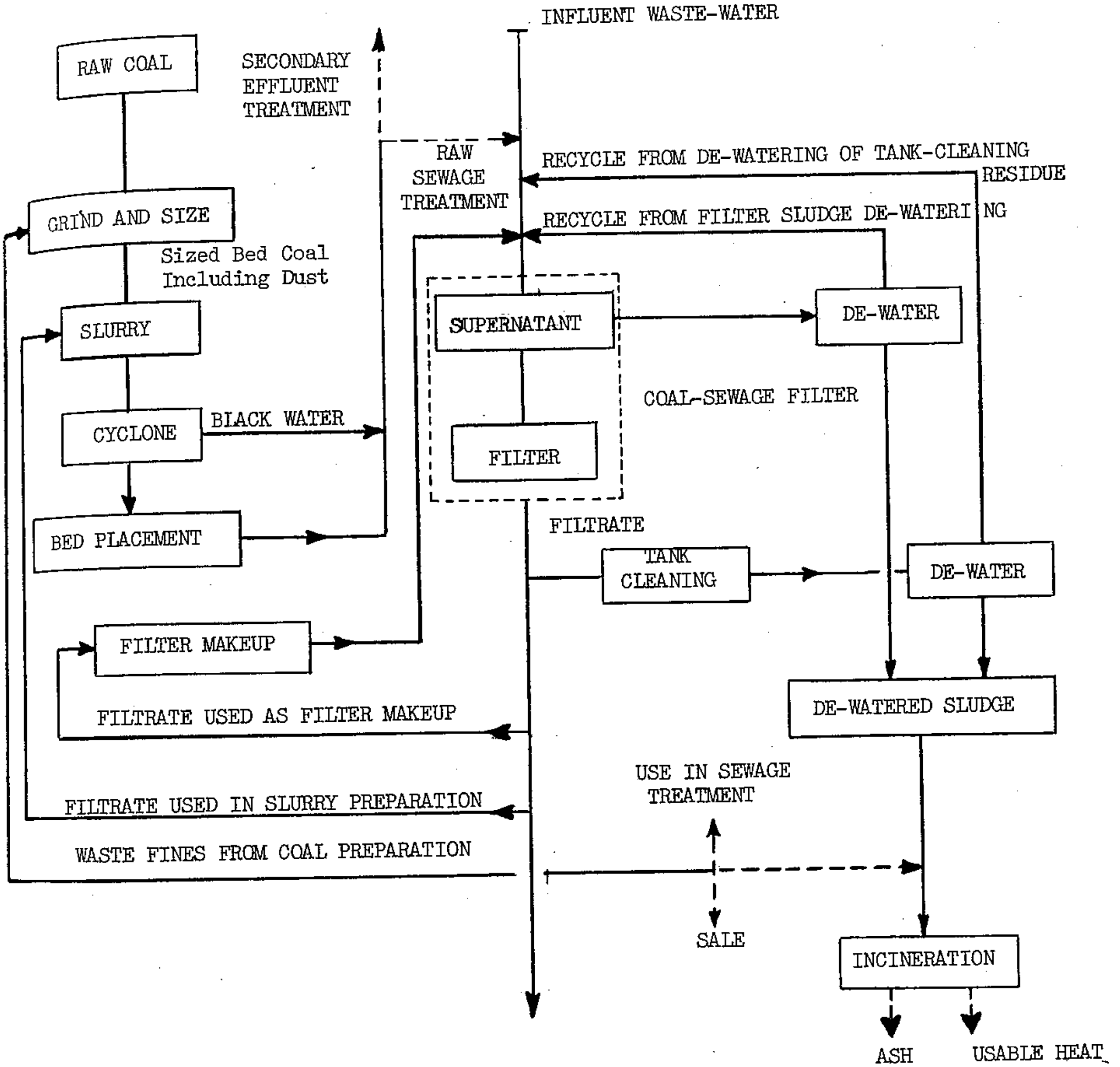


FIGURE 4-31
GENERAL FLOW SHEET,
COAL - SEWAGE PROCESS

A PROPOSAL FOR A

SEWAGE TREATMENT PIPELINE

FOR THE

CAPITAL REGIONAL DISTRICT

SUBMITTED BY

R.G. TENNANT AND ASSOC.

JUNE 14, 1990

R.G. TENNANT AND ASSOC.
P.O. Box 35691, Stn. E
Vancouver, B.C.
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June 11, 1990

Mr. Mike Williams, Chief Engineer
Capital Regional District
524 Yates Street
Victoria, B.C. V8W 1K8

Dear Mr. Williams:

Please find attached a proposal to build a 34 mi. long pressure sewer pipeline to export and treat Victoria's sewage for industrial use at the Jordan River Hydroelectric Project. Basically, the pipeline is viewed as a potentially economically practical method of resolving both a chronic drought situation at the reservoir and the promiscuous problem of dumping raw sewage into Victoria'a nearshore waters. It could also serve to catalyze industrial development of Jordan River.

This proposal is primarily the result of an intuitive-based assessment of how best to minimize the environmental and social conflicts inherent in the construction and operation of the pipeline, and it remains to be seen whether this assessment can be reconciled with detailed engineering and economics. While R.G. Tennant and Assoc. are not qualified to undertake such a complex pipeline study, our interest would be served by licensing and by contracting with the CRD to pursue a feasibility study.

We look forward to your endorsement of any components of interest in the proposal.

Yours sincerely,

Richard Tennant
President

RT/da
Enclosure

SUMMARY

The following provides a conceptual outline for a 37 mile long sewage treatment pipeline to export up to 30 MGD of raw sewage from Victoria and treat it for use at the Jordan River Hydroelectric Project. The pipeline would be utilized as a pressurized aerobic biological reactor (see attached Appendix #1) whereby 48,000 CFM of compressed air would be injected into the sewage, along with a host of nitrifying aerobes, to degrade it to a secondary level during its journey up to the reservoir. The outflow from the pipeline would be further treated in stabilization ponds situated above the reservoir, followed by either soil filtration or extended aeration in oxidation ditches running along side the reservoir. Eventually, the resulting effluent would be employed to reduce the vulnerability of the reservoir to drought, thereby increasing the reliability of contingency power reserves for Victoria.

Pipeline installed cost is projected at between $60-80 million, based on vendor estimates for constructing a steel force main, (arbitrarily sized at 36 in. dia.) along with nine pump stations, each to be equipped with a four pump system. Gross power consumption is calculated to be 25 mwh/day, at maximum flow rate of 21,000 GPM (1.31 m^3/S). Total power cost is estimated at $5 million/yr.. based on having B.C. Hydro deliver it from the mainland at a cost of 2.9 cents kwh, inclusive, and assuming an even credit from Hydro for generating 5 mwh/day from effluent discharge. An independent electrical service would provide backup power from the Jordan River hydroplant (26.5 mw).

The projected flow rate is roughly based on combining the average annual discharge permits for Victoria's two main outfalls at Clover Point and Macauley Point. At maximum flow, friction head loss was calculated to be .544 ft. per

100 ft. section of pipe, plus 10% for major bends enroute. Velocity is estimated at 8 ft./sec.

The first six pump stations are to operate with submersible pumps to deliver pre-macerated, raw sewage 24 mi. from Ogden Point through to West Sooke, where it will then be injected with the compressed air and aerobes. A suitable submersible pump would be the ITT-Flygt model 3350, each rated at 8000 USGPM at 250 ft. head with 670 h.p. motor. After aeration, the last three pump stations would operate horizontal splitcase pumps, in wet wells, to deliver the effluent, over eight miles, up to a pipeline peak of 1,772 ft. (540 m). This will then be followed by a 2 mi. long descent and final discharge into the stabilization ponds at 460 m elevation. A variety of horizontal splitcase pumps are available, including the Worthington-Dresser model 10LN-26, each rated at 7000 USGPM at 600 ft. head with 1500 H.P. motor. Proposed station locations were determined on the basis of combining pump performance characteristics with static and friction head loss estimates only, with static loss determined from topographical mapping at scale no. 1:50,000.

TREATMENT

To oxygenate the pipeline, air compressor design would be based on a system aboard the "Thames Bubbler", a river aeration barge, whereby 2000 L/S of water is aerated with a compressor powered by a 2 MW generator, with the air first cooled, then fed through zeolite beds to remove nitrogen before injection. (No consideration was given to calculating possible head loss due to the increased air volume during pumping, or to controlling its dissolution at the splitcase pump stations). It was roughly estimated that compressed air injection at a rate of 48,000 CFM would be equivalent to adding 5 tons/day of oxygen and that this should suffice to mitigate the dissolved oxygen deficiency to allow aerobic breakdown and oxidation of contaminants. (No consideration was given to determining either the volume or type of inoculum). Compressor aeration may also be supplemented with atmospheric aeration by placement of open flumes along interrupted sections of the discharge pipeline. The outflow pipe would be gated and remotely-controlled, with alternate-loading of each stabilization pond. Although the total land area for the ponds was not calculated, it should be substantially less than that required for a conventional lagoon system due to the pre-aeration in the pipeline and consequent reduction in required retention time.

The ponds should prove a low cost, simple operation to set up and run, particularly as the terrain at the reservoir is wide open and gentle-sloping. The ponds could be created behind a series of filter dams that would automatically decant settled effluent into a common sand filter to further reduce nitrate levels from BOD breakdown. (Sand filter dimension would be approx. 350 ft.long x 150 ft. wide x 50 ft. deep.) The filtrate would then leach onto terraces carved above the reservoir to allow slow soil filtration and biotreatment. If necessary, an artificial marsh could also be created to increase filtration and nutrient absorption.

An alternative to filtration is to discharge the ponds directly into either flumes or oxidation ditches running alongside the Bear Creek reservoir, with final discharge into either the mid-Diversion or lower Elliot reservoirs. These structures could be lined with rocks encased in gabions, with bulkheads installed at strategic points to encourage additional turbulence and oxygen exchange. As gabions are semi-permeable, they could also serve to fine-filter sediment, and possibly, to capture phosphates and catabolize contaminants. Given sufficient length, ammonia ion gasification and subsequent de-aeration would be assured, and the final effluent could be diluted with fresh water as needed for direct injection into the hydro penstock.

ROUTE PROFILE

No. 1 submersible pump station would be situated along the Ogden Point breakwater to receive sewage diverted to it by short feeder pipes from the nearby outfalls. The feeders would also serve for storage and to buffer flow variations. The station head works would be equipped with a channel-mounted rotating screen and grinder to macerate the sewage.

Beginning at 15 m depth and not exceeding 25 m depth, the force main would extend 5,750 m across the harbour to land on the Colberg Peninsula (tow-out construction). From Colberg, it would proceed 900 m up to the southwest corner of Royal Roads military college, discharging into no. 2 station to be situated at 25 m elevation.

From no. 2 station, the pipeline would proceed 1900 m up Allendale Road to Highway 14. It then runs 1900 m down along the highway to connect with the old CN Rail corridor, discharging into no. 3 station at the junction.

From no. 3 station, the pipeline would proceed along the CNR bed for 12.6 km, discharging into no. 4 station at the junction with Rocky Point Road in Metchosin, near a B.C. Hydro transformer station.

From no. 4 station, the pipeline would continue along the CNR for 8 km, through the Matheson and Roche Cove parks, until parallel to the entrance to Cooper Cove in East Sooke basin. It would then leave the CNR and cross 500 m of water to the Goodrich Peninsula, discharging into no. 5 station to be situated near the recently-closed Lamford Forest Products mill.

From no. 5 station, the pipeline would proceed up the Goodrich Causeway to re-connect with the CNR at 20 m elevation. It then continues along the CNR for 2300 m to the vicinity of the Cedar Glen Mobile Home Park where it finally leaves the CNR with a 1200 m long section which proceeds across the Sooke River at 5 m depth to discharge into no. 6 station above Philips Road at 45 m elevation (a simple pipe bridge could also cross the river, depending on political acceptability).

A horizontal tunnel, 2400 m long, would receive the discharge from no. 6 station. This tunnel would be excavated through clay-like soils and would exit in the mid De Mamiel Creek area to connect with a surface pipeline extending 700 m up to the entrance to Boneyard Lake Road. Discharge would occur at 104 m elevation into a lined glory hole that would feed the sewage through a short tunnel equipped with air-injection lances preceding no. 7 pump station (no. 1 horizontal splitcase) at 91 m elevation.

From no. 7 pump station, the pipeline would proceed up Boneyard Lake Rd. for 1800 m to 220 m elevation where it would then continue horizontally for 2000 m to the west of Boneyard Lake, with a final jog directly west for 900 m, toward the Butler Mainline Logging Rd., discharging into no. 8 station on the plateau at 250 m elevation.

From no. 8 station, the pipeline proceeds across the plateau to connect with the Butler Rd., continuing up it for 3 km to discharge into no. 9 station to be situated at 410 m elevation.

From no. 9 station, the pipeline would continue up the Butler Rd. for 4.5 km to its peak at 540 m elevation (1,772 ft.). It then continues horizontal for 1000 m, followed by a 2 mi. long section proceeding down along the road to the upper Bear Creek reservoir area.

Total length of pipeline route from Ogden Point to reservoir area is 34 mi. (51.5 km).

LIST OF POSSIBLE MODIFICATIONS AND BENEFITS

Installing submersible pump stations will ensure a virtually noiseless, low profile operation. These stations would not require priming and should prove easy to control from a remote location equipped with the latest in real time computer technology. Buried land construction should prove economical as igneous geology would occur up to no. 4 station only, with sedimentary then occurring through no. 7 station, after which, the pipeline could likely proceed safely on the surface.

The proposed easement along the CNR right-of-way is ideal for providing sewerage to the Western Communities, via pressure feed with small diameter pipes and macerator-equipped pumps. It also allows easy accessibility to facilitate construction and maintenance and is within economical proximity to existing power transmission lines. When completed, it could be either fenced in and revegetated, or blocked in cement to serve as an elevated bike path. Its use would not preclude developing the CNR for LRT between Victoria and Colwood.

To maintain the pipeline below no. 7 pump station, suitable arrangements could be made available to empty it by cross-connecting to existing outfalls. Above no. 7 station, the glory hole-oxygenator pit could serve for storage from no. 8 station, or a branch pipeline could loop back from no. 8 to discharge into two gravel pits located above the oxygenator, near Young Lake. With liners installed, these gravel pits could also serve to produce a settled effluent suitable for washing gravel imported from a proposed mining operation on nearby Muir Creek that would require at least 1 MGal./day (BCFP - Ocean Cement Ltd.). The spent wash could then be re-settled prior to pipeline re-injection, or distribution onto terraces carved above Boneyard Lake to receive tertiary-level treatment via slow overland flow. With the construction of a small dam, the lake could then serve as a clear well to hold the effluent for either drought control, irrigation, or sewerage use in the W. Communities.

During its construction, the pipeline bed and saddles could be pre-built to accommodate new domestic and irrigation water pipelines, thereby providing the CRD with a low-cost opportunity to both extend and rehabilitate its aging water supply system. Accommodation could also be made to twin the force main to bring the system within range of dealing with maximum daily overflows. With twinning, overflow storage could be incorporated into the design for new sea walls, with the no. 1 pump house serving first to anchor a sea wall running directly across to Holland Pt., followed by a second one across Ross Bay. Backfilling of these sea walls would create significant new additions to Beacon Hill Park, albeit at an elevated level as Victoria's initial strategy to defend against the extraordinary storm surges and higher tides that are projected in the near future due to the greenhouse effect. Air emissions could be controlled by either vacuum distillation units or soil filters incorporated into the landscaping.

Sea wall storage of overflow, in combination with lining the gravel pits above Young Lake, could result in these facilities also serving as day storage reservoirs to allow night pumping at off peak power rates. In addition, equipping the discharge pipeline from the peak with a series of horizontal bulb turbine power units would generate more power during the descent to the reservoir, or reservoir water could be recycled back to a new storage reservoir at the peak by installing reversible pump vertical turbine power units, thereby significantly increasing the capacity for peak power generation. Operating such turbines would, however, likely dictate production of a silt-free effluent, either from pre-settlement in a new peak reservoir, or from a filter plant installed in place of the proposed glory hole-oxygenator.

