ABSTRACT
The term biosolids does little to convey the broad range of material properties associated with its production and use, unless that's the reason they spelled it with a trailing s. Biosolids are routinely applied to land in many forms, as a liquid, thick slurry, semi-solid cake, compost, alkaline amendment, dried pellet, or soil blend - each with distinct handling characteristics. The uses for biosolids products are also wonderfully diverse in objective, fertiliser or soil amendment, and in land form, (e.g. forest, farrrh mine, or park). Designing a product delivery system which accounts for the handling characteristics of the biosolids, the application site characteristics, and the application objectives can be challenging. To meet this challenge, there are a wide variety of technologies and approaches available, which are limited only by your imagination. The trick then is to match the correct technology to the application.

In the development of the Greater Vancouver Regional District's Residuals Management Program, we have been faced with many unconventional biosolids application challenges in silviculture, rangeland, and reclamation projects, using a changing variety of biosolids types and products. This has given us cause, or an excuse, to investigate, develop, or test a wide variety of biosolids application methods and technologies. In this paper, we will discuss the results of our trials and tribulations, and suggest which of these technologies are best suited to what types of biosolids applications. It is our hope that some of this information will be helpful to other biosolids recycling practitioners, -and perhaps inspire others to innovate, or perhaps not.

BIOSOLIDS - THE SHAPE SHIFTER
Reminiscent of a D-grade Sci Fi monster or X-Files phenomenon, biosolids can assume almost any form, liquid, slurry, semi-solid dewatered cake, alkaline amended, dried pellet, briquette, compost, soil product, char, slag, or glass, to name a few. The physical, chemical, and biological characteristics of biosolids vary widely between the forms of material, and even within one form. Factors such as, the type of sludge - primary or secondary, industrial and commercial contributions, wastewater treatment processes, sludge treatment processes, dewatering method, temperature, additives or amendments, age, storage conditions, and handling prior to application can all influence the characteristics of the biosolids to be recycled or land applied.

With respect to applying the biosolids to land, it is primarily the physical characteristics of the biosolids and the site conditions which govern the choice of application method and technology. The chemical and biological composition of the biosolids may raise odour, vector, or public contact considerations, but this discussion will focus primarily on the physical characteristics. For neat or un-adulterated biosolids, the key factors affecting their physical properties are, solids concentration, sludge type - primary or secondary, sludge treatment, and age in our experience. The characteristics of amended biosolids products like alkaline amended, compost, and soil products depend mostly on the relative proportions of biosolids and amendments in the product and the physical properties of the amendment.

APPLICATION OBJECTIVES
The primary objectives of most biosolids applications is to apply the biosolids where you want it, at the correct rate, as uniformly as possible, with minimal site impacts, and as efficiently and economically as possible. Biosolids application is basically materials handling, and the key to materials handling is
matching the handling method or technology to the characteristics of the material being handled. For example, a wheel-loader is not usually the first choice for loading liquid biosolids. The wide range of physical properties represented by differing biosolids products necessitates an equally broad range of materials handling methods to efficiently apply these materials.

Other factors to consider when selecting the most efficient application technology are the terrain and site conditions anticipated at the time of application, the application rate, treatment objectives, off-site impacts, and availability of equipment. Equipment availability and short-term cost savings frequently prevent better technologies from being used. The benefits of a better application, i.e. more uniform application, fewer breakdowns, less odours, can be subjective and difficult to assess economically.

SITE CONDITION CHALLENGES

In our experience, overcoming site conditions has presented the greatest challenge and has most often governed our choice of application technology. Most of our applications have been on forest, landfill, mine, and rangeland sites, with few applications on cultivated farm land. As such, we have been faced with undulating forest and range sites, extremely rocky and rugged mine and landfill sites, and slopes ranging from flat to very steep (angle of repose). Meeting these challenges has caused us to evaluate a wide variety of materials handling methods and possible biosolids application technologies.

Agriculture

Agricultural sites can generally be subdivided into cultivated and un-cultivated sites. Cultivated sites are by definition generally accessible with conventional farm equipment. Un-cultivated sites such as rangeland will often have coarser soils and more varied terrain. Conventional agricultural equipment and tillage methods may have limited application on these types of sites due to slopes or rockiness of the sites. Factors to consider are traction during wet weather, ability of equipment to traverse-the site, soil compaction, vegetation type and susceptibility to damage, application rate and uniformity, ease of tillage, and odour sensitivity. Cultivated farm land is amenable to almost any application; method, but conventional manure spreading methods are most commonly used.

