

## **Peer Review Panel Preliminary Findings February 27, 2009**

The Peer Review Panel had its initial meeting in Victoria on February 12-13, 2009. The meeting included presentations by the consulting team and by the authors of the Integrated Resource Management (IRM) report and discussions with the presenters. The Panel also toured portions of the service area. This report describes some of the Panel's initial observations and findings. The Panel's work is still in its early stages. Because much of the consulting team's work on system recommendations and related costs was not yet complete when the panel met, much of this preliminary report addresses general issues and provides some comments related to the IRM report. The Panel will be reviewing the ongoing work by the consultant team to refine and complete its findings over the course of the next 2-3 months. The majority of the Peer Review Panel work lies ahead.

### **Summary**

**Integration of liquid and solid wastes** - Solid waste and biosolids handling and processing should be addressed separately. It provides the flexibility to optimize processing of each solids source to account for their different characteristics and it will better accommodate future technology advances. As an example, the Los Angeles system generates 127 megawatts of power from separate processing of its liquid and solid wastes, uses 29 megawatts of this for operation of its wastewater treatment facilities and transmits the remaining 98 megawatts to the local electric grid.

**Water Reuse Considerations** –The wastewater treatment costs shown in the IRM report underestimate the cost of providing the level of treatment and reliability required for the desired reuse applications.

**System Revenues** – The Peer Review Panel has several questions related to the system revenues shown in the IRM report. For example, \$35 million of the annual revenue projected comes from the existing landfill gases that will decrease with time if the new solids wastes are handled differently, not increase. While collection of landfill gas and its utilization is important and must be done, including it in the integrated plan does not seem appropriate. The various sources of revenues should be spelled out more clearly.

**Flexible Phasing of System Construction** - The Panel believes that it would be more appropriate to consider the three system options being developed by the consulting team as describing elements that could constitute potential phases of a long-term system rather than three separate overall system options. The first phase would focus on the elements common to the three system options. Such a phasing approach would allow flexibility to adapt the system to best manage resource recovery by meeting future demands for energy, heat and reclaimed water when and where they occur. The Saanich East plant would provide a good opportunity to test and demonstrate heat recovery and water reuse as part of the first phase.

**Relative Value of Wastewater Management Infrastructure** - In evaluating the various configurations for the wastewater management system for Victoria, the value of the existing collection system infrastructure relative to the projected cost of the wastewater treatment components is a consideration. Typically 60 to 80 percent of the cost for wastewater management is associated with the collection system.

**Risk of Endocrine Disrupting Chemicals (EDCs) from Sludge Application to Land** - If biosolids are applied under conditions that prevent runoff and at low application rates, the potential for the contamination of surface and groundwater from EDCs is limited.

**Assessment of Relative Greenhouse Gas Emissions (GHG)** – The carbon dioxide emissions resulting from well-designed and centralized water and wastewater treatment are less than 1% of the total carbon dioxide emissions from buildings and transportation. Although every effort should be made to reduce these emissions, the expenditure of energy to achieve higher wastewater treatment objectives should be assessed in this context.

**Other Sources of Greenhouse Gas Emissions** - There are many sources of GHG emissions that should be included in a long-range waste management plan beyond those typically associated with wastewater and biosolids treatment. Methane releases from septic tanks, wastewater collection systems and landfills as well as nitrous oxide releases from nitrification and denitrification treatment processes need to be considered.

**Triple Bottom Line Analysis** - TBL analysis is an accepted methodology for assessing the relative merits of several competing development paths for a project and many jurisdictions have adopted it for broad use. Differential weighting of criteria involved in the analysis should be based on careful consideration of the project-specific circumstances. Wherever possible for social and environmental issues, criteria should be established that are as quantifiable as possible with a hard number. An alternative is to qualitatively rank each option as being positive, neutral or negative against a list of economic, social and environmental criteria and use the resulting matrix as the focus of a facilitated discussion to reach agreement on the preferred option.

Each of the above topics is discussed in more detail in the following sections.

### **Integration of liquid and solid wastes**

The IRM report is based on the integration of solid and liquid wastes. An important question is whether the kind of integration proposed represents the soundest policy in terms of resource recovery, financial benefit, environmental protection, and flexibility to take advantage of unknown future opportunities while meeting today's needs; or whether solid and liquid waste streams can reach these desirable goals better if each is optimized separately. The Peer Review Panel recommends that the overall benefits can be better achieved if the evaluation of solid and liquid waste facilities are addressed separately. Such separation provides more transparency and flexibility to better meet future opportunities presented by rapidly changing technology and economic variables as well

as to meet growing needs for resource recovery and ever increasing environmental concerns.

The recovery of resources in a financially and environmentally sound manner from municipal waste streams and water systems does not represent a new way of thinking. The “Traditional Waste Management” approach criticized in the IRM report was common perhaps 50 years or more ago, but is not common today. A typical decades-old example of good management of solid and liquid wastes handling for resource recovery is given later for the Sanitary Districts of Los Angeles County (SDLAC).

The IRM report approach to integrate liquid and solid waste handling is illustrated in Figure 3 of the IRM report. The only integration between wastewater and solid wastes shown is the combined digestion of sludge (biosolids) from wastewater treatment with wet organic solid waste. This raises two questions. First, is it better economically, socially, environmentally, and politically to transport untreated wastewater biosolids to a central wet organic waste anaerobic digester than to treat the biosolids in digesters at the wastewater treatment plant where the energy is needed? Secondly, is anaerobic digestion of wet organic waste solids economically and environmentally the best approach for obtaining the energy and resource content of solid wastes? The first question has to do with the potential benefit of integrating liquid and solid wastes treatment. The second is related to a question as to the best method for handling wet organic wastes.

A major concern with integration of wet organic waste with wastewater biosolids in the manner shown in Figure 3 is that if the two are tied together at a fixed location in this concept, everything has to be brought to that location for processing. The options that would be available now and in the future for possibly better handling of them separately are thus quite limited. Flexibility is highly desirable in handling wastewater biosolids, which have high moisture content, and solid wastes, which are dry, as newer technologies for handling each is changing rapidly, a flexibility that tying the two together could greatly reduce. This is a major concern of the Peer Review Panel.