A filtration plant could eliminate any requirement to artificially aerate the sewage by allowing a silt-free effluent to be atmospherically aerated down an open flume in place of a discharge pipeline from the peak. This could also eliminate any requirement for further treatment at the reservoir. A filter plant could prove very economical to operate as a result of employing pre-filtered effluent stored at the Young Lake gravel pits to hydraulically backwash the filter on a continuous basis. If the pipeline is twinned, it may also prove feasible to rebuild an abandoned B.C. Hydro flume that ran 5 mi. from Diversion Reservoir down to the Forebay feeder reservoir at the coast, thereby also eliminating any requirement to pre-oxygenate the sewage in the pipeline.

Unlike a conventional sewage treatment plant, the pipeline would not cause PAH and VOC emissions over the urban area, nor will it require costly source separation programs and could even encourage the use of household garburators, thereby significantly reducing regional solid waste collection and disposal costs. In addition, it would not produce sludges loaded with toxic metal hydroxides from the use of flocculants, nor will it have to meet future considerations to guarantee sterilization of antibiotic resistant bacteria and viruses in order to protect soil microflora and the public health from land application of sludges. For local fishermen, the pipeline would halt the increasing sanitary closures of shellfish production areas and would also prevent increases to the high accumulations of trace metals around local outfalls.

With the cost of power likely to represent at least 80% of total operating costs, it is recognized that a primary determinant in securing the right to pump the sewage will be assuring that its cost will be relatively fixed for the life of the contract and not subject to variations dictated by the international energy market. With a detailed investigation of its positive environmental and social benefits, the provincial government may also be induced to issue an order-in-council mandating a lower power cost. If the pipeline is co-developed with B.C. Hydro as a pumped storage hydroplant, then major cost reductions could also occur. Given an integrated, sustainable approach to project development, it may also prove feasible to build and operate a small coal-fired power plant of 50 mw capacity. Its capital and operating costs, including the related coal mining and transportation infrastructure, could be paid for largely by taxpayerrs and industries in other locales being charged competitive rates for the treatment of their waste streams at Jordan River. (e.g. electrolytic reduction of special wastes, soils-from-waste production and distribution for long range forestry research programs).

Coal could also be used to first filter sewage by simply discharging the pipeline atop a "live" coal slot storage device containing run-of-mine coal in place of the proposed glory hole-oxygenator. As the device would be continually discharged, there would likely be no requirement to backwash the filter.
Assuming that B.C. Hydro would make available its Hat Creek steam coal deposit, (a very hard, porous coal) then an environmentally-sound method of burning spent coal filter would be as coal-water-mix fuel. Given the availability of used boilers and generators from B.C. Hydro's closed Port Mann and Georgia generating stations, a CWM power plant could likely be built for $500.00 per installed KW ($25 million). Spent coal filter delivered to Jordan River from pulp mills or GVRD sewage plants could also be burned for power, with the cost of coal filtration likely to be substantially less than their projected costs for conventional secondary treatment. An alternative to burning this spent coal

could be to store it in sealed sections of the Jordan River canyon, along with agricultural and other wastes for conversion to biogas. The leachate would be treated, along with other special wastes, by an electrolyzer, (UOP Direct Contact chemical Hydrogenation Process) with the system eventually evolving to electrlytic refining of aluminum scrap or copper ore (Bechtel "Portelex" Process) and hydrogen production.

Jordan River

General Information

Project Name:	Jordan River
Dam Names:	Elliott, Jordan Diversion, and Bear Creek
Dam Heights:	27.4 metres (Elliott) 39.9 metres (Jordan) 19 metres (Bear Creek)
Reservoir Names:	Elliott, Diversion, and Bear Creek
Reservoir Areas:	16 hectares (Elliott) 168 hectares ; $20.4 \times 10^6 m^3$ (Diversion) Storage 75 hectares ; $9.8 \times 10^6 m^3$ (Bear Creek) storage
Water Course:	Jordan River

diversion 80 m^3/sec

Description

Storage dam on Bear Creek, a tributary of the Jordan River. Downstream from the confluence of Bear Creek and Jordan River is the main Diversion Reservoir which controls the flow into the small Elliott Reservoir. The water flows from the Elliott Dam through a 5.3-kilometre tunnel and 1.6-kilometre penstock to the 170 MW powerhouse, just upstream from the mouth of the Jordan River.

History

Original 26 MW plant first operated in 1911. Old plant was retired and replaced with a 170 MW unit in 1971.

Drainage Basin

Jordan River drainage basin on the west coast of Vancouver Island experiences high annual precipitation mostly as rain.

Inflow

Heavy rains in the fall and winter produce high peak flows. Average annual inflow is 12 m^3/s.

Reservoir

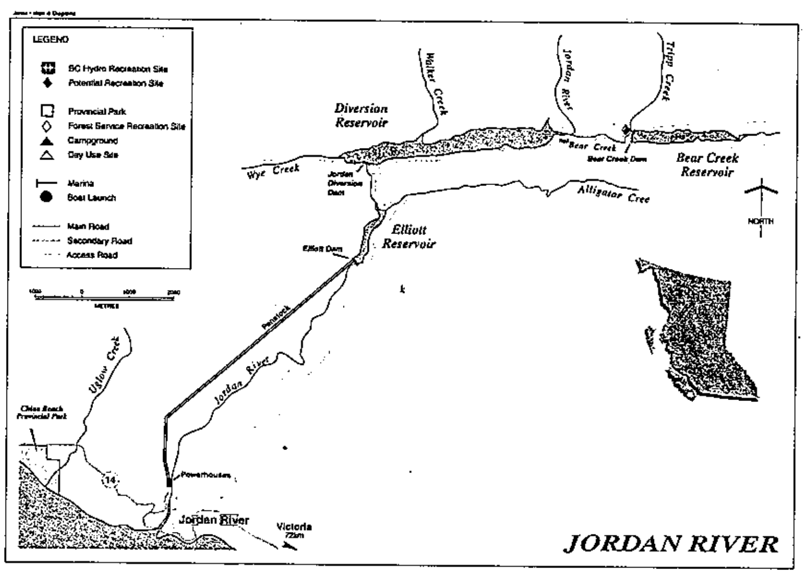
The Diversion Reservoir has little storage.

Operating Constraints

The Fish and Wildlife Branch should be notified prior to any draft of the Bear Creek and Diversion Reservoir close to their minimum operating levels. Prior to dewatering of the Jordan G1 penstock, the holding tank is to be filled to ensure adequate supply of water for the town of Jordan River during the outage.

Capability

Maximum Sustained Generating Capacity:	170 MW
Turbine type:	High Head Francis
Historic Annual Average Plant Generation:	242 GW.h
Storage:	28 million m^3



RIVER JORDAN PROJECT AREA

River Jordan is located 39 mi. northwest of Victoria along Highway 14. It is a small coastal settlement (pop. 250) which has served primarily to exploit the hydroelectric and timber resources of the Jordan River Valley since the turn of the century. Existing operations include a 26,500 KW power plant run by B.C. Hydro to provide peaking power for Victoria, and a log dump and truck maintenance yard run by Western Forest Products (Doman Industries). The hydraulic works consists of a 10 mi. long, three-reservoir system that is highly vulnerable to drought and currently under repair, while logging operations on the area are winding down due to a severe shortage of logs that has resulted in the recent closure of the area's largest employer, Sooke-based Lamford Forest Products.

Coastwise, the undeveloped offshore consists of a raised undersea platform extending west 1.5 mi. at an average 35 ft. depth, with its outer shelf situated at 114 ft. depth approx. 2 mi. out from the river mouth. The river mouth is dredged occasionally to allow tug access, with ingress restricted to 1/2 mi. upriver due to heavy rock debris at the entrance to the river canyon. Along the shore, the land rises abruptly in a bluff which then proceeds as a long, sloping plateau divided by the steep and narrow river canyon.

Area soils are primarily shallow, ferro-humic podzols that are highly leached and sensitive to either fertilizer or atmospheric-induced acidity due to a near total lack of buffering capacity. Area forests have generally not been managed on a sustained-yield basis and a review of aerial photographs shows large areas have been subjected to severe soil degradation and exposure to bedrock.

Geographically, the reservoir area is separated from the Greater Victoria

Water Supply System by two mountain ranges and the Leech River system. The geology of the area is mostly sedimentary. The offshore has been identified as an excellent candidate for oil, and a major wind energy potential also exists. Both the nearshore and lower canyon have extensive, untrapped deposits of sand and gravel, while the reservoir area contains identified deposits of cryanite, garnet, gold, quartz and talc. Substantial deposits of high grade iron ore and limestone exist in the nearby Gordon River area (e.g. Bugaboo, Renfrew, Harris and Nixon Creeks). While an abandoned copper mine at Jordan River, now flooded, could yield at least another 15,000 tons/cu. (Mine tailings were discharged 3500 ft. off shore).

In terms of wildlife and fisheries value, with the exception of some fish in the upper reservoir and a high density kelp bed on the outer coastal shelf, both the Jordan River reservoir and its coastal environs are considered essentially sterile by government biologists. (e.g. no shellfish resources, no salmon spawning or fishing areas, no seabird or mammal colonies). As such, there is virtually no capability for recreation, conservation or biological resources management.

In conclusion, if it can be fairly stated that the primary pre-condition for any waste management system is to select a site suitable for implementing a strategy of containment, then the derelict lands of the Jordan River Valley are possibly ideal for developing waste management strategies that should prove unassailable from any critic's view.

ELLIOT RESERVOIR

1.0 LOCATION

The Elliot Reservoir is approximately 8 km upstream from the mouth of the Jordan River on the south coast of Vancouver Island. Access is gained from the northeast along the Shawnigan Lake - Port Renfrew Highway or from the south along the Victoria - Port Renfrew Highway. All roads into the reservoir itself are active logging roads with public use restrictions.

2.0 LAND STATUS

B. C. Hydro owns the land around the reservoir and at the associated project facilities. The surrounding land on the north side of the reservoir is within the Esquimalt and Nanaimo Railway Lands Grant and that on the south side is within Tree Farm Licence 25. The remaining land adjacent to the penstock and power house is Crown-owned.

3.0 GENERATION FACILITIES

Facilities at the reservoir include a 35 m high concrete dam, intake structure and 68 m spillway. A 5.8 km long tunnel and 1.6 km penstock carry water to the 150,000 kW capacity power house near the mouth of the Jordan River. This plant provides vital peaking and standby power for the Vancouver Island system. The Elliot Reservoir serves as a headpond with virtually no storage function and undergoes extreme drawdowns.

4.0 RECREATION PERSPECTIVE

This reservoir is exclusively a generation facility with no recreational opportunity or use. Wildlife, fish and aesthetic values in this area are low. Extreme drawdowns and debris accumulations are major hazards to public use.

5.0 RECREATIONAL OPPORTUNITIES

Due to low resource values and extreme hazards, this area is considered to provide no opportunity for recreation.

6.0 RECREATIONAL DEVELOPMENTS

No recreational developments exist in this area.

7.0 USE

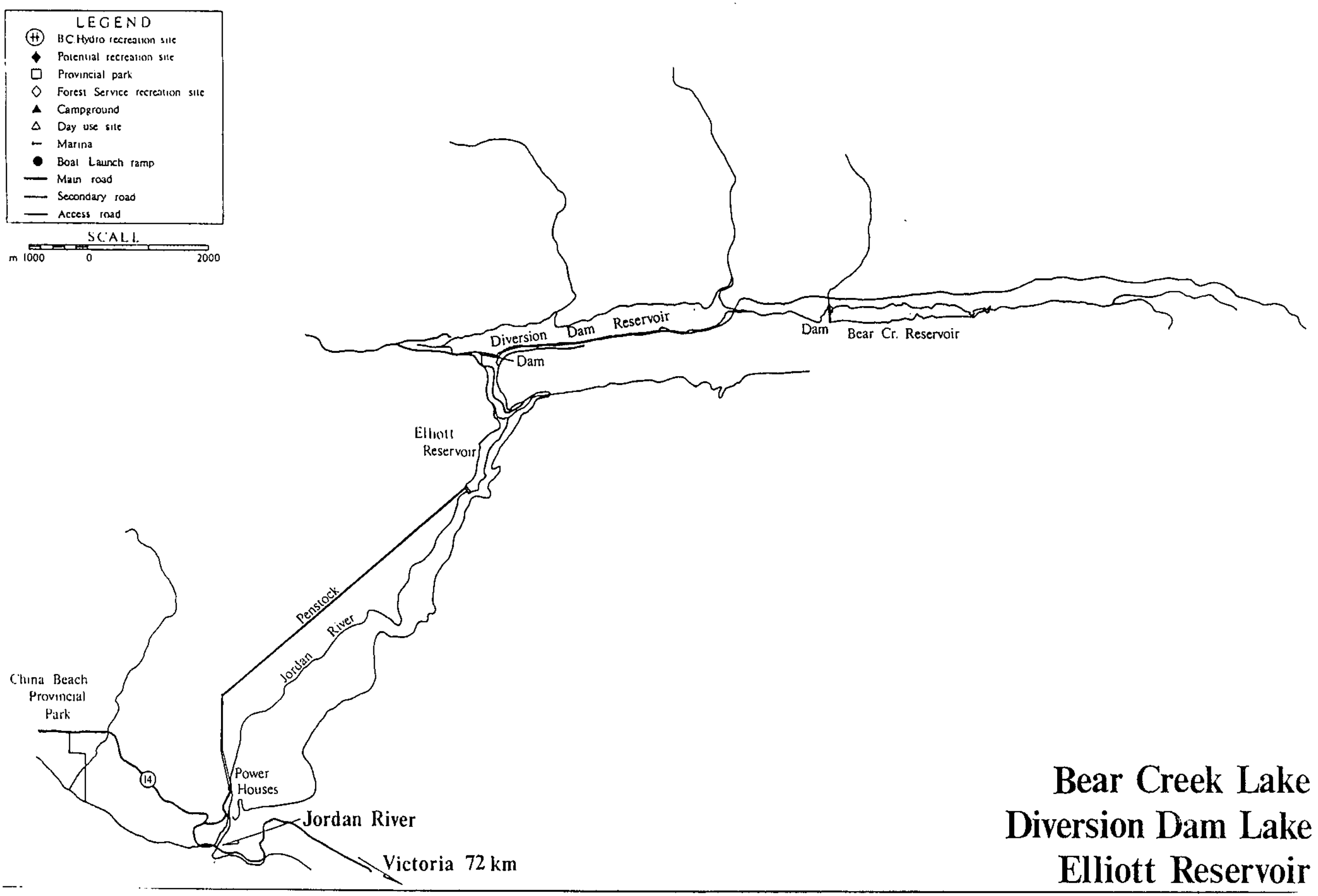
There is no significant recreational use of this area.