This does not mean that there are no opportunities for integration of solid and liquid waste handling, but the impacts are rather minor compared with overall costs and benefits. For example, adding a portion of the wet organic solid wastes generated to digesters located at wastewater treatment plants does offer one possibility that deserves closer evaluation. This is being considered at many treatment plants in the United States and around the world to help meet the need for energy to run the treatment plants. A common manner in which this is accomplished is through the use of home garbage grinders, which reduce garbage particle size as needed for efficient handling and digestion, and at the same time provides transportation of these solids to the treatment facilities at essentially no cost. Typically, this increases the suspended solids loading at a treatment plant by about 25 percent and increases the biogas production proportionately. Separation of garbage in the home with separate collection of dry wastes and surface transport is a different matter with additional costs and environmental impacts. Hence, by designing new wastewater treatment plants to accept a 25% increase in organic solids loading, the separation of various recyclable solid waste constituents becomes easier and

the major organic component of the normal solid waste stream is automatically transferred to the wastewater solids treatment facility with no additional transportation costs.

**Integration of Fat, Oil and Grease** - Another opportunity for integration of wastes is offered by the material collected in grease traps used to separate residual cooking fat, oil, and grease (FOG) from the flow entering wastewater collection systems. Waste FOG that does enter wastewater collection systems can accumulate and reduce the effective diameter of the pipe, potentially leading to clogging. Crews are sent out routinely to remove these grease blockages. Thus, it is advantageous to have a municipal program to ensure that grease traps are installed, maintained and serviced adequately. The FOG that goes down the drain and accumulates in grease traps is known as brown grease, while the grease that is discharged from fryers is known as yellow grease. Due to its higher quality and reduced contaminant and moisture content, yellow grease is collected separately for use in animal feeds and cosmetics. Grease traps are emptied using vacuum collection trucks which haul the material to local facilities that accept the trap waste. One option is to haul the grease to a wastewater treatment plant where it is injected into the anaerobic biosolids digesters. As a result, the amount of methane gas and potentially recoverable energy produced by the anaerobic digesters is increased. Conversion to biofuels is also an alternative. In the short term, anaerobic digestion of trap waste can be implemented easily where digestion facilities already exist or are being installed. In the medium to long term, it is likely that larger cities with many food service establishments (FSEs) will develop regional facilities for the conversion of brown and yellow grease to biofuels, principally biodiesel. A number of processes are under development or in pilot phase to demonstrate the production of biodiesel from waste grease. The biodiesel fuel can be used directly to offset the use of petroleum derived diesel fuel, greatly reducing anthropogenic GHG emissions. Even when brown grease is recovered from trap waste, the so called white water, which is the liquid pumped along with the brown grease from grease traps, contains a significant amount of biodegradable organic waste. The organic material in white water is comprised of residual dissolved oils and miscellaneous food wastes that are discharged along with the waste grease. Because of the energy that can be recovered from the white water, after brown grease has been recovered the remainder of the trap waste can be processed using anaerobic digestion. Thus, biodiesel processing facilities are often co-located with wastewater treatment facilities where anaerobic digestion is used for the recovery of methane. Alternatively, the white water can be trucked or pumped from a remote biodiesel processing facility to the wastewater treatment plant.

Other than consideration of handling fats, oils and grease in anaerobic digesters located at a wastewater treatment plant, the Peer Review Panel recommends that solid waste and biosolids handling and processing be addressed separately. The following Los Angeles example illustrates a system that has long benefited from such an approach.

**Los Angeles Example** -At the Sanitary Districts of Los Angeles County (SDLAC) the recovery of valuable resources such as energy, reclaimed water, and recyclable materials from solid and liquid wastes has been a core part of their mission for decades. Presently,

using satellite wastewater treatment systems, over 430,000 m<sup>3</sup>/day (113 million gallons per day), equivalent to the wastewater from a population of about 1 million people is recovered for landscape irrigation and groundwater replenishment. Simultaneously at 12 renewable energy power plants, SDLAC generates 127 megawatts of power from their separate solid and liquid wastes, transmitting 98 megawatts to the local electric grid while using 29 megawatts for operation of their facilities. As a result, \$21.3 million of energy purchase was avoided and net energy sales of \$23 million were made in fiscal year 2006-2007. As in many other sanitary districts, they continually strive to recover energy, water, and nutrient resources from wastes, while protecting the environment, including a more recent emphasis on reducing greenhouse gas impacts.

However, in terms of integrating operation, the energy derived from digester gas at the SDLAC wastewater treatment plants is all used on-site. These plants typically require additional import of power. Even when the energy content of wastewater is used to the maximum, it is still insufficient to completely satisfy that needed to operate the SDLAC wastewater treatment systems. The integration achieved is through the offsetting of the excess energy generated from their separate facilities handling solid wastes to make up for the deficiency in energy generated by biosolids digestion at their wastewater treatment plant. However, this is not a direct transfer of energy, but is achieved through simultaneous sale and purchase from the power grid. Even when solid and liquid wastes are handled by the same agency, this example of a well established system shows that the separation of liquid and solid wastes handling and treatment is the policy that generally makes most sense from an economic, social, and environmental viewpoint.

To illustrate the relative amount of energy generated from solid versus liquid wastes, the SDLAC's power generation capacity from its separate solid waste facilities is 105 megawatts (65 from landfill biogas and 40 from solid waste combustion), while that from wastewater biosolids digestion is about 23 megawatts. The district's wastewater treatment facilities require 39 megawatts for operation, significantly more than the 23 megawatts produced from the anaerobic digesters at the wastewater treatment facilities.

A useful example for Victoria of wastewater system integration practiced by the SDLAC is the use of satellite or distributed plants for wastewater treatment to recover water for reuse where it is needed for landscape and groundwater replenishment inland and up gradient from the ocean. The satellite Whittier and San Jose plants draw wastewater from the trunk sewer to produce the 430,000 m<sup>3</sup>/d of usable water already noted. The biosolids these plants produce are not treated where produced, but are discharged back into the trunk sewer for flow down gradient for treatment and recovery at the Joint Water Pollution Control Plant located near the ocean, where digestion of the combined biosolids from these other plants and from the Joint plant permits the production of 22 megawatts of energy onsite, sufficient to meet 95% of the Joint plant's power needs. This plant is one of the largest in the world, serving a population of about 3.5 million people. Transport of the biosolids through the trunk sewer to the Joint plant has no energy costs because the sewer flow is down gradient and the biosolids do not need to be transported by surface means, thus avoiding a common social and environmental concern with such transport.