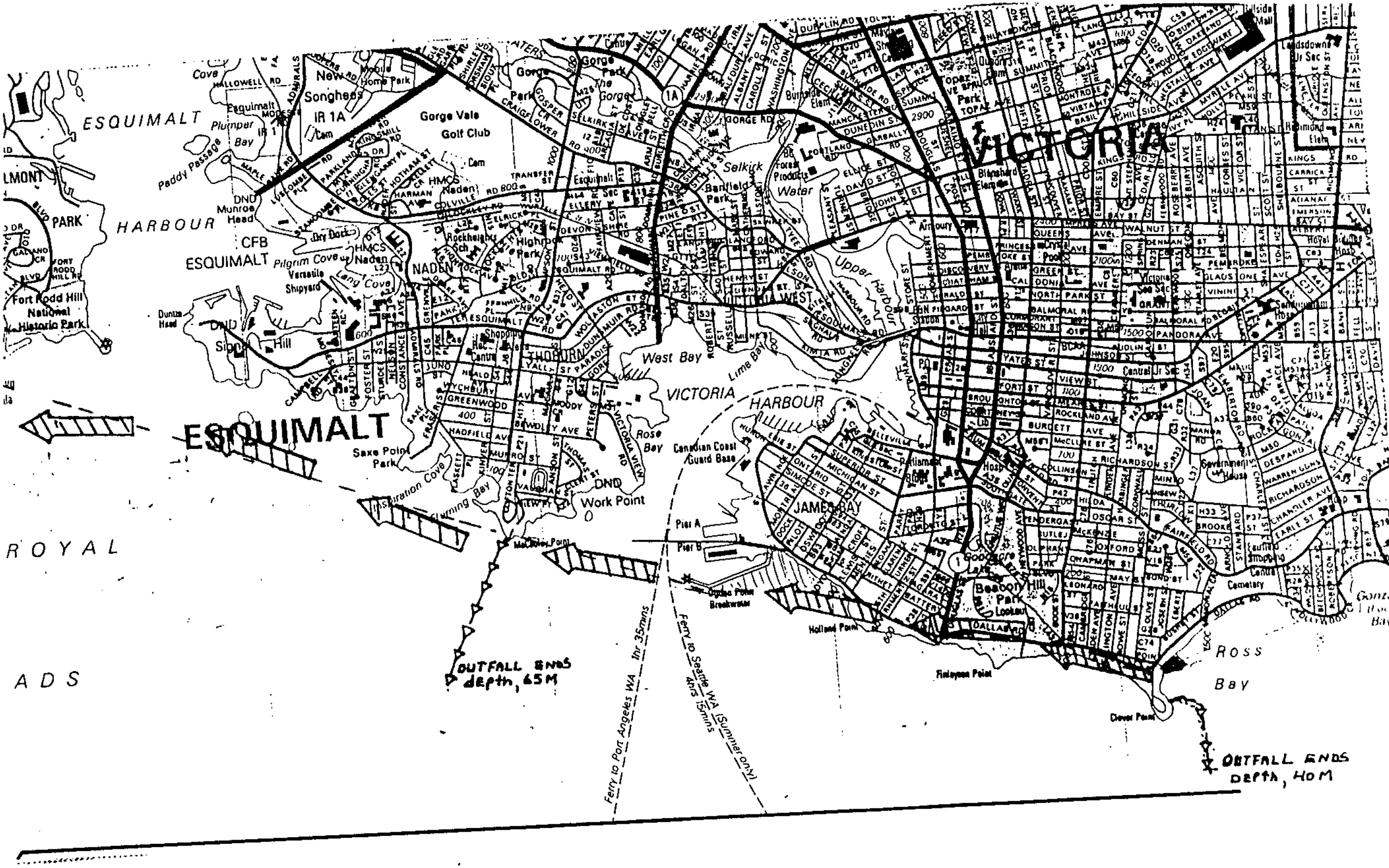
8.0 DEVELOPMENT POTENTIAL

There is no development potential on this reservoir.

9.0 ISSUES

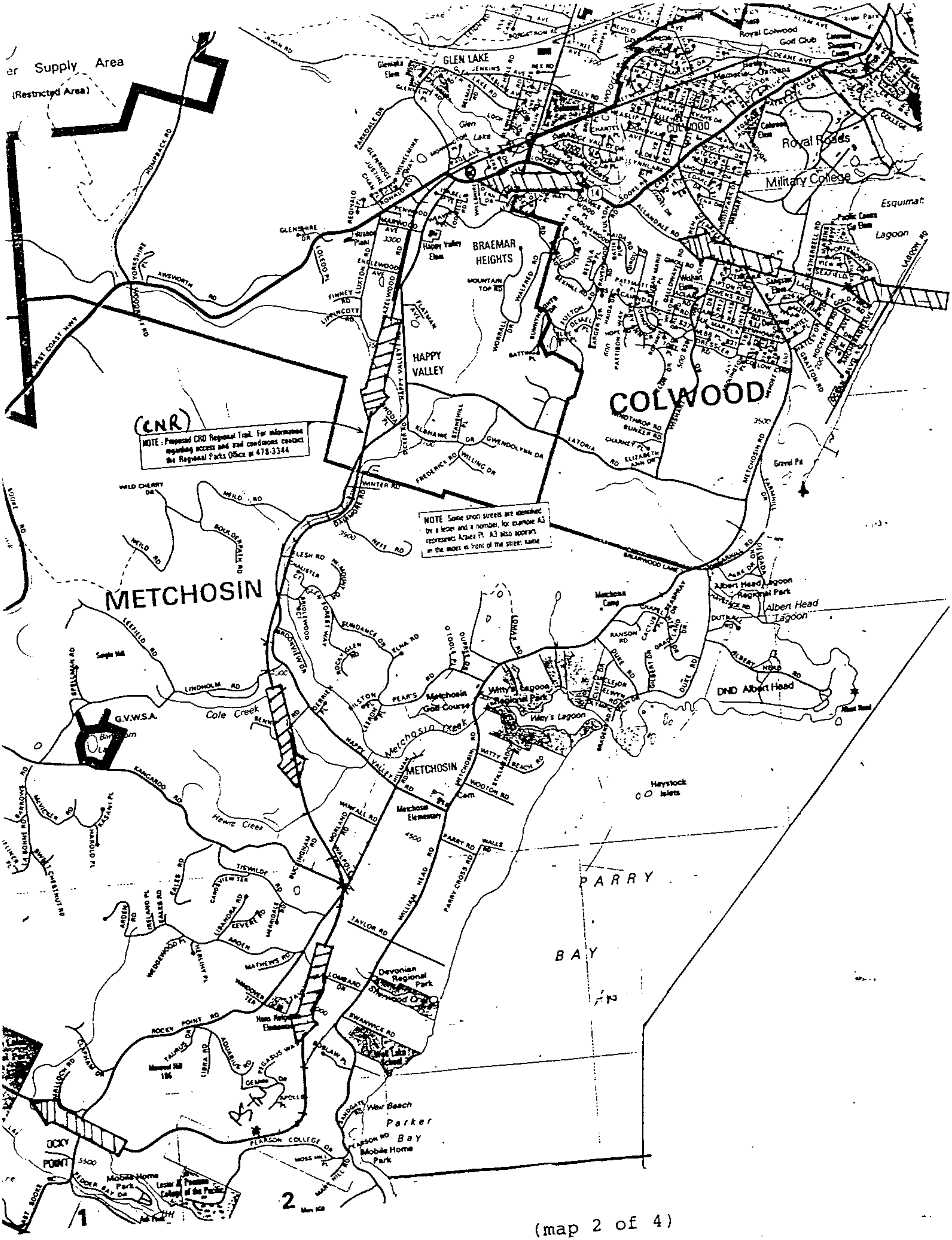
Since area resource values are so low, and development potential non-existent, there are no issues related to recreational development of this reservoir.


LEGEND
BC Hydro recreation site
Potential recreation site
Provincial park
Forest Service recreation site
Campground
Day use site
Marina
Boat Launch ramp
Main road
Secondary road
Access road
SCALE
m 1000
0
2000
Diversion Dam Reservoir
Dam
Dam
Bear Cr. Reservoir
Elliott Reservoir
Penstock
Jordan River
China Beach Provincial Park
14
Power Houses
Jordan River
Victoria 72 km
Bear Creek Lake
Diversion Dam Lake
Elliott Reservoir

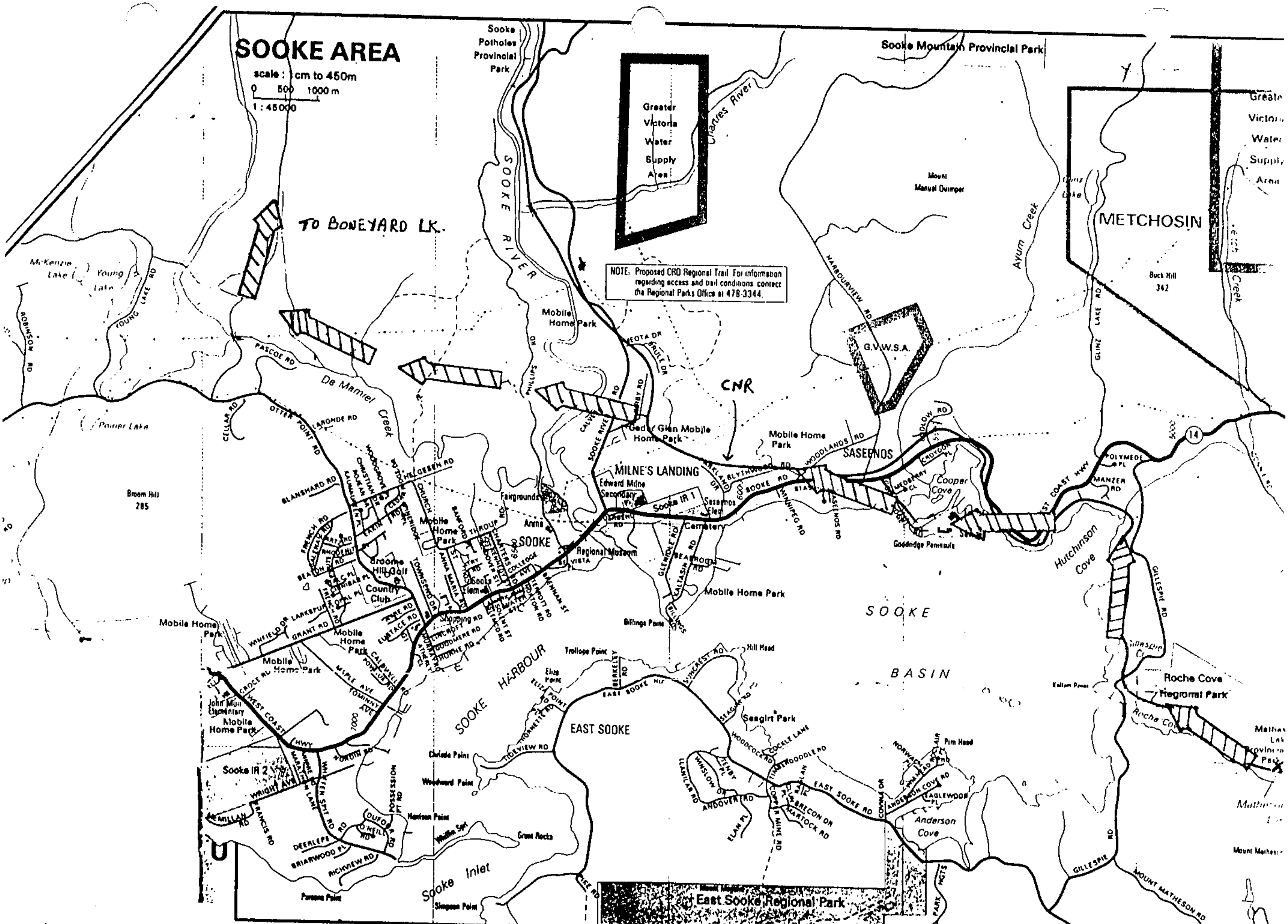


Route of Proposed Sewage Treatment Pipeline

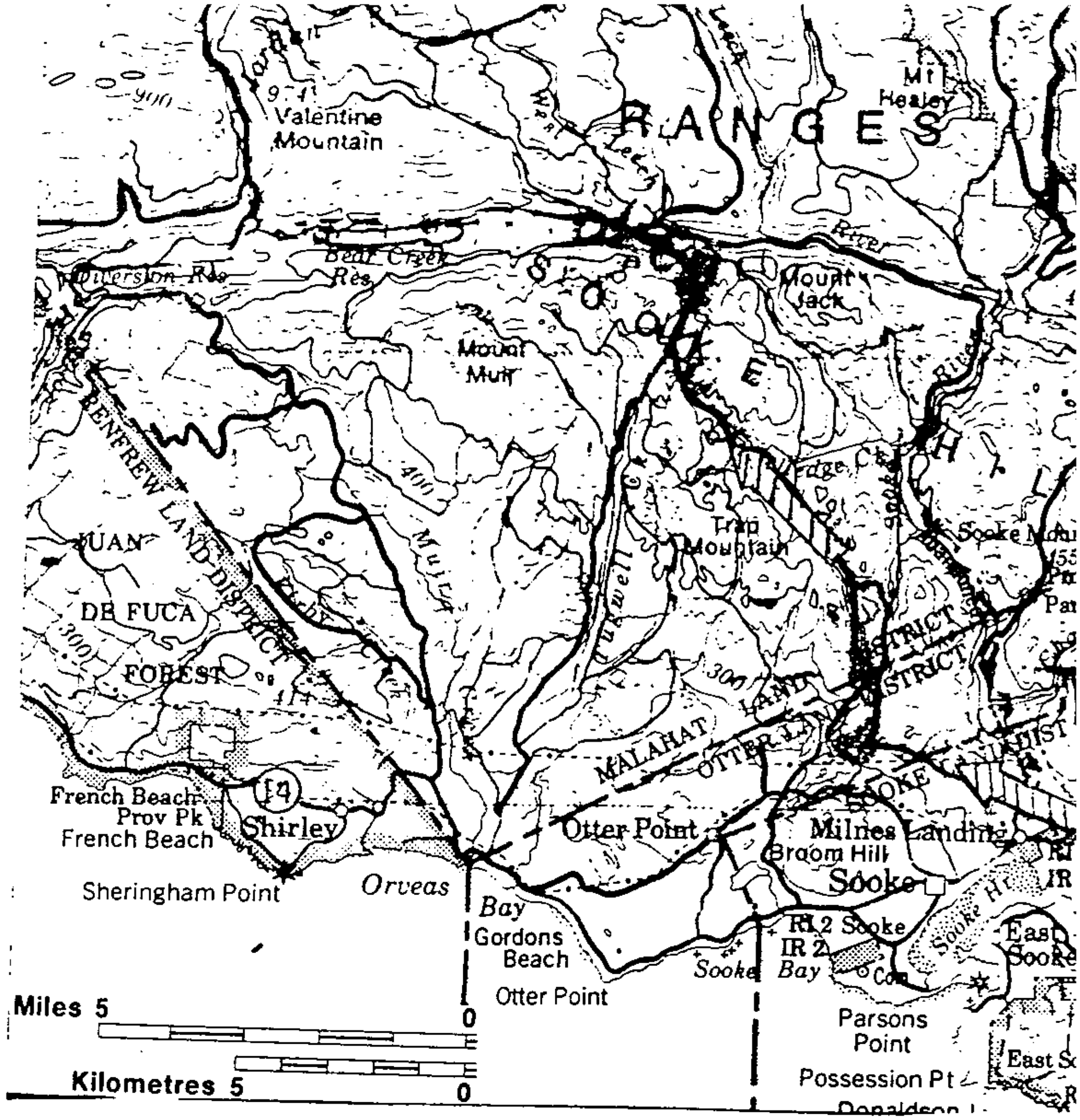
(map 1 of 4)


Supply Area
(Restricted Area)
GLEN LAKE
Royal Colwood
Golf Club
COLWOOD
Royal Roads
Military College
Esquimalt
Lagoon
BRAEMAR
HEIGHTS
HAPPY
VALLEY
COLWOOD
(CNR)
NOTE : Proposed CRD Regional Trail. For information regarding access and trail conditions contact the Regional Parks Office at 478-3344
NOTE Some short streets are identified by a letter and a number, for example A3 represents Azalea Pl. A3 also appears in the index in front of the street name
METCHOSIN
Albert Head Lagoon
Regional Park
Albert Head
Lagoon
DND Albert Head
G.V.W.S.A.
Cole Creek
Metchosin Creek
Witty's Lagoon
Regional Park
Witty's Lagoon
METCHOSIN
Metchosin
Golf Course
Haystock
Islets
Metchosin
Elementary
PARRY
BAY
Devonian
Regional
Park
Weir Beach
Parker
Bay
Mobile Home
Park
Lester B. Pearson
College of the Pacific
1
2

(map 2 of 4)