Numerous other examples of energy, water, and nutrient recovery from solid and liquid wastes at municipalities exist in California and elsewhere to support this view. Typically, only about 50% of the energy required for secondary wastewater treatment is available from wastewater biosolids digestion. Because of increasing energy costs and greenhouse gas concerns, greater efforts are being made through newer technological approaches to bring this closer to 100 %. However, this is not yet achievable. In any case, what makes the most sense financially, socially, and environmentally is to generate power through biosolids digestion at the wastewater treatment plant where the power is needed, rather than through surface transport of untreated biosolids, often with significant energy, social and environmental costs, to mix with solid wastes and generate the power elsewhere as in the IRM report example case.

### **Water Reuse Considerations**

Treated water quality objectives in the IRM report (Figure 17, Page 89, Appendix D) are inadequate for many of the reuse objectives indicated. CBOD and TSS of 10 mg/l are much too high. Also, the treatment system needs to provide a high degree of reliability and protection against discharge of water quality unsuitable for reuse during periods of treatment process upset. Effluent quality and the needed reliability compatible with a wide range of reuse applications could be met with membrane bioreactors. The Peer Review Panel believes that the wastewater treatment costs shown in the IRM report underestimate the cost of providing the level of treatment and reliability required for the desired reuse applications. It also does not adequately consider the cost of underground construction and subsurface effluent disposal.

### **System Revenues**

The Peer Review Panel has several questions related to the system revenues shown in the IRM report. It would be most desirable if the various sources of revenues summarized in Table 16, Page 145 were spelled out for better analysis. To what is the annual revenue of \$114 million attributed? In Figure 15, Page 41, the IRM report indicates that the revenue is divided between biofuels (62%), heating and cooling (21%), GHG Credits (16%), and water (1%). However, in Table 16, Page 145, a tipping fee of \$8/ton is indicated, which for the 182,000 tons of solid waste indicated would equal \$15.3 million. Is this included in the \$114 million? Why not in Figure 15? The landfill gas plus the tipping fee total about \$50 million dollars, a large portion of the \$61 million net revenue predicted. If a tipping fee for solid wastes is included, why not include a sewer charge? Even then, should sewer charges and tipping fees be listed separately from revenues for resource recovery? The analysis given is not transparent, and is very difficult to analyze.

Revenue from the biogas produced from the current landfill as well as that from the newly generated solid wastes is included in the IRM revenues. The revenue from the landfill will decrease with time if the new solid wastes are handled differently, as will the quality of the landfill gas. Also, revenue is proposed from reduction in landfill GHG emissions through collection and use of the biogas. Not summarized in the report is the

proposed revenue from this legacy landfill, but based upon the various figures given, it is estimated that the IRM report has given an annual revenue value of this legacy landfill gas \$18.2 million for the GHG component, and about \$16.8 million from the biogas itself. Thus \$35 million of the annual revenue projected comes from this legacy, which will decrease with time, not increase. While collection of landfill gas and its utilization is important and must be done, including it in the integrated plan does not seem appropriate.

### **Flexible Phasing of System Construction**

The consulting team described three system options to the Peer Review Panel during the February 12-13 meeting. The Panel believes that it would be more appropriate to consider these as describing elements that could constitute potential phases of a long-term system. The first phase would focus on the elements common to the three system options. Such a phasing approach would allow flexibility to adapt the system to best manage resource recovery by meeting future demands for energy, heat and reclaimed water when and where they occur. It also provides an approach for implementing energy recovery and water reuse based on an evaluation of the economics and management issues for the Victoria area. The Saanich East plant would provide a good opportunity to test, demonstrate and evaluate the economics and management of heat recovery and water reuse as part of the first phase. Information from this demonstration would be useful in planning and implementing heat recovery and reuse projects in future phases. Treatment and resource recovery elements from the system options developed by the consulting team would be selected as appropriate for future phases.

### **Relative Value of Wastewater Management Infrastructure**

In evaluating the various configurations for the wastewater management system for Victoria, the value of the existing collection system infrastructure relative to the projected cost of the wastewater treatment components is a consideration. As discussed below, the value of the existing local and regional wastewater collection systems is very significant and also represents an ongoing operation and maintenance cost which must be considered in the overall wastewater management program.

Modern wastewater management systems are composed of three major elements: (1) the wastewater collection system, (2) the wastewater treatment facilities including sludge management facilities, and (3) facilities for the dispersal of treated effluent to the environment or to reuse applications. In turn, wastewater collection systems are composed of systems of pipes, access ports (manholes) and other structures, pump stations, force mains, and other ancillary facilities used for the collection and transport of wastewater for treatment and dispersal. Although alternative types of collection systems are used in less densely populated areas, gravity collection systems are used most commonly in densely populated areas, as is the case in greater Victoria. Force mains are used to overcome the barriers posed by topography and development. Attention to the design and implementation of wastewater collection systems infrastructure is of critical importance because of the large percentage of the total cost for wastewater management associated with the collection system. In general 60 to 80

percent of the cost for wastewater management is associated with the collection system. Three recent examples will be used to illustrate the relative value of collection and treatment infrastructure, based on initial investment.

**Hayfork, California** - The first example is Hayfork, CA, a small community in Trinity County with a population of about 2,300 and an average wastewater flow of 570 m<sup>3</sup>/d. The area is located in a mountain valley with shallow groundwater and clay soils. Due to widespread ground and surface water contamination from failing septic tank systems, a community scale collection and treatment system was installed in 1998/99. The collection system is constructed of PVC pipe (about 31 km of collection piping), and includes 5 lift stations. The treatment system consists of an integrated pond system followed by constructed wetlands. All effluent is land applied to forested land during the summer (winter flows are stored in a holding pond). The bid prices for the wastewater management system were as follows: pipeline and access ports, \$4,725,927; five pump stations, \$596,000; and treatment facilities \$1,978,200 for a total system cost of \$7,300,127 (Hair, 2009). The percentage ratio of the cost of the wastewater collection to wastewater treatment is 73 percent.

**Los Osos, California** - The second example is Los Osos, California, a community with a population of 14,351 in 2000, located on the coast in central California. Currently, wastewater management is by means of seepage pits. Plans have been developed to provide a community wastewater collection system with secondary treatment and land dispersal of the treated water. Topographically the community is similar to Victoria, BC. The range of costs for the gravity collection system, including pump several stations, is in the range from 80 to 90 million dollars; the cost for the wastewater treatment is estimate to be between 15 and 22 million dollars, depending on the type of process (Carollo Engineers, 2007). If average values are used, the percentage ratio of the cost of the wastewater collection to wastewater treatment is 81 percent. Los Osos is a good example because currently there are no wastewater collection or treatment facilities in the ground.

**Ontario Municipalities** - The third example is from a study conducted by Burnside and Associates for the Canadian Ministry of Public Infrastructure Renewal. The study was based on "water and wastewater assets typically found in Ontario Municipalities" (Burnside and Associates, 2005). The results of their study are as follows. Water treatment and water distribution facilities accounted for 55 percent of the total infrastructure value and wastewater collection and wastewater treatment accounted for the remaining 45 percent. The percentage ratio of the cost of the wastewater collection (31 percent) to wastewater treatment (14 percent) is 69 percent.

### **Risk of Endocrine Disrupting Chemicals from Sludge Application to Land**

CRD requested that the Peer Review Panel address concerns that have been raised over the long term viability of applying biosolids to land due to the presence of endocrine disrupting chemicals (EDCs) and pharmaceutical and personal care products (PPCPs). Over the past 20 years, analytical methods have improved to the extent that the presence of extremely small concentrations of EDC's and PPCPs can now be measured in treated

wastewater effluents and biosolids. The concentrations of these compounds measured in the aquatic environment are typically below 100 ng/L (Sedlack, 2005). The source of these compounds in surface waters is generally acknowledged to be from treated effluent discharged to the environment and from uncontrolled runoff from land application of biosolids.

Recognizing the potential significance of these compounds, numerous laboratory, pilot, and full-scale studies have been undertaken to assess the fate of these compounds, particularly EDCs, in wastewater treatment and in effluents and biosolids discharged to the environment. It should be noted that in many of the studies, the concentration of EDCs used was considerably higher than the concentrations found routinely in wastewater. Another problem that has been encountered in the study of the fate of these compounds is that it is very difficult to complete a mass balance because of the many abiotic and biotic conversions that occur during treatment.

Based on a review of the numerous researcher papers and reports, and discussions with treatment plant operators it is estimated that about 40 to 80 percent of the influent concentration of EDCs is reduced during activated sludge treatment, as measured in the effluent. Further, it appears that the removals achieved are site specific depending on the activated sludge process configuration, method of operation, and solids retention time. The longer solids retention times provided in MBR systems are advantageous in terms of EDC removal. The EDCs that have been removed have either been converted to other products or sorbed onto activated sludge mixed liquor suspended solids. Where anaerobic digestion is used, the observed removals have been on the order of 10 to 20 percent of the EDCs sorbed onto the mixed liquor suspended solids. The amount of EDCs associated with the biosolids applied to land will depend on the processing the biosolids are subjected to before land application. For example, if the biosolids are dewatered, it has been observed that many of the sorbed EDCs will desorb and be returned to the plant headworks for further processing. Most likely, the variability observed in the overall removal rates is affected by the presence of EDCs in the return flows.

In the studies of the land application of biosolids, it has been observed that the EDCs will sorb onto the soil particles and in time will undergo abiotic and biotic conversion to simpler end products. It has also been observed that if runoff is allowed to occur after the biosolids have been applied, that sorbed EDCs will desorb and that the runoff will contain measurable concentrations of EDCs. Thus, based on the limited findings to date, it can be concluded for the concentrations of EDCs actually present in biosolids if the biosolids are applied at low application rates under conditions that will not result in runoff, the potential for the contamination of groundwater and surface water is limited (Vogel et al., 2003, Pepper et al., 2008, Ying et al., 2004). Further, well before secondary treatment facilities are designed and implemented, a number of studies currently underway to assess the fate of EDCs in biosolids applied to land will have been completed. A notable study is the Agricultural Research Study Research Project cited in the list of references.

## **Assessment of Relative Greenhouse Gas Emissions**

While the emission of greenhouse gases (GHGs) from wastewater treatment facilities is of importance in the design and selection of treatment operations and processes, it is equally important to put the resulting quantities in perspective with respect to other emission sources, especially when the use of energy for wastewater treatment is questioned. Currently, the equivalent carbon dioxide emissions (CO<sub>2</sub>e) per capita in both the Canada and United States are essentially the same and are in the range from 20 to 24 tonne/capita•yr, depending on the source of the information. Based on the analysis prepared by New York City (2008) and the Energy Information Administration (2008), the carbon dioxide emissions per capita from centralized wastewater treatment facilities are on the order of 0.04 to 0.07 tonne/capita•yr. The overall distribution by sector for New York City is: buildings 77 percent; transportation 22 percent; and other, including solid waste and water and wastewater treatment, 1 percent. Also, it should be noted that the overall carbon dioxide emissions per capita for New York City are somewhat higher than the national average. Clearly, the carbon dioxide emissions resulting from the vital services provided by well-run water and wastewater treatment are a small fraction of the total. Although a small fraction of the total, every effort should be made to reduce these emissions to the lowest possible value consistent with the protection of public health and the environment. Similarly, the expenditure of energy to achieve higher treatment objectives, which may result in additional carbon emissions, must be assessed in terms of the protection of public health and the environment and other uses of energy.

## **Other Sources of Greenhouse Gases**

Although the carbon emissions from wastewater treatment, based principally on electrical energy consumption, are relatively small, there are other sources of GHG emissions that should be included in any long-range waste management plan. More specifically, GHG emissions related to the release of methane and nitrous oxide should be considered. Methane, produced under anaerobic conditions, is considered to be 21 times more potent as a greenhouse gas than carbon dioxide. Nitrous oxide, formed during nitrification and denitrification in wastewater treatment, is estimated to be 296 times more potent as a greenhouse gas than carbon dioxide.

Sources of methane include: wastewater collection systems, septic tanks, and landfills. The amount of methane released from wastewater collection systems is currently under investigation. The carbon dioxide equivalent of the methane released from septic tanks could be as high as 0.2 to 0.5 tonne CO<sub>2</sub>e/capita•yr, and, thus, about 8 times more than that from a well design and operated centralized treatment plant as noted above. Methane production from organic solids in landfills may be even greater, but can be controlled using modern bioreactor containment designs, methane degrading biofilter covers, gas collection and combustion designs, and diversion of organic waste to aerobic composting operations.