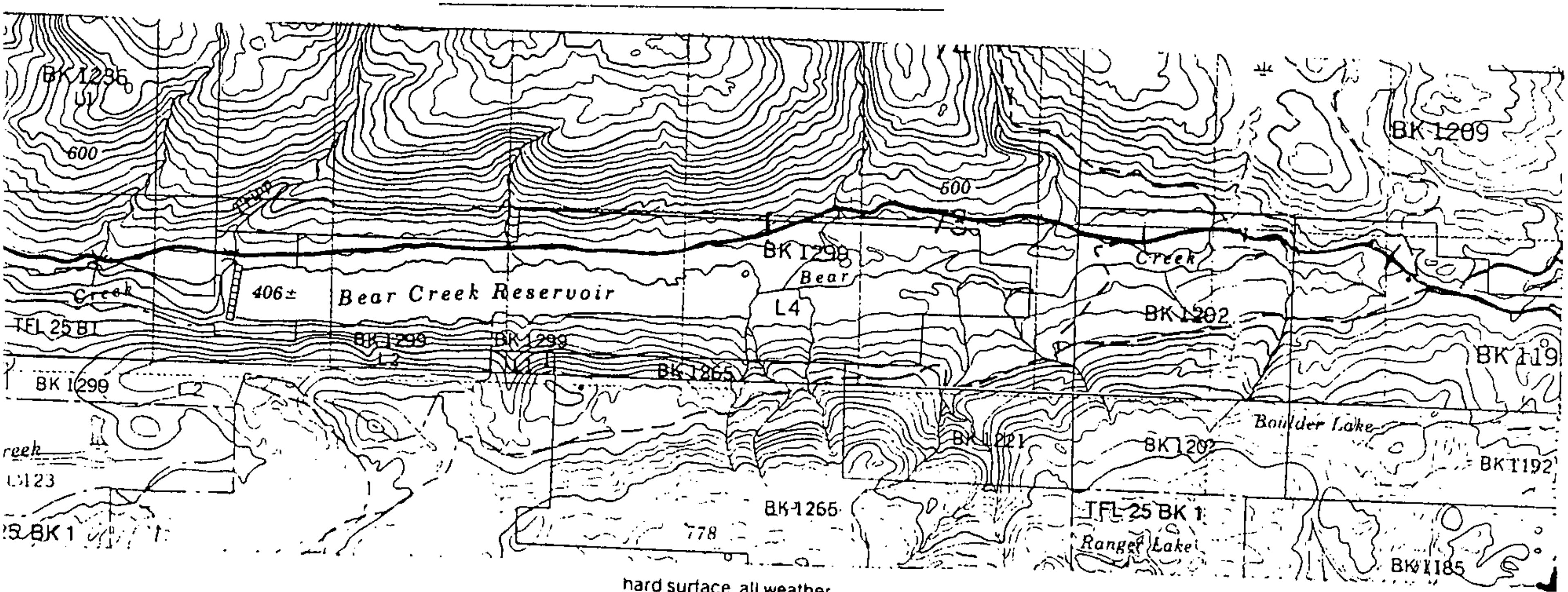

SOOKE AREA
scale : 1 cm to 450m
0 500 1000 m
1 : 45000
TO BONEYARD LK.
CNR
NOTE: Proposed CRD Regional Trail. For information regarding access and trail conditions contact the Regional Parks Office at 478-3344.
Sooke Potholes Provincial Park
Sooke Mountain Provincial Park
Greater Victoria Water Supply Area
G.V.W.S.A.
METCHOSIN
Mount Manuel Quimper
Buck Hill 342
Broom Hill 285
SOOKE RIVER
Charles River
Ayum Creek
De Mamiel Creek
Poirier Lake
Young Lake
McKenzie Lake
Glinz Lake
MILNE'S LANDING
SASEENOS
SOOKE
SOOKE HARBOUR
SOOKE BASIN
EAST SOOKE
East Sooke Regional Park
Sooke Inlet
Roche Cove Regional Park
Hutchinson Cove
Cooper Cove
Anderson Cove
Goodridge Peninsula
Seagirt Park
Mobile Home Park
Cedar Glen Mobile Home Park
Edward Milne Secondary
Sooke IR 1
Sooke IR 2
Regional Museum
Fairgrounds
Cemetery
Broome Hill Golf Country Club
John Muir Elementary
Billings Point
Trollope Point
Eliza Point
Hill Head
Pim Head
Christie Point
Woodward Point
Harrison Point
Whiffin Spit
Grant Rocks
Parsons Point
Simpson Point
Kellett Point
WEST COAST HWY
OTTER POINT RD
SOOKE RD
EAST SOOKE RD
HARBOURVIEW RD
GLINZ LAKE RD
GILLESPIE RD
MOUNT MATHESON RD
PHILLIPS RD
SOOKE RIVER RD
WHIFFEN SPIT RD
ROBINSON RD
YOUNG LAKE RD
PASCOE RD
CELLAR RD
LARONDE RD
BLANSHARD RD
CHURCH
TOWNSEND DR
GRANT RD
MAPLE AVE
WRIGHT AVE
FRANCIS RD
WOODLANDS RD
WINNIPEG RD
GLENIDGE RD
BEAUFORT RD
POSSESSION PT RD
TIDEVIEW RD
COPPER MINE RD
ANDOVER RD
LLANILAR RD
WINSLOW DR
ANDERSON COVE RD
COVINA DR
SEAGIRT RD
SUNCREST RD
BERKELEY
BRENNAN ST
SAANICH ST
NAHANNI
CROYDON
POLYMEDE PL
MANZER RD
14

(map 3 of 4)


RANGES
Valentine Mountain
Mt Healey
Bear Creek Res
Mount Jack
Mount Muir
Trap Mountain
RENFREW LAND DISTRICT
JUAN DE FUCA FOREST
MALAHAT LAND DISTRICT
OTTER LAND DISTRICT
French Beach Prov Pk
French Beach
Shirley
Sheringham Point
Orveas Bay
Gordons Beach
Otter Point
Otter Point
Milnes Landing
Broom Hill
Sooke
RI 2 Sooke IR 2
Sooke Bay
East Sooke
Parsons Point
Possession Pt
Miles 5
0
Kilometres 5
0

(map 4 of 4)

PROPOSED PIPELINE DISCHARGE AREA



hard surface, all weather ....

NOTE,

Power development of Jordan R. began in 1911 with an earthfill dam on the Bear Crk tributary.This dam is 57ft.high,impounds a 238 acre lake of 328 million cu.ft. storage capacity.This capacity can be doubled by increasing dam height to 75ft. Drainage area above dam is approx. 8sq.mi.with a gentle sloping upper valley that is composed of coarse slate bedrock. Soils immediatly below dam are of coarse sand and glacial gravel mixed with clay to a depth of 85ft.

R.G. Tennant
R.G. Tennant and Associates
P.O. Box 35691, Station E
Vancouver, B.C. V6M 4G9
ph. 325-2958

June 18, 1991

R.W. Warman, P. Eng.
Technical Assistant to the Chief Engineer
Capital Regional District
524 Yates Street, P.O. Box 1000
Victoria, B.C.
(Fax # 388-4621)

Dear Mr. Warman:

Pursuant to the upcoming meeting of the environment Committee, I would like to offer the following comments in response to your letter of last November 14.

Your idea for treating the sludge as a resource for return to the system is an excellent concept, however, it should be weighed against the availability of commercial micro-organisms that can be tailored to the job, thereby eliminating the capital cost of equipment to continuously extract and return it. Given a high storage capacity for sludge, it may also prove feasible to import surplus activated sludge from other treatment works. In either case, it is roughly calculated that the system (30 mgd) would require approximately 160 tons/day of microbial culture in active circulation along with a daily production of new cells at the rate of 17 tons/day (dry matter). Alternatively, the proposed coal prefilter could eliminate any requirement for an inoculum.

Rather than intercept and remove the sludge before it reached the Bear Creek reservoir, it is now proposed to discharge directly into the reservoir. Then, a submarine manifold and/or a floating curtain system would allocate the discharge so as to maximize the settlement of sludge below the level of new reservoir outlets. During periodic drawdowns of the reservoir, the sludge would be consolidated with reservoir sediments and sluiced into nearby pits that were burrowed during dam construction. Reservoir drawdowns would substantially reduce the potential for algal growth and establishment, while the presettlement of sludge would also substantially reduce trace metal levels in the effluent. The sludge pits would be isolated from the reservoir biota and would be easy to monitor and control in terms of either' accelerating or retarding sludge breakdown. Aside from directly exporting the sludge to the oxygenator, it could also be diverted to irrigate and fertilize catchment forests and, in this sense, sludge production and recovery could be viewed as an investment in sustainable development of the local forest economy.

As to whether there may exist other practical problems that could significantly inflate the price when compared to a conventional system, it must be emphasized that, unlike a conventional plant, determining the economics of a pipeline is a relatively simple undertaking and, that while pipeline treatment would be decidedly unique, it does not signify any major deviation in either pipeline technology or known sewage treatment methods. In fact, as a hybrid of both the activated sludge and stabilization pond methods, it promises to greatly increase treatment efficiency while being for less demanding in both design and operation due to the elimination of any requirement for multi-stage, highly mechanized treatment units. The reservoir discharge also ensures a high degree of operational flexibility by providing an ideal set of natural and highly engineered operating conditions that can be easily manipulated to deal with a short term upset of the bioreactor. Therefore, given that the combined pipeline and reservoir treatments would exceed all fundamental requirements, then your concern about the fact that no comparable pipeline bioreactors were ever built has likely more to do with lack of a proper venue to develop the technology, particularly in face of the potentially high costs for pipeline routing, power and sludge handling in other jurisdictions and, in face of the extreme difficulty of developing a political strategy to justify such a pipeline in a business where extreme conservatism, pork barrel politics and substandard operation are the norm, not the exception.

To your suggestion for a shorter pipeline, I reiterate that the proposed design already includes a nearly 50% reduction in recommended reactor length with respect to the oxygen injection point. This reduction was assumed to be viable because no additional inflows would occur to slow degradation rates while the potential for cascading atmospheric aeration would significantly increase the renovation capacity of the system before impacting on any natural water bodies. Unlike a shorter pipeline, the proposed post-oxygenator route would eliminate any requirement for a conventional backup system and, could significantly reduce both corrosion-related maintenance requirements and related concerns for public safety while eliminating any potential for aesthetic pollution. A shorter pipeline would also have a much more difficult sludge handling problem, along with a likely far tougher public relations problem due to the suggested use of existing outfalls as primary conduits. In terms of cost, the longer pipeline should also prove easier to privately finance and pay down due to its integration with hydropower operations and its capability to generate revenues and attract industrial interest in the region.

The assertion that environmental scientists would prefer an ocean to the river discharge further discounts both the stated purpose and setting of the project, and it is likely more in line with the appalling record of conventional plants to meet design requirements. As discussed, untreated wastewater would not be discharged into the river and the system poses no threat to any natural water bodies. The Bear Lake reservoir should also make an excellent settling and stabilization basin as long as its storage capacity is kept high in relation to its operating requirements. Effluent exiting the reservoir will not affect the Jordan River above its confluence with Bear Creek and, any downstream uses of the river are virtually nonexistent due to peaking hydro operation and the penstock bypass. Preoxygenated effluent could also be injected directly into the penstock and, on a seasonal basis, it could also be employed to induce energy intensive mixing to overcome thermal stratification in downstream reservoirs, thereby maintaining the necessary level of dissolved oxygen at all depths. Downstream reservoir operations are also characterized by rapid water exchange conditions which enhance self-purification while the generating station itself discharges into an essentially nonestuarine river mouth that is characterized by high rate salt water incursion and flushing, which means that pollutants are unlikely to accumulate. Therefore, given the high dilution potential of the storage and, the fact that the addition of preoxygenated effluent would allow regulation of the oxygen regime both upstream and downstream of the dams, then the assimilative capacity of the river is unlikely to be overtaxed even if it were to receive the discharge. In any case, it is well established that diluting effluent with fresh water greatly increases its safety prior to ocean discharge.

As you are aware, ocean systems are very dynamic and subject to wide seasonal fluctuation. With discharges of municipal sewage being held responsible for at least half of all pollution in the oceans, ocean scientists are now concerned that the increasing number of red tide events are possibly being stimulated by sewage-sourced nutrients. In the U.K., the Select Committee on the Environment also recently concluded that sewage-sourced bacteria and viruses commonly survive up to 3 weeks after discharge and, in some cases, up to 18 months. Given that the general public recognizes that we live in an era of ubiquitous global contamination, then the direct discharge to the ocean of raw wastewater can only continue to earn the wrath of neighbours who are interested in preventing the widespread dispersal of pollution on ocean currents and contamination of resources destined for the dinner table. In contrast to the extreme difficulty of achieving even sporadic monitoring of ocean discharged effluent, there is an excellent scientific and engineering capability to assess all water quality and biological production parameters within hydro reservoirs. Also available is a wide variety of established physical, chemical and biological process treatments which are potentially tertiary. Therefore, if we can't understand and control the impact of the discharge on this highly engineered river system, then there is just not much hope for raising Canadian water science and technology above its historic low point.

Treating and diverting the effluent into the reservoir is unlikely to invite public criticism because worldwide, there are several comparable precedents which are considered successful examples of advanced sewage treatment. Also, for nearly a century, the Jordan river has served solely the interests of the energy, mining and forestry industries and, as the discharge would also be compatible with these traditional uses, then it cannot be considered in conflict with the public interest. The project also engenders public support by offering development of a reliable supply of carbon dioxide-free energy, along with development of a least cost hydropower resource that is likely to decrease, not increase, the requirement for new hydroworks in pristine areas. Other net environmental and social benefits could also result due to effluent increasing the currently minimal lake habitat for waterfowl and fisheries while allowing increased downstream flow to enhance riparian habitats during the constant cycle of droughts that ,are now a severe constraint on both river ecology and power operations. Therefore it can be argued that the public interest demands a vastly more efficient use of water than is encompassed in either the direct ocean discharge of watewater or, in the current single-purpose use of the reservoir of power production.

As to why CRD residents should pay to pump wastewater up the hill, the economic case for the scheme rests upon its competitiveness with conventional systems and, upon other option to improve hydro operations in terms of cost per installed KW. The cost must also be assessed in terms of avoided cost to the taxpayer because the system would likely eliminate any requirement for facilities dictated by the maintenance of the present outfall system, such as separate stormwater collection and treatment, a separate composting plant and a separate sewage plant for the Western Communities. As such, the pipeline would likely prove far more attractive to taxpayers because it would greatly simplify waste management and a portion of the resulting savings from developing separate systems could also be transferred into increasing pipeline pumping and storage capacity. While the pipeline would likely have a higher energy use than a conventional plant, the overall cost is likely to be lower because of the power sale, while a conventional plant would contribute nothing to the energy security of the district. The system would also provide every opportunity to recover a high quality water supply for distribution to agriculture on the Saanich Peninsula and, reclaimed water and energy could meet new industry needs in terms of the planning for creating a complex of environmental industries at Jordan River, thereby easing the strain on the domestic water supply.

Regarding the wisdom of pumping wastewater up hill in this area, to not do so would obviate the purpose of the exercise, which is not to simply treat wastewater, but which is to recover it for distribution as a large amount of valued peaking power. Basically, this means that the proposal addresses the vital issue of inadequate storage capacity for standby power generation on Vancouver Island and is not concerned as to the capability of mainland sources to meet its relatively minuscule pump energy demand. Generation capacity at Jordan River is far in excess of its storage capacity and its power is distributed independently of the constrained main transmission on the Island, which means that the proposal could significantly reduce CRD vulnerability to system-wide blackouts while ensuring sufficient contingency power well into the next century. Therefore, your concern about a possible net loss of hydroelectric generating capacity is irrelevant.

From the perspective of Mr. E. Kelgaard, a retired chief hydraulics engineer from the Trans Mountain Pipeline Co., the proposed route profile is to be considered a "piece of cake". It is also his opinion that pipeline cost is unlikely to exceed $1 million/mi. and, that it is probably overdesigned by at least two pump stations. It should not prove necessary to incorporate sufficient capacity to handle all foreseeable demand at the time of construction because while economics of scale are the premiere feature of pipeline economics, the proposed route profile offers to allow easy expansion after initial construction. In any case, it is not expected that any major additional investments will be required beyond the provision of the pipeline, with the possible exception of an estimated $5 - 6 million cost of upgrading the Bear Lake reservoir to increase storage and manage sludge.

As stated, if additional investments are required, they are expected to be paid for by taxpayers and industries in other locales as the result of an integrated approach to project development. Such an approach will certainly be required to maximize the potential for private investment in the project because it ensures other revenue streams to backup pipeline debt and pay down the pipeline. As the project would also represent superior planning with respect to meeting the goals of the recent Green Plan, then it is also more likely to attract senior government financing than could a conventional system.