With respect to nitrous oxide, great uncertainties exist over what fraction of the ammonia nitrogen transformed by nitrogen removal processes is converted to nitrous oxide. By

some estimates, it could be as high as 1.4 to 5% (Crutzen et al., 2008, Shiskowski et al., 2004). Thus, emissions from nitrogen removal processes, such as membrane bioreactors, could produce an equivalent of perhaps 0.1 tonne CO<sub>2</sub>e/capita•yr. As part of a long-range wastewater management program, these sources of GHGs must be evaluated and, if necessary, control strategies developed, especially for landfills and septic tanks. Along with the above concerns, uncertainties in the future economics of energy production, water supply shortages, discharge standards, regulations on GHG emissions, and the rapid evolution of newer technologies there is a need to provide maximum flexibility in waste treatment systems design to better meet future needs.

### **Triple Bottom Line Analysis**

CRD requested that the Peer Review Panel comment on the Triple Bottom Line (TBL) approach. TBL analysis is an accepted methodology for assessing the relative merits of several competing development paths for a project and many jurisdictions have adopted it for broad use. To provide the Panel’s view of its future use, comments are provided on TBL in general and also on how it was applied in The Path Forward effort as detailed in the following two background documents:

- Discussion Paper #2 – Triple Bottom Line Criteria, January 8, 2007
- Discussion Paper #6 – Triple Bottom Line Analysis, March 2, 2007

TBL analysis was applied in the above documents in an acceptable manner, although schedule and budget constraints may have precluded a more exhaustive analysis that would overcome some of the potential drawbacks of TBL analysis as described in the following paragraphs.

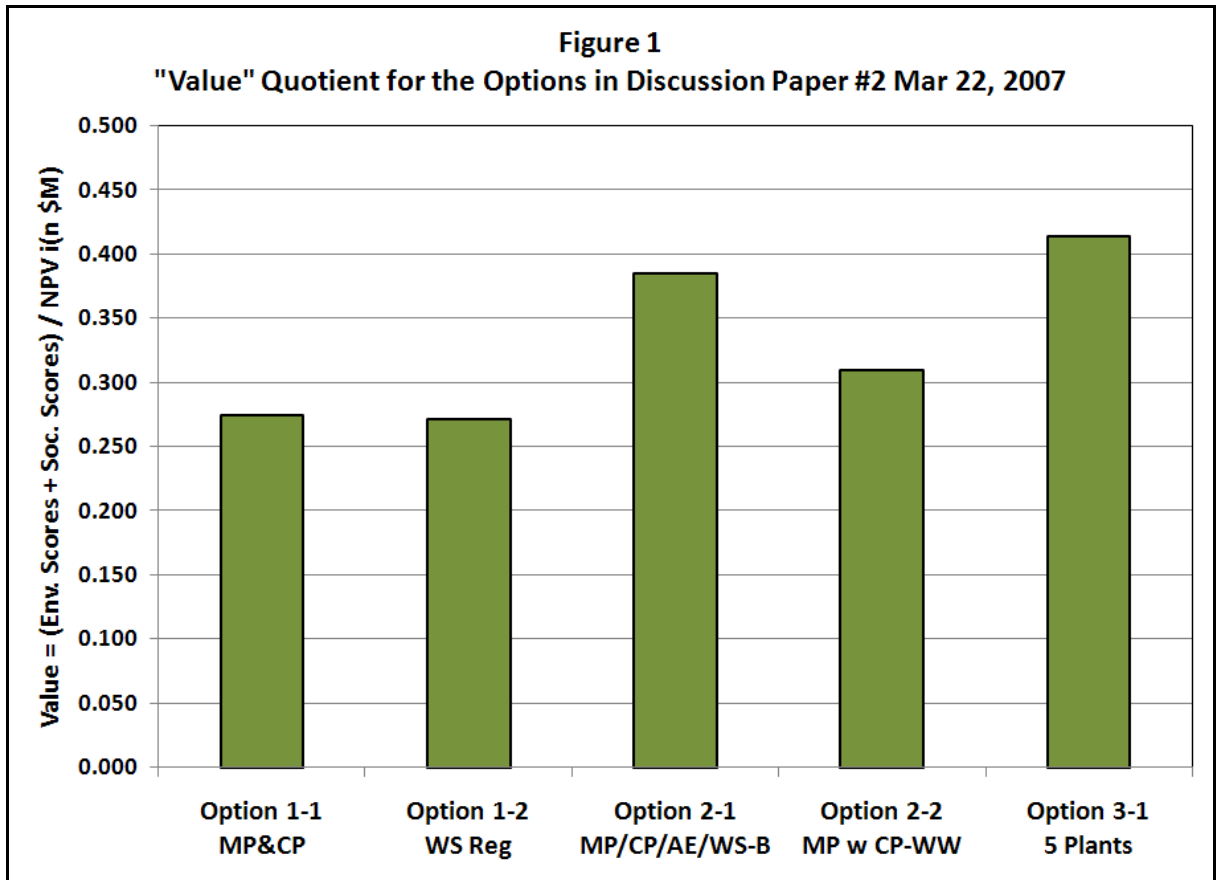
The three groupings of environmental, social/community and economic issues commonly employed in a TBL analysis are not truly comparable. Environmental and social/community concerns usually involve subjective judgments and thus are often difficult to quantify in absolute terms. On the other hand, the economic aspects of a project can usually be quantified by a dollar figure, which admittedly may have an uncertainty band associated with it depending on the level of the estimate. For municipal infrastructure projects which usually do not have a net payback, one can separate economic aspects from the non-economic issues and arrive at a quotient that is a measure of the “value” of an optional development path by dividing scores for the non-economic criteria by the cost of that development path. The cost figure can be expressed as net present value (NPV), or as capital cost, or as operating and maintenance (O&M) cost, or as a particular component of each. A simple formula for the value quotient is:

$$\text{Value} = \frac{\text{Environmental Score} + \text{Social/Community Score}}{\text{Cost}}$$

Thus when comparing optional development paths that have similar costs, the one with the highest score for the non-economic criteria has more “value” than the others. Conversely when comparing optional development paths that have similar non-economic scores, the one with the lowest cost has more “value” than the others.