In summary, it can be argued that the biggest problem facing the CRD is not sewage treatment, but rapid industrial decline. While there are many benefits of sewage treatment, these benefits are likely to be negated if there is not a corresponding increase in jobs and the tax base to offset the cost. Centralized, integrated waste management is what is required to achieve economic growth and reduce the cost of waste management. Therefore, based on the above, I would appreciate your further consideration of the proposal and funding to develop it as a means of generating viable options for integrated resource management.

Yours sincerely,

Richard Tennant, President

Capital Regional District

524 YATES STREET P.O. BOX 1000 VICTORIA B.C. V8W 2S6 TELEPHONE (604) 388-4421

26 June 1991 Eng. File: L55-3

'Mr. Richard Tennant
R.G. Tennant and Associates
P.O. Box 35691, Station E
Vancouver, B.C.
V6M 4G9

Dear Mr. Tennant:

Re: Sewage Treatment Proposal

The Environment Committee of the Capital Regional District considered your sewage treatment proposal and request for funding on 19 June 1991. Its decision was not to provide funding for further evaluation of your proposal.

Further to our discussion following the Environment Committee meeting, I am writing to confirm my suggestions to you about the type of proposal that might be favourably received by the Capital Regional District. I suggest that proposals should contain the following elements:

1. A conventional method of treatment should be proposed.

2. Environmental concerns and how they will be met should be addressed.

3. There should be a clear cost saving to the Region.

Table 4-1 from the report by CH2M Hill on treatment options is enclosed for your information. This table provides total project costs (bylaw costs) for the various options identified by the consultant. Approximately 55% was added to construction costs to obtain bylaw costs.

Yours very truly,

M.C. Williams, P.Eng.
Chief Engineer

CRD

Capital Regional District

524 YATES STREET P.O. BOX 1000 VICTORIA B.C. V8W 2S6 TELEPHONE (604) 360-3000

December 27, 1991

Eng. File: L55-3

Mr. Richard G. Tennant
P.O. Box 35691, Stn. E
Vancouver, B.C.
V6M 4G9

Dear Mr. Tennant:

Re: SEWAGE TREATMENT PROPOSAL - PIPELINE TO JORDAN RIVER

Thank you for your letters of 25 October 1991 and of mid-August. As discussed during our recent telephone conservation, I feel that it would be appropriate for the CRD to take a second look at your proposal, particularly in relation to your recent modification involving use of a reservoir on Bear Creek.

As part of the work on the Liquid Waste Management Plan, we will select a consultant within two or three months to review alternative treatment technologies. I will ensure that his terms of reference include a review of your proposal. You can expect to be contacted by the consultant when one is selected.

The Project Manager for the Liquid Waste Management Plan is Mr. Vernon Rogers. He may be reached directly by telephone at 360-3100 if you require further information about the project.

Yours very truly,

M.C. Williams

M.C. Williams, P.Eng.
Chief Engineer

VJR/

cc: V.J. Rogers, P.Eng. Head, Environmental Services Group
S.B. McDonnell, P.Eng. Manager, Engineering Services
R.W. Warman, P.Eng. Technical Assistant to Chief Engineer

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ASSOCIATED
ENGINEERING

August 26, 1992
File: VW01

R.W. Warman, M.A.Sc., P.Eng.
Technical Assistant to the Chief Engineer
Capital Regional District
524 Yates Street
P.O. Box 1000
Victoria, B.C.
V8W 2S6

Associated
Engineering
(B.C.) Ltd.

Suite 300
4940 Canada Way
Burnaby, B.C.
V5G 4M5

TEL (604) 293-1411
FAX (604) 291-6163

Re: REVIEW OF THE R.G. TENNANT AND ASSOCIATES JORDAN RIVER WASTEWATER TREATMENT AND REUSE PROPOSAL

Dear Mr. Warman:

The following letter report constitutes the results of our review of the R.G. Tennant and Associates Jordan River wastewater treatment and reuse proposal:

1.0 INTRODUCTION

On June 11, 1990 Mr. Richard Tennant of R.G. Tennant and Associates presented the Capital Regional District (CRD) with a letter proposal that promoted the concept that a 51.5 km long pressure pipeline (force main) could be built to export and treat Victoria's wastewater for industrial use at the Jordan River Hydroelectric Project. This initial proposal suggested that the wastewater could be treated in the pipeline en route to the Bear Creek Reservoir, that the treated wastewater could be used to generate hydroelectric power at the Jordan River power plant and that this extra power could be used to support new industries in the Jordan River area.

The original proposal and subsequent submissions included other possible additions to the main proposal. These additional possibilities included:

- sea wall storage of excessive wastewater flows
- the use of partially treated wastewater to wash gravel en route to the Bear Creek reservoir
- rock gabion filters
- cascade treatment

- wastewater treatment using coal and then using the coal to support a coal-water mix thermal power plant
- electrolytic reduction of special waste
- toxic/hazardous waste handling
- solid waste baling
- development of resource recovery centre at Jordan River
- transport of solid waste (garbage) concurrently with the wastewater and subsequent composting of the solid waste in lagoons in the Bear Creek area
- manufacture of soils from waste
- spreading of sludge on re-forested lands
- generation of methane through decomposition of algae that would grow in the Bear Creek reservoir or lagoons constructed in the Bear Creek area.

While some of these possibilities have some merit, they tend to dilute and diffuse the core of the proposal which is to transport raw wastewater to the Bear Creek Reservoir, treat the wastewater, use the wastewater in generation of hydroelectric power and to discharge the wastewater to the ocean via the Jordan River. This report will deal only with this core proposal and not with any of the possible add-ons.

2.0 TRANSPORT OF THE WASTEWATER

The original June 11, 1990 R.G. Tennant proposal was based on a stated maximum flow of "21000 GPM" or 1.31 m^3 /s which equates to approximately 113,200 m^3/day. There were to be nine pump stations en route, each with four pumps. Six pump stations would be based on submersible pumps and three would be based on horizontal split-case pumps. The pressure wastewater pipeline (i.e. force main) had been sized at 36 inch (915 mm) diameter. Using a pipe roughness factor, i.e. a Hazen-Williams "C", of approximately 105, friction head loss had been estimated at 0.00544 ft/ft (m/m) at a velocity of approximately 8 ft./s (2.44 m/s). Any additional head loss due to minor bend losses was estimated to add an additional 10% to the head loss. Based on this overall rate of head loss, a pipeline length of 51.5 km, an overall static lift of 540 m and a flow of 1.31 m^3/s, the proposal suggested that the gross rate of energy consumption would be "25 MWh/day" which would cost $5 million/year assuming a $0.029/kWh BC Hydro cost and an even credit for "5 MWh" per day that the proposal suggested could be generated from effluent discharge through the Jordan River hydroelectric power plant.

The discussion below addresses a number of elements of the wastewater transport portion of the proposal.

.1 Wastewater Flow

The flow rate of 1.31 m^3/s or 113200 m^3/day suggested by R.G. Tennant and Associates as the maximum pumping rate would be too low for future situations. The April, 1991 CH2M Hill CRD report, "Sewage Treatment Options and Location of Sites", estimated a year 2015 average daily regional wastewater flow of 164,500 m^3/day (which excluded Colwood and Langford). The maximum daily flow for the same year was estimated at 335,700 m^3/day but even this does not account for the possibility of shorter, i.e. maximum hourly, peaks. CH2M Hill also estimated the regional wastewater flows (excluding Colwood and Langford) for the year 2045 (i.e. 53 years in the future) as 188900 m^3/day for the average day and 387,500 m^3/day for the maximum day.

Although flow equalization capacity could theoretically be provided to permit no higher than the average flow rate to be pumped, there would still be problems. Provision of open raw wastewater overflows or storage ponds, such as R.G. Tennant and Associate's sea wall wastewater storage proposal, would likely be deemed an unacceptable solution to handling on-going peak flow problems based on aesthetic, if not health, reasons. Closed storage or holding tanks of adequate capacity would cost in the order of $35 million to $55 million. As a result, it would be best if the wastewater transport system be designed with sufficient capacity to handle at least the maximum daily 2015 flow. Furthermore, since a project of this nature must have a very low risk of failure, incorporation of excess capacity and/or redundancy would be prudent. Incorporation of the year 2045 flows would also be advisable, if at all possible.

.2 Selection of Pipe Type and Size

The R.G. Tennant and Associates proposal indicated that the pipe size had been arbitrarily set at 36 inches (915 mm). Pipe type was assumed to be unlined welded steel. The implied roughness of the pipe was high at a calculated Hazen-Williams "C" of approximately 105 based on a flow velocity of 8 ft/s (2.44 m/s) and a stated head loss rate of 0.00544 ft/ft (m/m). Improvements on these selections are possible.

Pipe sizing is a trade-off between capital cost and operating cost. For a given flow rate and transmission length, spending more money on pipe will allow larger, smoother pipes to be purchased which will decrease the flow velocity and, therefore, head loss, which in turn, reduces the operating cost, i.e. energy consumption costs, of the pipeline. Conversely, spending less money on pipe will result in higher head losses and higher energy costs. Furthermore, the interaction between pipe diameter and head loss will be non-linear because head loss is a function of the square of the flow velocity and flow velocity is a function of the square of the diameter.

Unlined steel pipe would likely not be the best choice for long term service as it would start off relatively rough and would be subject to a build up of "tubercular" corrosion nodules that would increase the pipe roughness, decrease the effective diameter of the pipe, increase flow velocity and increase head loss over time. A better selection would be cement mortar-lined welded steel pipe, epoxy- or enamel-lined welded steel pipe or bonded plastic-lined welded steel pipe as these pipe types would be less prone to corrosion and would maintain a relatively high Hazen-Williams "C" of 130 to 140 over

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their service life. For the purposes of this report, it has been assumed that cement mortar-lined welded steel pipe with a "C" of 130 would be employed.

As shown in Figure 1, pipe costs increase somewhat non-linearly with increasing diameter. Energy costs would be linear in the \$0.0375/kwh price block (according to a letter dated November 16, 1990, from BC Hydro to R.G. Tennant and Associates), not \$0.029/kwh as had been suggested by R.G. Tennant and Associates in the original proposal.

On this basis, it is possible to set up an analysis that includes the increase of pipe cost and decrease in energy costs with increase in pipe diameter. Furthermore, as shown in Table 1 for the average daily 2015 flow of 164,500 m^3/day, it is possible to incorporate the present value into the analysis of such a system using an assumed design life and discount rate, which in this case have been selected as 50 years and 5%, respectively. As shown in Figure 2, the resulting summation of pipe cost and the present value of the energy cost has a minimum point. Selection of pipe sizes at, or slightly above, this low point would provide the least cost solution that would have at least the stated flow capacity.

For the example 2015 average daily flow of 164,500 m^3/day, this low point in Figure 2 occurs at a pipe diameter of approximately 1050 mm for a single pipeline with a Hazen-Williams C of 130. At this diameter, the estimated capital cost of the initial construction of the pipeline alone, i.e. excluding pump station costs, would be \$61.23 million. The energy cost would be approximately \$13,700/day or \$4.99 million/year, for a present value of the 50 years of annual energy cost of \$91.16 million. The total present value of pipe and energy would be \$152.39 million.

It should be noted that, in this example, the curve is very flat in the region of 1050 mm to 1200 mm diameter. The initial construction

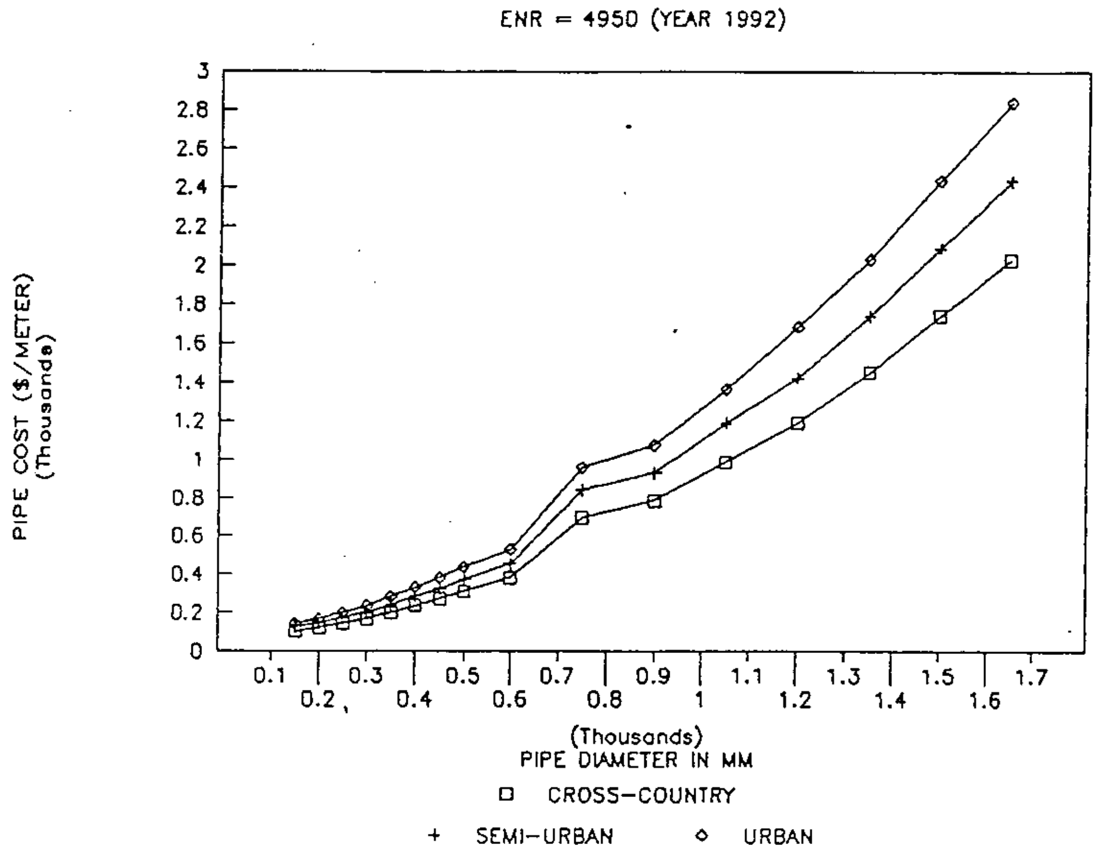

Figure 1 Estimated Pipe Costs

TABLE 1 PIPELINE SIZING CALCULATIONS FOR THE AVERAGE DAILY 2015 FLOW CONDITONS

Q=	164500 M3/DAY	(	1.904 M3/S)
C=	130 FOR HAZEN−WILLIAMS		
ENERGY COSTS=	0.0375 $/KWh		
PIPELINE LENGTH=	51.5 KM		
MAX. ELEV. =	540 METERS		(STATIC HEAD)

PIPE DIAMETER (mm)	UNIT PIPE COST ($/M)*	TOTAL PIPE CAPITAL COST	FRICTION HEAD (M)	TOTAL HEAD (M)	AVE. DAILY ENERGY COST**	YEARLY ENERGY COST	PRESENT WORTH OF ENERGY COST (50 YRS,5%)	TOTAL COST (PIPE PLUS ENERGY)
750	841	$43,311,500	994.5	1534.5	$28,634	$10,451,461	$190,791,428	$234,102,928
900	928	$47,792,000	409.2	949.2	$17,713	$6,465,379	$118,025,492	$165,817,492
1050	1189	$61,233,500	193.2	733.2	$13,681	$4,993,714	$91,160,243	$152,393,743
1200	1421	$73,181,500	100.8	640.8	$11,958	$4,364,648	$79,676,646	$152,858,146
1350	1740	$89,610,000	56.8	596.8	$11,137	$4,064,911	$74,204,944	$163,814,944
1500	2087	$107,480,500	34.0	574.0	$10,711	$3,909,609	$71,369,912	$178,850,412
1650	2435	$125,402,500	21.4	561.4	$10,476	$3,823,596	$69,799,743	$195,202,243

* costs taken from the semi−urban cost curve in Figure 1

* based on flow rate in m3/s, 9.801 kN/m3 density, the total head, and an overall pump−motor efficiency of [illegible]0%

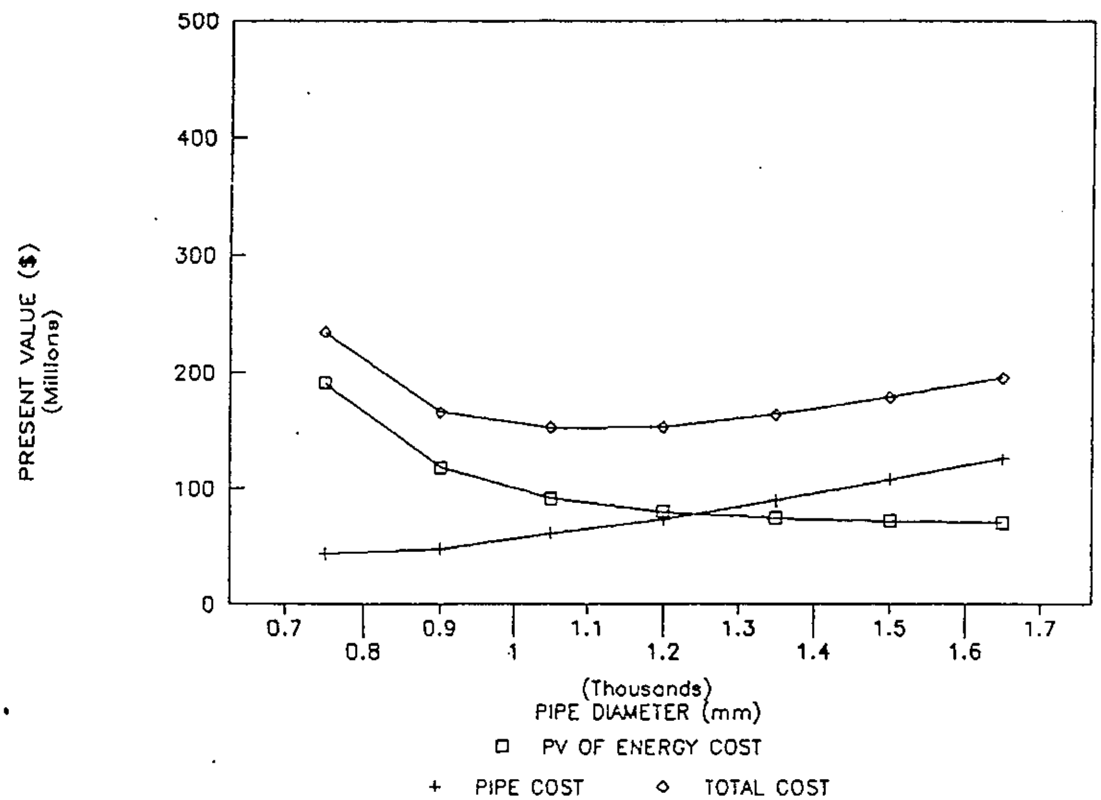

Figure 2 Wastewater Pipeline Costs for Q = 164,500 m^3/day

capital cost of a 1200 mm diameter pipeline would be $73.18 million but the yearly energy costs of $4.36 million would yield a present value of $79.68 million. The total present value of $152.86 million is almost the same as that for the 1050 mm diameter pipeline ($152.39 million). On this basis, it would likely be best to select the 1200 mm pipe for the given flow example, as it would provide some extra capacity at minimal extra cost.

It also should be noted that, while these costs fit within the ranges suggested in the R.G. Tennant and Associates proposal, they do not include the cost of the nine pumping stations. Furthermore, it should be noted that, although the proposal had suggested that the gross power consumption would be "25 MWh/day", the actual the calculated gross power consumption for the average daily 2015 flow would be approximately 365 MWh/day for the 1050 mm diameter pipe and 320 MWh/day for the 1200 mm diameter pipe. These latter figures compare well with 366 MWh/day (133.6 Giga Watt hours (GWh) per year) interpreted from BC Hydro's analysis of six 1500 kW and three 3360 kW pump stations and an 80% load factor, as contained in their November 16, 1990 letter to R.G. Tennant and Associates.

If the pipeline system was to function with little or no risk of inadequate capacity over an assumed 50 year design life, it is necessary to use design flows that are greater than the average daily 2015 flow. In this case, the design flow should be the 2045 maximum daily flow, 387,500 m^3/day. This would also provide extra capacity to handle the maximum daily flows, if not the peak hourly flows, up to that time. From Table 2 and Figure 3, it may be seen that, if the maximum daily 2045 flow was pumped continuously, the best pipe size choice would be 1650 mm. A similar analysis for the maximum daily 2015 flow of 335,700 m^3/day yields a best pipe diameter of 1500 mm, with 1650 mm only marginally higher in total cost. On this basis, a single pipeline of 1650 mm diameter has been selected for use in the remainder of the discussions in this report.

TABLE 2 PIPELINE SIZING CALCULATIONS FOR THE MAXIMUM DAILY 2045 FLOW CONDITONS

Q= 387500 M3/DAY (4.485 M3/S)
C= 130 FOR HAZEN-WILLIAMS
ENERGY COSTS= 0.0375 $/KWh
PIPELINE LENGTH= 51.5 KM
MAX. ELEV. = 540 METERS (STATIC HEAD)

PIPE DIAMETER (mm)	UNIT PIPE COST ($/M)*	TOTAL PIPE CAPITAL COST	FRICTION HEAD (M)	TOTAL HEAD (M)	AVE. DAILY ENERGY COST**	YEARLY ENERGY COST	PRESENT WORTH OF ENERGY COST (50 YRS,5%)	TOTAL COST (PIPE PLUS ENERGY)
750	841	$43,311,500	4852.8	5392.8	$237,051	$86,523,786	$1,579,491,707	$1,622,803,207
900	928	$47,792,000	1997.0	2537.0	$111,519	$40,704,552	$743,061,589	$790,853,589
1050	1189	$61,233,500	942.6	1482.6	$65,173	$23,788,049	$434,250,831	$495,484,331
1200	1421	$73,181,500	492.0	1032.0	$45,362	$16,557,061	$302,249,152	$375,430,652
1350	1740	$89,610,000	277.2	817.2	$35,922	$13,111,641	$239,353,009	$328,963,009
1500	2087	$107,480,500	165.9	705.9	$31,031	$11,326,479	$206,764,879	$314,245,379
1650	2435	$125,402,500	104.3	644.3	$28,323	$10,337,775	$188,716,091	$314,118,591

* costs taken from the semi-urban cost curve in Figure 1

* based on flow rate in m3/s, 9.801 kN/m3 density, the total head, and an overall pump-motor efficiency of 90%

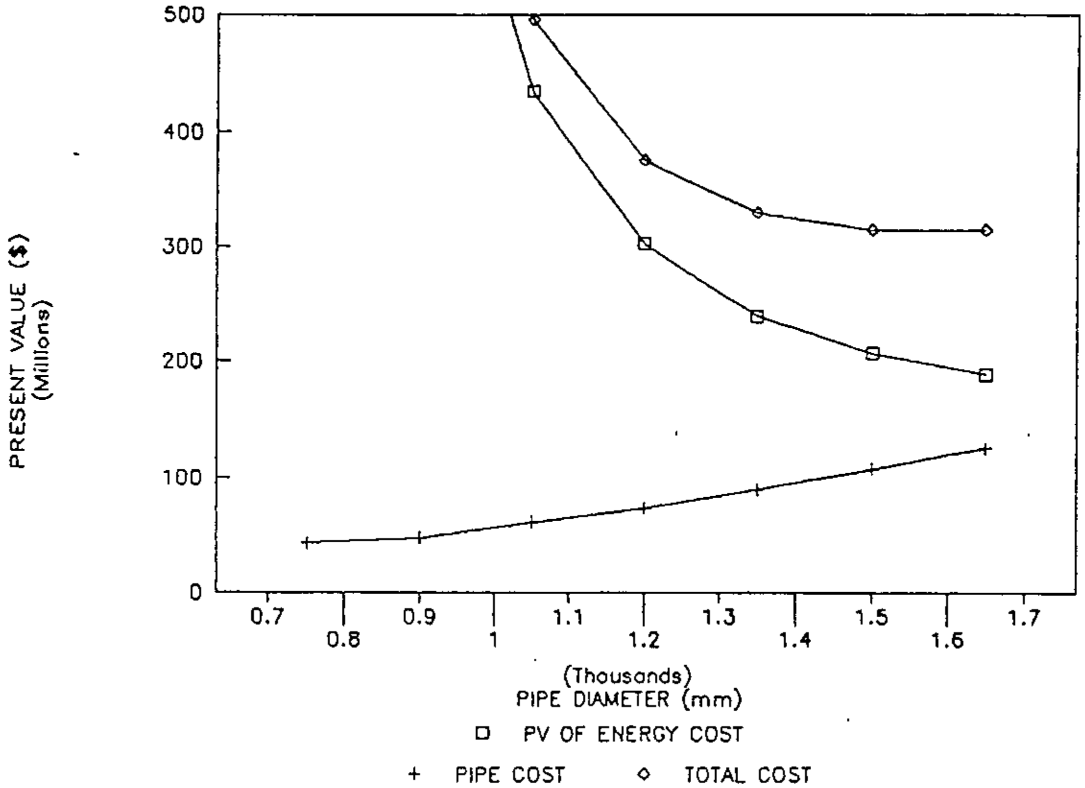

Figure 3 Wastewater Pipeline Costs for Q = 387,500 m^3/day

The initial construction cost of this 1650 mm pipeline would be approximately $125.4 million (excluding pump station costs). This can be compared with the $82.87 million initial construction cost of conveying wastewater to a regional wastewater treatment site in the Colwood area using submerged pipelines and more urban construction (Reference: Table Cost-2-P.WK1 in the Appendix to Chapter 4 in the April 1991, CH2M Hill report).

Using the 1650 mm diameter pipeline, pumping the 2015 average daily flow would yield a self-cleansing flow velocity of 0.89 m/s which would exert a power demand of 11.64 MW and consume 279.4 MWh/day (or 102.0 GWh/year) of energy at a cost of $3.82 million per year. The maximum daily 2015 flow would exert a power demand of 26.23 MW. In the same 1650 mm pipeline, the 2045 average daily flow, 188,900 m^3/day, would exert a power demand of 13.51 MW and consume 324.3 MWh/day (or 118.4 GWh/year) of energy at a cost of $4.44 million per year. The maximum daily 2045 flow would exert a power demand of 31.47 MW.

.3 <u>Pump Stations</u>

The above analysis did not include the cost of pump stations which would be at least somewhat independent of the pipe size that was selected. However, since the pipeline could not function without the pump stations, it is necessary that they be analyzed and costed as part of the analysis of the total wastewater transport system.

The original R.G. Tennant and Associates proposal suggested that there would be a total of nine pump stations needed, each with four pumps: six pump stations would have relatively low static heads and would use submersible pumps; three pump stations would have relatively high static heads and use split case pumps. Although there was some pump costing information appended to the original proposal there was no comprehensive pump station costing provided. It was inferred that the pump station costing was included in the suggested pipeline cost of $60 million to $80 million.

To refine these pump type selections and develop detailed cost estimates, it would be necessary go into a great deal of detailed analysis. This analysis would have to determine the optimum locations of the pump stations that would suit a wide range of flows over the life of the project. Properly done this would also have to investigate the optimum pumping regime (e.g.fixed speed or variable speed) and the necessary pumping control system.

A simpler approach is to assume that each of the pump stations would be equivalent in magnitude, complexity and degree of required redundancy and safety to the influent pump stations suggested in the CH2M Hill report for a regional CRD treatment plant. Furthermore, each of the six low static head pump stations would be assumed to have an initial construction cost approximately the same as the influent pump stations in the CH2M Hill report, i.e. approximately $10 million (in Appendix to Chapter 4 in the CH2M Hill report). The three higher static head stations would cost somewhat more than this. A value of $12 million per station for these three stations has been assumed. On this basis, the total initial construction cost of the pumping stations becomes significant at a total of $96 million.

The total initial construction cost of conveying the wastewater to the Bear Creek reservoir area would be the summation of the pipeline cost and the pumping station cost, i.e. $125.4 million plus $96 million, for a total of $221.4 million. Although this total does not include the cost of any treatment, it compares closely with the total initial construction costs of $187.5 million for a regional primary treatment plant at Colwood and $287.6 million for a regional tertiary treatment plant at Colwood (as given in Appendix to Chapter 4 in the CH2M Hill report for the 2015 flows). Annual operation and maintenance costs for the nine pump stations would total approximately $2.4 million, excluding the required $3.82 to $4.44 million energy costs for pumping the wastewater.

Although the pipeline could be designed and constructed to last fifty years, the pump stations would have to be at least partially replaced well before that time. This would add to the present value of the cost of the pump stations.

3.0 TREATMENT OF THE WASTEWATER

The original R.G. Tennant and Associates proposal included the suggestion that adequate secondary treatment could be achieved simply by injecting air into the pipeline, perhaps with some externally-sourced bacteria inoculum (unspecified as to source, type or cost). This suggestion was based on an article in the scientific literature regarding a lab-scale experiment. Since this potential treatment process can not be backed-up with any full-scale experience, it is unlikely that the process would be considered for use in the CRD situation.

The main treatment alternatives suggested by R.G. Tennant and Associates would be to use the decent from the peak 540 m elevation to the 406 m Bear Creek reservoir elevation as a "cascade" treatment and then to use Bear Creek as a sludge removal and treatment lagoon, complete with integral sludge holding and digestion. In any event, the cascade treatment would aerate but likely only partially treat the wastewater. Furthermore, having potentially leaky channels on a hill side slope could cause slope stability problems and, potentially, localized landslides. For these reasons, cascade treatment is rejected as a viable, effective, long-term treatment possibility for the CRD.

The Bear Creek reservoir is the upper most reservoir in a three reservoir system (which also includes the Diversion and Elliot reservoirs) that serves the Jordan River hydroelectric power plant. Investigations conducted by B.C. Hydro determined that the Bear Creek reservoir is not seismically safe, i.e. the dam could fail during a moderate earthquake. This posed three possibilities to B.C. Hydro: upgrade the dam so that it could withstand the design earthquake at the original full supply (water) level (FSL), abandon the reservoir and dam, or upgrade the dam but to meet the design earthquake requirements for a new, lower, FSL.

According to B.C. Hydro (Mr. Bill Walker, 722-5231 - Victoria and Mr. Aneel Kumar, 663-4156 - Vancouver), it is not technically or economically feasible to upgrade the dam to meet earthquake standards for the original FSL. As a result, B.C. Hydro seriously considered the abandonment option and had an environmental impact assessment conducted. This study concluded that there would be net environmental benefits if the reservoir was maintained in some form. As a result, B.C. Hydro has implemented a program in which the FSL will be decreased by lowering the elevation of the overflow spillway and a berm will be constructed in the area of the dam toe to help stabilize the dam and contain any water overtopping the dam during the design earthquake.

The Bear Creek reservoir will therefore continue to exist, albeit in a somewhat diminished form. Since this will likely require maintenance and/or improvement of existing fresh water quality in the reservoir, the discharge of raw or partially treated wastewater to the reservoir would likely be unacceptable.

Based on the trends developing in the Ministry of Environment, Lands and Parks with respect to minimum wastewater treatment standards, it assumed in this report that the minimum acceptable treatment for discharge into a freshwater body such as the Bear Creek reservoir and Jordan River system would be secondary treatment. The least expensive method of providing this level of treatment, given the availability of land in the Bear Creek reservoir area and the lack of people in the area to cause conflicts, would most likely be aerated lagoons since they eliminate the need for both primary treatment and separate sludge digestion. These lagoons could be designed with a nominal 15 days retention time in the aerated portion of the lagoons and 7.5 days in settling ponds. The Bear Creek reservoir could then serve as a final polishing pond. This level of treatment should serve to satisfy the Ministry of Environment as well as BC Hydro which had expressed some concern about pathogens in the wastewater in their November 16, 1990 letter to R.G. Tennant and Associates.

It is estimated that, excluding the cost of an upgraded road to the site, the initial construction cost of an aerated lagoon of the above capacity would be in the order of $50 to $75 million, with the higher value reflecting more difficult geotechnical conditions, which is likely the case. Even using the lower optimistic value, the total initial construction transport and treatment cost would be $271.4 million. Applying an engineering and administration factor of 1.2 and the CRD project implementation factor of 1.55 (as per the CH2M Hill report), would convert this cost to a project capital cost of $504.8 million which can be compared to the least expensive secondary treatment project capital cost of $403.8 from Table 4-1 of the CH2M Hill report.