An example of how this was applied in a recent project for another municipality is illustrated in the attached spreadsheet. In this example, the traditional economic, social and environmental criteria from the TBL approach were supplemented with a fourth group of criteria – “Other Project-Specific Criteria” that related to certain issues that did not readily fall under the traditional TBL categories for the project under consideration. The spreadsheet is set up such that weights can be assigned to each criteria grouping as well as to an individual criterion within each group. However in the example presented here, equal weighting is applied to everything. Also in this example, the maximum scores for each group were normalized to 3.00. The last six rows in the table clearly show how the preferred rankings can change depending on which criteria are used to place “values” on the optional pathways under consideration.

To see how this might be applied to extend the TBL analysis reported in Discussion Paper #6, the social and environmental scores reported in Attachment C in Discussion Paper #6 for the various options were added and each sum divided by the life cycle costs reported in Discussion Paper #5 to get the value quotient. The value quotients corresponding to each option are plotted in Figure 1 on the next page. In this instance, the relative outcome is more or less similar to that shown in the bar chart plotted on page 3 of Discussion Paper #6 for equal weighting of all TBL elements; however, Option 2-2 is somewhat closer to Options 2-1 and 3-1, and Options 1-1 and 1-2 are essentially equal in ranking but are still the least favoured options. Regardless that the outcome is more or less the same in this instance, it is suggested that this approach could make a difference for other situations that may arise in subsequent work on this CRD project.



Other comments offered by the Panel for consideration by the engineering team are:

- The scoring spreadsheet sheet for applying the criteria can be set up such that individual criteria can be weighted as desired, or criteria grouped and weighted according to goals such as the five goals identified in Discussion Paper #2, or grouped and weighted into the three broad criteria groupings of the TBL analysis (i.e. social, environmental and economic). The scores for the various groups can be normalized in the spreadsheet if desired to account for the possibility that some groups may contain more criteria than others.
- The first base case is with the weights of all criteria being equal. In any group of people, there will be a variety of opinions about the relative weight that should be assigned to economic versus social versus environmental criteria. To test the effect on the outcome of the TBL of these differences of opinion, various weightings can be used in a sensitivity analysis. This was done in Discussion Paper #6 with three cases reported – one for a 20 percent increase in each weighting for economic, social and environmental criteria groupings. Experience on similar exercises on other projects is that a 20 percent change in weighting is not likely to make much difference in the outcome. For example if one knows that environmental issues are likely to trump social issues for a specific project, then the spreadsheet could be redone using double, triple or even quintuple the weighting on environmental criteria to see the outcome. Alternately if one knows that a certain issue(s) is (are) particularly sensitive for the community (say for

example minimizing disruption during construction, or possibly achieving a high degree of resource recovery), then one can increase the weighting for these criteria by a factor of 2 or 3 or more.

- Wherever possible for social and environmental issues, it is preferable to establish criteria that are as quantifiable as possible with a hard number. For example under Goal 1.0 for the environmental criteria in Table 4-1 of Discussion Paper #2, rather than using statements beginning with “avoid . . .” it might be preferable to count the number of crossings of streams or waterbodies by forcemains or siphons and score the criteria as appropriate – a higher score for fewer crossings and vice versa. Similarly, it might be helpful to count the number of sewage and/or stormwater pumping stations for each option. And so on.

Even though the TBL analysis performed as described above results in a relative quantitative scoring of options, a major value of the process is the discussion of the evaluation of each option against the scoring criteria. Once the scoring is complete, this preceding discussion then can form the basis for reflection upon the results to decide upon the preferred option.

Although the TBL analysis is a widely accepted approach, some agencies have used other methods. In one approach, the criteria and system alternatives are shown in a matrix with the criteria listed vertically in the left hand column of the matrix and the alternatives listed across the top of the matrix with a column dedicated to each alternative. A discussion is held about the merits of each option relative to a given criterion. If the option rates favourably against that criterion, a “+” is entered. If the option is considered neutral against that criterion, a “0” is entered. If the option is rated negatively against that criterion, a “-“ is entered. The process is repeated for each criterion for all of the options. Once the matrix is completed, a facilitated discussion is held to reach agreement upon the preferred alternative considering the relative positives, neutrals and negatives of each option. During this discussion, individuals may express opinions about the relative weights of the criteria but no quantitative differences are assigned.

### **References - Risk from Sludge Application to Land**

- Agricultural Research Study Research Project: Modeling the Impacts of Land-Applied Municipal Biosolids on Ecosystem Services Across Urban, Agricultural, and Wildlife Interfaces, Start date: Jun 01, 2008 Completion date: Jan 31, 2011.  
[www.ars.usda.gov/research/projects/projects.htm?accn\\_no=413433](http://www.ars.usda.gov/research/projects/projects.htm?accn_no=413433)
- Pepper, I. L. H. Zerzhib, J. P. Brooks, and C. P. Gerba (2008) "Sustainability of Land Application of Class B Biosolids," *J Environ. Qual.*, 37:S-58-S-67 (2008)
- Sedlak, D. L., K. Pinkston, and C-H. Huang (2005) Occurrence Survey of Pharmaceutically Active Compounds, AWWA Research Foundation and WateReuse Foundation, Denver CO.
- Vogel, D. et al. (2003) "Mobility and Fate of Endocrine Disrupting Compounds (EDCs) in Soil Application of Sewage Sludge to Agricultural Land," Proceedings ORBIT 2003 Conference *Biological Processing of Organics*, Perth, Australia
- Ying, G-G., R. Kookan, and T. D. Waite (2004) Endocrine Disrupting Chemicals (EDCs) and Pharmaceuticals and Personal Care Products (PPCPs) in Reclaimed Water in Australia, Australian Water Conservation and Reuse Research Program, Australian Water Association and CISRO, Sydney, Australia

### **References - Assessment of Relative Greenhouse Gas Emissions**

- EIA (2008) Emissions of Greenhouse Gases Report, Energy Information Administration, Washington DC.
- City of New York (2008) Inventory of New York City Greenhouse Emissions 2008, Plan YC, City of New York.
- List of Countries by carbon dioxide emission per capita from 1990 through 2004, source Wikipedia

### **References - Relative Value of Wastewater Management Infrastructure**

- Burnside and Associates (2005) *Water and Wastewater Asset Cost Study Ministry or Public Infrastructure Renewal*, Orangeville, ON, Canada.
- Carollo Engineers (2007) *Viable Project Alternatives Fine Screening Analysis*, San Luis Obispo County Los Osos Wastewater Project Development, Walnut Creek, CA.
- Hair, C. (2009) Personal Communication, Trinity County Waterworks, Hayfork, CA.