Since the flow in the Jordan River during dry periods could essentially become entirely secondary treatment effluent, it is possible that the Ministry would require nutrient and/or addition metals removal at some time in the future. However, this possibility is not costed in this report.

4.0 GENERATION OF POWER AND ENERGY

Power is the rate of doing work. In terms of hydroelectric power plants, power is calculated by the following equation:

$$\text{Power} = \text{Flow rate} \times \text{liquid density} \times \text{head} \times \text{efficiency}$$

If the flow rate is in m^3/s, the liquid density in Newtons (N)/m^3 (e.g.9801 N/m^3 for water) and the head is in meters, the resulting power is in units of Watts (W). Energy is calculated by measuring the power demand and multiplying it by the time over which that power is demanded and is expressed in units such as kiloWatt-hours (kWh).

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The Jordan River power plant is fed from a penstock located in the Elliot reservoir. The inlet to the penstock is at Elevation 322.9 m and the elevation of the reservoir is maintained between a low of 325.0 m and the spillway crest at 335.0 m. In their November 16, 1990 letter to R.G. Tennant and Associates, BC Hydro estimated that the incremental energy that would come from the 1.31 m^3/s wastewater flow (from the original proposal) would be 30 GWh, i.e. 30 million kWh, per year. This estimate is based on a continuous flow and uses an average reservoir elevation of 330.0 m and an overall efficiency (including turbine efficiency and friction losses in the penstock) of 81%. If the higher year 2015 average wastewater flow of 164500 m^3/day (1.904 m^3/s) was used, the energy that would be generated would be 43.6 GWh/year. This is much less than the 102.0 GWh/year estimated in this report that would be consumed in the pumping of the wastewater to the Bear Creek reservoir in a 1650 mm diameter pipeline.

In the same November, 1990 letter, BC Hydro indicated that they would only pay $0.03/kWh generated from the increased flow. As a result, the extra 43.6 GWh/year would return only $1.31 million per year. This must be compared with the $3.82 million cost required to pay for the energy required by the pumps to get the wastewater to the Bear Creek reservoir.

The original premise of the R.G. Tennant and Associates proposal was to use the extra electrical energy which would result from the extra flow in the Jordan River system to stimulate industry in the Jordan River area. Even if the Jordan River plant was able to run as a base load power plant (instead of a peaking plant) and all of the wastewater flow was used to generate electricity on a continuous basis, the amount of electrical energy that was generated would always be less than that consumed from the power grid to get the wastewater to the top of penstock. Although this is true for many reasons (e.g. significant friction losses over the 51.5 km of pipeline), the main reason is the higher elevation (540 m) over which the wastewater would be pumped and the lower elevation of the Elliot reservoir (less than 335 m). It isn't physically possible to come out even on an energy balance if over 205 m of static head are simply lost. When turbine inefficiencies are factored in, it becomes even less possible to have any extra energy. Since the Jordan River power plant does not exist in isolation but is part of the BC Hydro power grid from which the pumping energy would be consumed, the overall effect of the project is not extra energy available but less energy available.

Furthermore, unless there was adequate storage to permit pumping of CRD wastewater to occur only at off-peak hours, the pumping of the wastewater would actually add a significant load to the electrical distribution system, i.e. a minimum of 11.64 MW (using the average daily 2015 flow). This load would be demanded during most portions of the day, including the peak electric load periods. For comparison purposes, this 11.64 MW load is about 44% of the nominal 26.5 MW capacity of the Jordan River power plant. If the maximum daily 2015 flow of 335,700 m^3/day had to be pumped through the 1650 mm diameter pipeline, the instantaneous load would be 26.23 MW or 99% of the Jordan River power plant capacity. Using the 2045 flows, the average daily flow rate would exert a 13.51 MW demand (51% of the Jordan River power plant capacity) and the maximum daily flow would exert a 31.47 MW demand (119% of the Jordan River power plant capacity).

6.0 CONCLUSIONS

The proposed project would not result in any overall extra energy as a result of pumping CRD wastewater to the Jordan River system for the generation of electrical energy. When compared to a conventional air activated sludge regional wastewater treatment plant located in either Colwood or Burnside West (as per the April 1991 CH2M Hill report), the R.G. Tennant and Associates Jordan River proposal would likely have a net energy consumption that was very much in excess of the total regional treatment plant electrical energy consumption. As a result, the proposal should be rejected as a net source of electrical energy.

The proposal would offer the possibility of using relatively inexpensive aerated lagoon wastewater treatment technology because of the availability

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of land and the remoteness of the site. However, the capital cost to accomplish this treatment would be considerably more than the least expensive air activated sludge secondary treatment option presented to the CRD in the April 1991 CH2M Hill report. Furthermore, cost of operating nine major pumping stations over a 51.5 km distance as well as operating a wastewater treatment plant at a relatively remote site would be distinct drawbacks. In addition, there would still be some risks, such as potentially flooding areas with raw sewage if a pipeline section broke or was somehow damaged, that have not been dealt with in this report. Since the capital costs of the proposed works would be more than the least expensive conventional treatment option and there would be considerable operational difficulties and risks associated with the R.G. Tennant and Associates proposal, the proposal could be rejected as a economically viable treatment alternative.

We thank you for the background information which was provided to us and trust that this report will provide you with the necessary information to make a final decision regarding the R.G. Tennant and Associates proposal. Should you have any questions, please contact either of the undersigned.

Yours truly,

PROFESSIONAL ENGINEER — PROVINCE OF BRITISH COLUMBIA — J. R. E. CORBETT

David Forgie

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cc: W. Moorman, P.Eng., Assistant Project Manager - CRD

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28/11/95

Dear Mr. Warman,

RE; SEWAGE EXPORT ALTERNATIVE TO JORDAN RIVER

I would like to offer the following comments in response to the AEL letter report of 26/09/92 and to your ongoing program to locate a sewage plant site.

The only revision to be made to the original proposal is to first continue the pipeline down from the peak to the abandoned Forebay Reservoir at the coast. The Forebay, re-lined with asphalt and tunnel clay, would function as a dissolved air flotation plant with a solids skimmer. Enroute from the peak, controlled quantities of atmospheric air could be freely induced into the pipeline by employing venturi tube pumps.

Regarding safety concerns, there is a wide body of knowledge available on operating such pipelines in similiar terrain. High-alloy steels, advanced fiberglass liners or corrosion-resistant concrete sections can all be employed as needed. Earthquake and waterhammer problems are solved by burst discs, terrain diversion pipes, surge arrestors and back flow prevention valves. B.C. Hydro also has electrical sensor technology that actuates large shut-off valves in the event of a big quake.

In addition to the B.C. Hydro power contract I want to look at using the reclaim water for an aggregate slurry pipeline (10 in. dia.) running at sea level to Victoria at a cost of $5/ton. The idea is based on a 1 M/ton yr. limestone slurry pipe operating in Rugby, England. The aggregate and ore reserves at JR are substantial and a contract ore crushing operation could likely be set up within a re-opened Sunro copper mine, with additional cu, fe, and caco ore feeds imported by a multi-materials ropeway from Gordon River. Crusher energy requirements can be supplemented by pipeline reversible generator pumps or, with pelton wheel generator plants installed inline from the peak. Limestone could also be produced for filtering of domestic water, to upgrade the pH of forestry and reservoir soils, etc.

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Other developments could include a sewage gas power plant and, an experimental coal-water-slurry power plant that would export it's flue gases for algae conversion. These plants could support a DC generating station that would serve for both large scale hydrogen production and, for running an electric railroad running between a new merchant hydrogen complex located at Leechtown and a new railship dock at Becher Bay. Liquified H and O could then be exported to be used to gasify/liquify coal slurry; for "Ballard" fuel cell infrastructure developments; for pipeline oxygen injection; ozone generation for domestic water treatment, etc.

Offshore, developments could include both wind and wave energy power plants. These could be connected to a mile-long breakwater, built at low cost by using local granite and mine tailings mixed with pozzolanic-flyash cement that would be placed by using an aerial ropeway employing recycled offshore oil rigs as platforms that, in turn, could be used to distribute sterilized, nutrient-enriched sewage for maraculture ponds and for kelp processing. The breakwater would establish an ideal harbour and lightering area for LASH-type ships and barges. This harbour would also prove ideal for single-point mooring and transfer of slurried coal and ores, oil spill/ballast water offload and, ultimately, a large floating airport. → quarantine facility

Magor pipe preparation and distribution facilities, steel fabricating for ropeway components and LASH feeder-ship and barge construction is also likely to occur, as would lower cost electric people-mover infrastructure and many other developments which, upon review, offer to provide the CRD with an opportunity to develop a linkage between sewage treatment and succeeding economic development that has not been recognized in the current liquid waste management plans, thereby also providing the key to a sustainable industrial development strategy to reverse the recent heavy loss of primary industries and the regions 80% economic dependency on the automobile. If this is the case, then the CRD is likely obligated to deal with possible industrial add-ons to the proposal before concluding as to wether it is economically viable to proceed or not, particularily as each would likely have strong merit and would be unlikely to weaken the argument for proceeding over more costly conventional plants.

Certainly, CRD taxpayers should not be putting up funds for designing sewage treatment schemes that promise only very high costs for the mere sake of convenience and, while the engineering necessity to baseline a comparison between conventional treatment plants and the export pipeline is understood, it is not fair because of the CRD's continuing inability to define any need for a treatment plant. Further, given that the argument in support of outfalls is primarily based on scientific, not economic reasons, then any definition of need for a treatment plant must be based on first considering the potential of the plant to stimulate sustainable economic development and wealth creation in order to help pay for it and retire any public debt.

Conventional treatment plants located at any of the proposed sites would have virtually no capability to either reclaim waste water, attract new industries to the area or, to expand in order to meet any new mandates to upgrade treatment, thereby dictating that maximum flow capacity be uneconomically capitalized upfront because of the likely increase in shoreline/land values, along with the inevitable public opposition to any future additions. A much harder time dealing with sludge is also promised and, much more money will have to be assigned to deal with aesthetics and odor control. Siting at Jordan R. not only solves such problems, it offers opportunities to raise substantial equity capital by pre-selling a multi-million dollar power contract, land and water leases, mineral rights, process patents, contract ore crushing, inter-regional waste collection/disposal contracts etc..

To reiterate, the design goal behind the export pipeline is to create high demand markets for Victoria's municipal sewage by taking advantage of the unique topographical features of the nearby JRHP. These features are most important because they ensure the technical flexibility needed to demonstrate a wide range of treatment technologies in preparation for expansion to handle the magor portion of all wastewater flows generated on South Vancouver Island, (Crofton, Port Alberni, Harmac/Naniamo, Bamberton, etc.), including the treatments suggested in the AEL report.

Like the AEL suggestion, pipeline oxygenation also offers a much simplified method to achieve secondary-level treament objectives while greatly improving the competitiveness of pumped hydro storage plants due to the ability to capitalize the magor portion of the high capital and operating costs with public sewerage operations. This combination promises success in the highly competitive and lucrative markets for these systems, ($5 Billion/yr.) however, the export pipeline must first generate taxpayer support by demonstrating that the magor portion of CRD sewage flows can be treated at substantially less cost than projected for conventional treatment and, that it can be treated for re-use without adverse impact on either the Jordan River or it's hydroelectric project.

The immediate goal then is to acquire the technical, economic and performance data needed to build, operate, patent and finance a first-of-it's-kind operating system, thereby creating a visible application to stimulate worldwide demand and encourage political support for the technology. The principal barrier likely to be faced is not the relatively minor hydro energy demand of a pilot-scale operation, but the lack of capacity to commercialize an environmental technology that, under a worst case pollution scenario, would dump highly-oxygenated effluent into a well-flushed estuary that flows into the northern part of a strait where circulation is environmentally superior to southerly circulation patterns impacted by existing methods.

Meeting the pipeline design goal and maintaining the identified markets means the magor design criteria must be to ensure the rapid paydown of construction debt and earn an adequate return on the investment. This can only be achieved by ensuring a high degree of operational effeciency (per unit of treatment capacity) while minimizing operating costs. Conventional plant designs have very low operating efficiencies due to being sized to deal with highly variable flow regimes. By contrast a sewage reclaim pipeline must be sized on the basis of dealing first with the permitted average daily flow rate in order to allow continuous running at a level close to total available capacity, thereby maximizing the impact of projected revenues while minimizing standby capacity operating costs.

Putting it another way, comparing the export pipeline with conventional treatment is not meaningful because economic viability cannot be assessed at the level of operational efficiency established for conventional treatment designs which exclude any return-on-investment design criteria and, which further ignore economic viability by dictating upfront construction of an operational flow capacity sufficient to handle not only current, but all projected future peak flows to the facility, the net result of which can only prove a a highly inefficient and wasteful use of capital that at least doubles the cost of building any pipeline to Jordan River while also quaranteeing that it will achieve only a very low level of operating efficiency due to the resulting high level of upfront financing costs incurred (as a percentage of total operating costs) to subsidize provision of excessive standby flow capacities set by planners with few incentives to reduce costs.

Therefore, given that Greater Victoria's total permitted average daily flow is 21 Mgd, then my original proposal to build a 36 in. dia. export pipeline to handle up to 30 Mgd is likely still valid and deserving of a detailed evaluation because, while the pipeline would have some excess capacity on a day-to-day basis, it would still prove capable of handling between 60-70% of the existing peak flows. which also means that it would handle between 80-90% of the total permitted flow, thereby bringing it within range of commercial-level operating efficiencies needed to ultimately needed to fully develop the pumped bydro storage option.

It is recognized that friction-induced energy loss is a much larger concern in a smaller pipe however, this loss should be considered in terms of the design goal of the pipeline. Friction-induced energy loss may also be beneficially employed to heat the waste water by up to 10% to accelerate microbial-nutrient metabolysis, the power cost of which deserves to be compared to the highly sensitive batch process of conventional treatment.

In conclusion, the strict engineering necessity of optimizing pipe and pump sizes for any given pipeline is recognized, but a pipeline designed to serve a large pumped hydro scheme has it's economics for pump energy consumption determined primarily by reservoir capacity and by the size of the energy consumption market, a market that is generally considerably higher-valued than the base-load energy usually employed for the pumping, which means that much higher friction tolerances are allowed for pump energy loss and pipe friction. Therefore, in terms of evaluating the potential sewage reclaim market, the standard present value energy analysis applied in the AEL letter report is largely irrelevant, furthering my contention that there is likely no substance to AEL's recommendation that it would be best if my pipeline were sized to handle the projected 2015 flow or, that it's pump stations be anywhere near equivalent in magnitude, complexity and size as those recommended in the report. In fact , the only sound rational for proceeding on the basis of the AEL-recommended pipe size is if a renewable energy source or fossil-fueled power plant can be built to provide the base-load power needed to constantly pump the magor portion of waste waters generated on the south Island, with flows secured by concurrent construction of a waste water pipeline connecting to Crofton along the route of the CRD's rumored freshwater pipeline over the Malahat, thereby leaving little doubt that the project could play a magor role in the export electricity market, in improving overall system reliability and, in greatly reducing waste management costs to industries and consumers.

Thank you for your attention.

R.G. Tennant, President

CRD

Capital Regional District

524 YATES STREET P.O. BOX 1000 VICTORIA B.C. V8W 2S6 TELEPHONE (604) 360-3000

18 January 1996

Eng. File: L55-12-3

Mr. R.G. Tennant, President
Vanport Sterilizers Inc.
1032 Delestre Avenue
Coquitlam, B.C.
V3K 2H2

Dear Mr. Tennant,

Re: Jordan River Wastewater Treatment and Reuse Proposal

Thank you for your letter of 28 November 1995 in which you comment on the August 1992 review of your proposal by Associated Engineering Services Ltd.

I regret that we are not convinced of the need to spend more time on your proposal and do not intend to pursue it further at this time. Your latest letter provides little additional information and we have no authority at the present time to carry out additional studies of treatment alternatives. Our current priorities are completion of stage 2 of the liquid waste management plan, which does not include selection of a specific process for wastewater treatment, and selection of a site for a wastewater treatment facility. This latter item has been postponed until 1997.

Although we are not actively pursuing your proposal, you may wish to engage an independent third party to assess the proposal and to consider the points that you raised about the report by Associated Engineering. We would be pleased to reconsider the proposal at any time if supported by a favourable third party review. I suggest, however, that such a review should be carried out by an engineering firm with expertise in wastewater treatment so that costs for all aspects of treatment and disposal are taken into account. For example, if you propose to pump only the average wastewater flow, the study should consider the cost of dealing with the additional wastewater generated during peak flow hours and wet weather. Sludge management costs also must be considered. Costs should reflect Ministry of Environment, Lands and Parks guidelines and draft regulations for effluent and sludge quality at points of discharge to the environment.

Yours very truly,

R.W. Warman, P.Eng.
Technical Assistant to the Chief Engineer

cc M.C. Williams, P.Eng., Chief Engineer

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VANPORT STERILIZERS INC.

Mr. M. Williams, Chief Engineer,
Capital Regional District,
524 Yates Street, P.O. Box 1000
Victoria, B.C.
V8W 2S6

02/20/96 your file; L55-12-3

Dear Mr. Williams,

Re; Sewage Export Pipelines to Jordan River

This letter concerns the opinions expressed by Mr. Warman in his letter of 01/18/96.

The CRD's opinion that my letter provides little additional information is completely false. The letter offers a rational for the flow regime needed for commercial pipeline operations, it thereby justifies the design of my original proposal and totally refutes both the basic assumption and conclusions of the AEL report. As AEL's report is based on designs which are without relevance to commercial pipeline operations, then why shouldn't you now authorize a re-investigation of my proposal?

Given that proven, "off-the shelf" technology is available to support my recent revision of first stage operations, then my proposal doesn't deserve your classification as a "treatment alternative" for which you "have you have no authority to carry out additional studies". While it is recognized that the devil is in the details, it cannot be denied that the environmental and political problems related to the selection of any treatment process and plant site are largely solved by the Jordan R. site, which also provides sustainable development opportunities that the CRD has not factored into any of it's liquid waste management plans to date. These site-related opportunities are also highly relevant to your search for a definition of need for treatment.

My proposal is further relevant to your imminent plans to spend $30 million on a centralized treatment plant for the Saanich Pennisula because it would likely prove just as cost-effective to constuct an export pipeline from Bazan Bay to connect thru to my main pipeline at Colwood, (via a route along E. Saanich Rd. to Saanichton, then directly over to the Hartland Ave. dump where it would then continue along the Langford border to Colwood). Either a single, large tank could be built at Bazan Bay to handle peak flows or, a portion of the Heal Lake drainage could be reserved for use as a regulating reservoir, with a high density balefill operation then employed to upgrade and reduce the area required for your conventional landfill operations in the drainage.

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To further reduce landfill requirements, fresh garbage could be screened for injection into the pipeline to provide downstream compost or power via gasifiers at JR. Your dump could also serve to locate the proposed coal slurry power plant or, to serve as a terminus for the aggregate slurry pipeline, whereby de-watered, high-pH slurry wastewater could then be employed for power plant acid gas reduction/export. Aggregate reclaim water could also be exported for agricultural use, along with either fresh water or sterilized sewage reclaim in a dedicated, small-diameter pipe reserved for seasonal use. De-watered aggregates destined for export would be discharged into a pneumatic freight capsule pipeline connecting thru to a barge facility at Pat Bay, with a haul-back of imported coal, cement, etc.

A multi-pipeline corridor from Bazan Bay could also prove of value to the Water District in terms of greatly reducing the projected $100 million cost to export water to the CVRD and to the Gulf Islands, exporting from Bazan via either an underwater pipeline or along a planned highway bridge route across Satellite Channel. The bridge could also carry an LRT system or, a high speed electric train system connecting thru to Naniamo (via an upgrade of the E & N from Cowichan), thereby also providing the pipeline corridor to economically access up-Island wastewater flows. An alternative to trains could be to develop a new motor transport infrastructure based on production of hydrogen at JR.

Iregardless of the bridge, replacing a Bazan Bay plant with an export pipeline could prove economical for co-construction of an LRT line alongside the corridor. A "Ballard-Bus" service or an LRT shortline could also connect directly from Hartland Ave. thru to Royal Oak and to the planned LRT line that is currently being studied. As such, an export pipeline that catalyzes a variety of energy options would likely ensure more rapid implementation and economical operation of public transport systems.

Your continuing opposition and refusal to address the specific points I raised about the AEL report makes it very difficult for me to engage an independent third party to assess either my original proposal or the above alternative to a Bazan Bay plant. Furthermore, I believe that I have already provided economical and politically-acceptable arguments to deal with your concerns for managing the peak flow hours and wet weather flows (via staged development with an initial outfall bypass, followed by either additional lines or the option for an enclosed seawall storage). Despite your refusal of engineering support, I will press forward and submit the proposal to at least a couple of well-established engineering firms. I hope for a more positive attitude from the CRD to encourage their investment in a study.

sincerely yours,

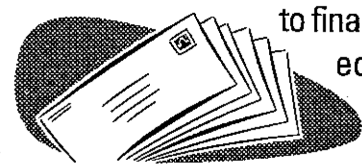
Richard. Tennant

Business in Vancouver December 19–25, 2006

LETTERS

Harnessed effectively, our waste can help us find the on-ramp to the hydrogen highway

Re: the Greater Vancouver Regional District's upcoming decision on a replacement for the Cache Creek landfill. My company has proposed that either the GVRD or the federal government buy the nearest closed pulp mill so it can be converted into a federally licensed agriculture quarantine control facility designed to steam sterilize and produce high-quality artificial forestry soils made from municipal solid wastes, agricultural wastes and contaminated soils. Waste generators would be given a competitive choice of sending their wastes to the facility, including liquid wastes to be converted into peak value electricity and hydrogen. Our proposal would essentially throw the entire municipal waste management system into reverse and employ waste disposal revenues to finance the drive to a hydrogen economy with off-the-shelf technologies, including technology for large-scale economical burning of liquid hydrogen in internal combustion engine vehicles.



Another mega-landfill or burned-out garbage incinerator is not much of a legacy compared to an infrastructure that increases forest productivity and catalyzes a hydrogen economy.

Richard Tennant,
president,
Van Port Sterilizers Inc.,
Coquitlam

BC RESEARCH Inc.

FAX COVER SHEET

ATTENTION TO		COMPANY NAME	
Richard Tennant		Vanport Sterilizers Inc.	
FAX NUMBER	**CITY**	**PGS**	**FROM**
604-936-4194	Coquitlam, BC	1	Norman Chow
DATE	**PROJECT NUMBER**	**SUBJECT**	
December 15, 2003	05663	Alternate Energy and Artificial Soils	

Dear Richard:

It was nice meeting you at the BC Research Open House.

Regarding your fax, typical electrolyzers use an electrolyte containing 20 to 25% sodium or potassium hydroxide solution, operate at 70 to 80 deg C and require approx. 4.2 to 4.6 kWhr to produce 1 m3 of H2 at STP.

I believe that your question on your fax is: How much H2 and O2 can be generated from 100 MGD of water?

The theoretical amount of H2 and O2 that can be produced from 100 MGD of water is 470.4 Mm3 per day H2 and 237.2 Mm3 per day O2. The biggest issue with H2 generation is not the availability of water but rather the power consumption.

Feel free to call if you have anymore questions.

Best Regards,

Norman Chow

3650 Wesbrook Mall, Vancouver, BC, V6S 2L2, Canada **Tel: (604) 224-4331** **Fax: (604) 224-0540**

Business in Vancouver Oct 3-9/06

Premature to discount the future practicality of ethanol and other alternative energy sources

Re: More energy answers in proven technologies (Peter Ladner's At Large column; issue 882, September 19 – 25).

The fact that the fuel cell industry owns the "hydrogen highway" trademark does not mean that a hydrogen economy cannot be developed without fuel cell vehicles. Witness BMW's recent announcement of full-scale production of its new series of hydrogen-fuelled sedans that burn hydrogen in an internal combustion engine (HICE).

Like the gasoline consumer economy, the competitiveness of a hydrogen economy will be not be defined by the laws of physics, but by the measure of its convenience and utility to the consumer, and, on this account, electric vehicles fuelled by an "electron economy" have never been considered practical since the dawn of the auto age.

As a layman, I have discovered that a lot of hydrogen (e.g. 400 million cubic metres per day) could be quickly produced by recycling municipal wastewater through hybrid pumped storage plants located near Vancouver and Victoria, whereby electrolyzing just one-tenth of the wastewater produced in these regions would result in a volume of hydrogen that is greater than the daily volume of natural gas consumed in B.C.

Renewables could have a big role to play in producing the hydrogen, and pumped storage solves two of the biggest problems with renewable energy, which are its lack of storage and low power density.

With regard to your unfavourable assessment of corn-based ethanol, recent research (at New York University) has demonstrated that ethanol can also be produced economically by acid hydrolysis of forestry wastes under a high pressure reaction.

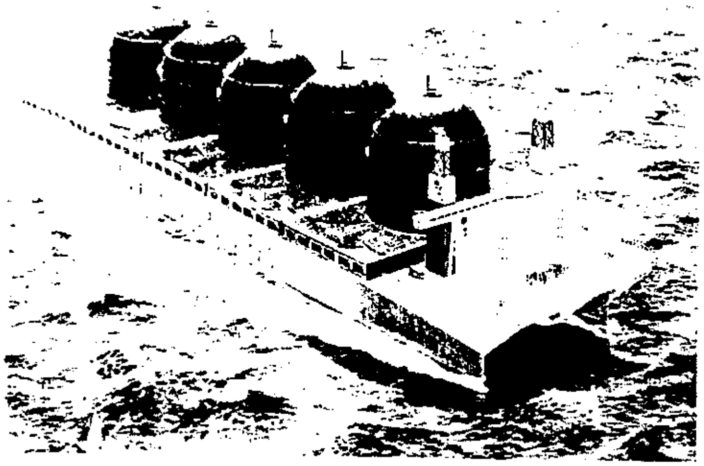
If the wastes could be economically imported to biorefineries located near major urban centres, then there would be no need to build and operate costly import pipelines.

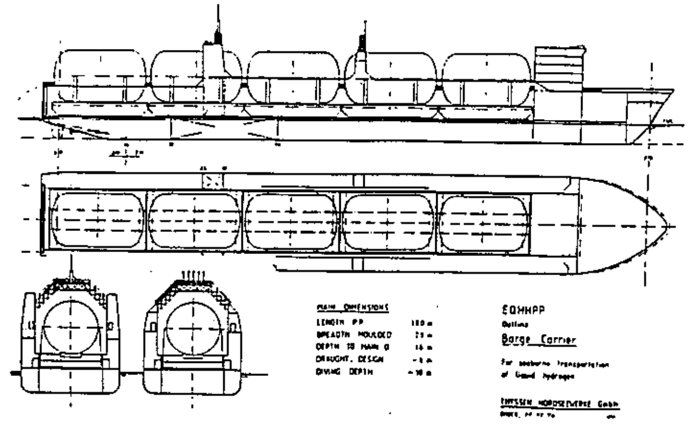
Therefore, I believe it is premature to argue that alternative fuels are not practical or that your vehicle could not be made more efficient and have an even longer driving range thanks to the addition of a liquid hydrogen storage tank and a flexible fuel burner.

Richard Tennant
Coquitlam

"The laws of physics speak against a hydrogen economy, and physics cannot be changed by wishful thinking, political initiatives, research programs or venture capital."

Dr. Ulf Bossel, chairman of the global Lucerne Fuel Cell Forum, on the limited light he sees at the end of the tunnel for the hydrogen economy. From a Peter Ladner At Large





Two alternative designs for sea-going liquid hydrogen carriers that would be deployed as part of the Euro-Quebec Hydro Hydrogen Project. Both designs envision the use of large platform-mounted liquid hydrogen tanks that would be removed entirely from the ship for on-shore storage to minimize energy losses that occur each time liquid hydrogen is pumped from one system to another. The rendering on the left depicts a SWATH (Small Waterplane Area Twin Hull) design by Howaldtswerke-Deutsche Werft AG, Kiel, Germany, shown as a 9-foot scale model at GASTECH 93, a LNG/LPG conference & exhibition Feb. 16-19 in Paris. A conference visitor told THL this was the first time that a LNG exhibitor showed a model of future LH2 technology.

The line drawing on the right shows a 180-meter (592 feet) barge carrier concept by Thyssen Nordseewerke, Emden, Germany. The five barge-mounted LH2 tanks would be floated out from the mother ship to shore. Each of the five tanks has a volume of 3000 cu.m. (NASA's storage tanks holds about 3800 cu. m.).

NREL News............

"Nanotubules" Promise Efficient H Storage

WASHINGTON, DC - A new variant of activated carbon adsorption may hold promise for efficient hydrogen storage for transportation, according to a researcher from the National Renewable Energy Laboratory (NREL) in Golden, CO.

Michael Heben presented early results of his work at a one-day hydrogen workshop that was part of the large joint Solar Energy Forum April 22-28 here presented by several solar energy groups. The workshop, paid for by NREL, was organized by the American Renewable Hydrogen Energy Alliance (ARHEA), the new trade association founded by the Solar Energy Industries Association (SEIA) (THL May 1992).

The program, which has been underway for about five months, is expected to yield tiny assemblies of parallel tubules. Each tubule would have a diameter of only about 20 Angstrom, and the diameter of the interstitial space between tubules would be about 5 Angstrom. These interstitial volumes would act as a kind of nano-capillary filling mechanism where hydrogen would be stored at densities of possibly 8% of hydrogen by weight, according to Heben.

Expected properties of the new material include density of 1 gm/cc; surface area of 5000 sq. m./gram and 4 kJ/mole heat of absorption per hydrogen molecule.

Could be Cost-Competitive Hydrogen Storage Medium

"It could be an important new mechanism for hydrogen storage," Heben said. "Carbon nanotubules hold promise for lightweight, high density and cost-competitive hydrogen storage."

Scott Hynek of Arthur D. Little, Inc., Cambridge, MA, presented an overview of its program of evaluating onboard hydrogen storage systems for future fuel cell vehicles, including the construction and testing of hardware, for the U.S. Energy Department with results due for delivery at the end of next year.

As part of the same program, Arthur D. Little also has a companion study underway to evaluate on-board reformer technology for fuel cell vehicles such as partial oxidation and autothermal reforming, according to program director Jeffrey Bentley. Bentley expects to have the first test prototype by the end of the year, followed by two years of testing.

Arthur D. Little Study to Test Storage in the Field

For storage, the four primary candidates are liquid hydrogen, metal hydrides, compressed vapor, and carbon adsorption. At a meeting last December, Hynek said while no storage technology is best for all applications, or obviously favored for fuel cell vehicles, metal hydrides are a near-term solution. But carbon adsorption is "the only developing technology likely to meet the goals of the DoE Hydrogen Plan for smaller fuel cell-powered vehicles," he wrote in a paper for the December meeting in Montreal.

Consequently, ADL is focussing on activated carbon in its program, Hynek indicated at the Washington workshop. Questions to be answered include, how well do activated carbons really adsorb hydrogen? How much can they be realistically improved? How sensitive are they to poisoning by reformate (hydrogen from reformed natural gas) and to shock and vibration? Do they deteriorate with repeated cycling?

Answers will be sought under field - not laboratory - conditions, Hynek added and will be incorporated in hardware for a transit bus, he added.

David Bruderly, of Tren Fuels Inc. and Bruderly Engineering Associates, Gainesville, FL, reviewed progress in introducing hythane, the hydrogen/methane blend which Bruderly says reduces NOx 75-90% compared to natural gas.

A brief mid-March interim report from an ongoing series of tests by Hydrogen Consultants, Inc. (HCI), Littleton, CO, said that hythane is lower in both carbon monoxide <u>and</u> NOx than pure natural gas in a vehicle tuned to take advantage of hythane's special properties. Usually it's a trade-off, with the decrease of one causing an increase of the other, says HCI.

Bruderly's company is funding construction of the second U.S. hythane station in York, PA, following Boulder, CO. Bruderly says conversion for hythane costs $1,500-4,500 depending on the type of vehicle, and hythane-powered vehicles "easily meet Ultra-Low Emission Vehicle standards.

"The technology is here today," he added. "The question is to find customers who are willing to try it and put up with the inconvenience."