### **References- Assessment of Relative Greenhouse Gas Emissions**

- EIA (2008) Emissions of Greenhouse Gases Report, Energy Information Administration, Washington DC.
- City of New York (2008) Inventory of New York City Greenhouse Emissions 2008, Plan YC, City of New York.
- List of Countries by carbon dioxide emission per capita from 1990 through 2004, source Wikipedia

### **References - Other Sources of Greenhouse Gases**

- Crutzen, P. J., A. M. Mosier, K. A. Smith, and W. Winiwarter (2008) "N<sub>2</sub>O Release from Agro-Biofuel Production Negates Global Warming Reduction by Replacing Fossil Fuels," *Atmos Chem Phys*, 8, 389-395.
- Shiskowski, D. M., R. A. Simm, and D. S. Mavinic (2004) "An Experimental Procedure for Identifying the Aerobic-Phase Biological Source of Nitrous Oxide in Anoxic-Aerobic Wastewater Treatment Systems," NRC Research Press Web site at <http://jees.nrc.ca>.

## Example for Application of Triple Bottom Line + Other Project-Specific Criteria to Optional Development Pathways

**Note 1:** You must assign scores in the range of 1 (not preferred) to 3 (preferred) in the cells under each pathway. You may adjust an individual criterion and criteria group weights as desired. Averages for criteria groups are normalized to 3.00.

**Note 2:** Unweighted averages for each Criteria Group will have a maximum value of 3.00 regardless of the weighting placed on any individual criterion in that group.

**Note 3:** Weighted averages for each Criteria Group will have a maximum value fo 3.00 multiplied by the respective Weighting Factor for that group.

| Criteria Group   | Description of each Criterion                              | Criterion Weight | Pathway ID and Description                |   |  |   |  |  |  |   |  |   |  |
|--|--|------------------|---|---|--|---|--|--|--|---|--|---|--|
|  |  |                  | 1A'                                       | 1C'                                       | 1B'  | 3A  | 3B   | 5C   | 5D   | 5B'                                       | 1C''                                       | 1B''  | 1A''                                       |
|  |  |                  | FC U/G ('16)<br>PC-2A ('16)<br>BB-D ('25) | FC U/G ('16)<br>BB-D ('16)<br>PC-2A ('19) | FC U/G ('16)<br>PC-2A ('16)<br>PC-2B ('25) | FC Decom ('16)<br>PC-2A&B ('16)<br>BB-D ('27) | FC Decom ('16)<br>PC-2A&B ('16)<br>PC-3A ('27) | FC Decom ('16)<br>NC-1 ('16)<br>PC-2A ('17)<br>PC-2B ('23) | FC Decom ('16)<br>PC-2A ('16)<br>NC-1 ('18)<br>PC-2B ('23) | FC U/G ('16)<br>PC-2A ('16)<br>NC-1 ('24) | FC U/G ('16)<br>BB-D ('16)<br>FC Exp ('19) | FC U/G ('16)<br>FC Exp ('16)<br>PC-2A ('22) | FC U/G ('16)<br>FC Exp ('16)<br>BB-D ('22) |
| Economic (to 2033)   | Capital cost (WWTP's + pumping & transmission)             | 1.0              | 3   | 3   | 2  | 2   | 1  | 1  | 1  | 1   | 3  | 2   | 3  |
|  | Net Present Value  | 1.0              | 3   | 3   | 3  | 2   | 2  | 2  | 2  | 2   | 3  | 3   | 3  |
|  | Value-1 = $\sum CAPI / NPVI$                               | 1.0              | 3   | 3   | 3  | 3   | 2  | 2  | 2  | 2   | 3  | 3   | 3  |
|  | Value-2 = $\Delta CAPI / NPVI$                             | 1.0              | 2   | 2   | 2  | 3   | 3  | 3  | 3  | 2   | 1  | 1   | 1  |
|  | Other?   |                  |   |   |  |   |  |  |  |   |  |   |  |
|  | Average for Economic Criteria Group                        |                  | 2.75                                      | 2.75                                      | 2.50                                       | 2.50  | 2.00   | 2.00   | 2.00   | 1.75                                      | 2.50                                       | 2.25  | 2.50                                       |
| Weighting factor for Economic Criteria Group   | 1.0  |                  |   |   |  |   |  |  |  |   |  |   |  |
| Weighted average for Economic Criteria Group   |  | 2.75             | 2.75                                      | 2.50                                      | 2.50                                       | 2.00  | 2.00   | 2.00   | 1.75   | 2.50                                      | 2.25                                       | 2.50  |  |
| Environmental (to 2075)  | Project footprint  | 1.0              | 2   | 2   | 2  | 3   | 3  | 2  | 2  | 1   | 2  | 2   | 2  |
|  | Length of trunk mains                                      | 1.0              | 2   | 2   | 2  | 1   | 2  | 3  | 3  | 3   | 2  | 2   | 2  |
|  | Number of new river crossings                              | 1.0              | 1   | 1   | 1  | 2   | 1  | 3  | 3  | 2   | 1  | 1   | 1  |
|  | Ease of regulatory approval                                | 1.0              | 3   | 3   | 3  | 2   | 2  | 1  | 1  | 1   | 3  | 3   | 3  |
|  | Average for Environmental Criteria Group                   |                  | 2.00                                      | 2.00                                      | 2.00                                       | 2.00  | 2.00   | 2.25   | 2.25   | 1.75                                      | 2.00                                       | 2.00  | 2.00                                       |
|  | Weighting factor for Environmental Criteria Group          | 1.0              |   |   |  |   |  |  |  |   |  |   |  |
| Weighted average for Environmental Criteria Group  |  | 2.00             | 2.00                                      | 2.00                                      | 2.00                                       | 2.00  | 2.25   | 2.25   | 1.75   | 2.00                                      | 2.00                                       | 2.00  |  |
| Social (to 2075)   | Proximity of WWTP plant to residents                       | 1.0              | 2   | 2   | 2  | 3   | 3  | 3  | 3  | 2   | 1  | 1   | 1  |
|  | Traffic thru/near sensitive areas                          | 1.0              | 2   | 2   | 2  | 3   | 3  | 3  | 3  | 2   | 1  | 1   | 1  |
|  | Noise near sensitive areas                                 | 1.0              | 2   | 2   | 2  | 3   | 3  | 3  | 3  | 2   | 1  | 1   | 1  |
|  | Aesthetics / Visual  | 1.0              | 2   | 2   | 2  | 3   | 3  | 3  | 3  | 2   | 1  | 1   | 1  |
|  | Trunk Main Length in built-up/sensitive areas              | 1.0              | 1   | 1   | 1  | 1   | 1  | 3  | 3  | 3   | 1  | 1   | 1  |
|  | Disruption during construction (plants & transmission)     | 1.0              | 1   | 1   | 1  | 2   | 2  | 3  | 3  | 1   | 1  | 1   | 1  |
|  | Public & Stakeholder Acceptability                         | 1.0              | 2   | 2   | 2  | 3   | 3  | 1  | 1  | 1   | 2  | 1   | 1  |
|  | Average for Social Criteria Group                          |                  | 1.71                                      | 1.71                                      | 1.71                                       | 2.57  | 2.57   | 2.71   | 2.71   | 1.86                                      | 1.14                                       | 1.00  | 1.00                                       |
| Weighting factor for Social Criteria Group   | 1.0  |                  |   |   |  |   |  |  |  |   |  |   |  |
| Weighted average for Social Criteria Group   |  | 1.71             | 1.71                                      | 1.71                                      | 2.57                                       | 2.57  | 2.71   | 2.71   | 1.86   | 1.14                                      | 1.00                                       | 1.00  |  |
| Other Project-Specific Criteria  | Ease of O & M re- no. of Pumping Stn's & Pumps             | 1.0              | 2   | 2   | 2  | 1   | 2  | 3  | 3  | 3   | 2  | 2   | 2  |
|  | Ease of O & M re- no. of WWTP's and different processes    | 1.0              | 1   | 1   | 1  | 3   | 3  | 2  | 2  | 1   | 1  | 1   | 1  |
|  | Expandability for population increases (flexibility)       | 1.0              | 1   | 1   | 1  | 2   | 2  | 3  | 3  | 3   | 1  | 1   | 1  |
|  | Upgradability for more stringent permit limits             | 1.0              | 1   | 1   | 1  | 2   | 2  | 3  | 3  | 3   | 1  | 1   | 1  |
|  | Treatment Process Complexity                               | 1.0              | 1   | 1   | 1  | 3   | 3  | 3  | 3  | 1   | 1  | 1   | 1  |
|  | Opportunities for Water Reuse                              | 1.0              | 2   | 2   | 2  | 1   | 1  | 3  | 3  | 3   | 2  | 2   | 2  |
|  | Average for Other Project-Specific Criteria Group          |                  | 1.33                                      | 1.33                                      | 1.33                                       | 2.00  | 2.17   | 2.83   | 2.83   | 2.33                                      | 1.33                                       | 1.33  | 1.33                                       |
|  | Weighting factor for Other Project-Specific Criteria Group | 1.0              |   |   |  |   |  |  |  |   |  |   |  |
| Weighted average for Other Project-Specific Criteria Group                               |  | 1.33             | 1.33                                      | 1.33                                      | 2.00                                       | 2.17  | 2.83   | 2.83   | 2.33   | 1.33                                      | 1.33                                       | 1.33  |  |
| <b>Sum of City's Triple Bottom Line weighted averages</b>                                |  |                  | <b>6.46</b>                               | <b>6.46</b>                               | <b>6.21</b>                                | <b>7.07</b>                                   | <b>6.57</b>                                    | <b>6.96</b>  | <b>6.96</b>  | <b>5.36</b>                               | <b>5.64</b>                                | <b>5.25</b>                                 | <b>5.50</b>                                |
| <b>Sum of City's TBL Plus Other Project-Specific weighted averages</b>                   |  |                  | <b>7.80</b>                               | <b>7.80</b>                               | <b>7.55</b>                                | <b>9.07</b>                                   | <b>8.74</b>                                    | <b>9.80</b>  | <b>9.80</b>  | <b>7.69</b>                               | <b>6.98</b>                                | <b>6.58</b>                                 | <b>6.83</b>                                |
| <b>Sum of only Non-Economic Criteria weighted averages</b>                               |  |                  | <b>5.05</b>                               | <b>5.05</b>                               | <b>5.05</b>                                | <b>6.57</b>                                   | <b>6.74</b>                                    | <b>7.80</b>  | <b>7.80</b>  | <b>5.94</b>                               | <b>4.48</b>                                | <b>4.33</b>                                 | <b>4.33</b>                                |
| <b>Net Present Value (\$E+06)</b>  |  |                  | <b>\$1,166</b>                            | <b>\$1,193</b>                            | <b>\$1,205</b>                             | <b>\$1,241</b>                                | <b>\$1,314</b>                                 | <b>\$1,339</b>   | <b>\$1,340</b>   | <b>\$1,318</b>                            | <b>\$1,172</b>                             | <b>\$1,203</b>                              | <b>\$1,206</b>                             |
| <b>Value Quotient #1 = [Sum of City's TBL Wgt'd Avg's] / [NPV] (x 1000)</b>              |  |                  | <b>5.54</b>                               | <b>5.42</b>                               | <b>5.16</b>                                | <b>5.70</b>                                   | <b>5.00</b>                                    | <b>5.20</b>  | <b>5.20</b>  | <b>4.06</b>                               | <b>4.82</b>                                | <b>4.36</b>                                 | <b>4.56</b>                                |
| <b>Value Quotient #2 = [Sum of only Non-Econ. Criteria Wgt'd Avg's] / [NPV] (x 1000)</b> |  |                  | <b>4.33</b>                               | <b>4.23</b>                               | <b>4.19</b>                                | <b>5.29</b>                                   | <b>5.13</b>                                    | <b>5.82</b>  | <b>5.82</b>  | <b>4.51</b>                               | <b>3.82</b>                                | <b>3.60</b>                                 | <b>3.59</b>                                |