Silviculture

Silviculture can also be roughly subdivided into plantation and natural forestry. Our definition of plantation forestry implies trees grown in rows on flat to gently rolling terrain that permits equipment to traverse between the rows. Natural forestry implies more randomly planted trees and can include much more difficult terrain and steep slopes. We have operated in both settings and tried a range of application technologies. Factors to consider are site access, ability of equipment to traverse the site, traction during wet weather, soil compaction, vegetation type and susceptibility to damage, application rate and uniformity, ease of tillage and incorporation, and odour sensitivity.

Reclamation

Reclamation uses can also present a variety of site conditions. Mine site conditions can range from very fine tailings deposits to very coarse waste rock dumps, with slopes from flat to angle of repose. Other reclamation sites such as, gravel pits, quarries, landfills, slides and erosion channels also present varied terrain and access challenges. A common element on reclamation sites is exposed and often loose mineral soils, that frequently contain a high percentage of coarse fragments (large rocks). Steep slopes, limited access, rugged terrain and loose soils present the greatest application challenges. Factors to consider are site access, ability of equipment to traverse the site, traction during dry or wet weather, soil compaction, vegetation type and susceptibility to damage, application rate and uniformity, ease of tillage or incorporation, and odour sensitivity.

APPLICATION TECHNOLOGIES

Fortunately, there are many application technologies to chose from when trying to match the material handling characteristics of your biosolids to the challenges presented by a particular site and set of project objectives. The following discussion presents some of our direct experiences and indirect observations about what works and what does not work. Table 1 suggests some technology matches.
### Table 1 - Application Technologies versus Biosolids Properties

<table>
<thead>
<tr>
<th>Texture</th>
<th>Liquid</th>
<th>Slurries</th>
<th>Dewatered Biosolids</th>
<th>Friable &amp; Granular Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Solids</td>
<td>1 - 4</td>
<td>4-10</td>
<td>10-15</td>
<td>15-22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sloppy</td>
<td>Thick</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>22-40</td>
<td>40-98</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fine</td>
<td>Coarse</td>
</tr>
</tbody>
</table>

#### Spray Methods
- **Sludge gun**
  - easy pumping
  - pump/hose limited
  - unsuitable
  - unsuitable
  - unsuitable
  - unsuitable
- **Spray tanker**
  - thin better
  - thin better
  - unsuitable
  - unsuitable
  - unsuitable
  - unsuitable
- **Vac/press tank**
  - best range
  - thin better
  - unsuitable
  - unsuitable
  - unsuitable
  - unsuitable
- **Bark blower**
  - unsuitable
  - unsuitable
  - unsuitable
  - marginal
  - drier better
  - unsuitable
- **Shotcrete system??**
  - not practical
  - practical
  - might work
  - probably best range
  - pump limited
  - dry tech. may work
  - unsuitable
- **Sludge Squirter??**
  - unsuitable
  - unsuitable
  - not practical
  - probably best range
  - under 30% solids
  - unsuitable
  - unsuitable

#### Spreading Methods
- **Honey Wagon or Tanker**
  - best range
  - pressure assisted
  - marginal thin better
  - unsuitable
  - unsuitable
  - unsuitable
  - unsuitable
  - unsuitable
- **Sleigh Foot Applicator**
  - best range
  - pressure assisted
  - marginal thin better
  - unsuitable
  - unsuitable
  - unsuitable
  - unsuitable
  - unsuitable
- **Rear-cast spreader**
  - some with gates
  - some types
  - best range
  - dust prone
  - tolerates coarse bits
- **Side-cast spreader**
  - some with gates
  - some types
  - best range
  - bridges & dust prone
  - bridges & plugs
- **Top Dress spreader**
  - unsuitable
  - unsuitable
  - unsuitable
  - marginal thick better
  - thicker better
  - probably best range
  - tolerates coarse bits
- **Flinger**
  - unsuitable
  - unsuitable
  - unsuitable
  - marginal thick better
  - probably best range
  - dust prone
  - classifies material

#### Injection Methods
- **Hose fed injector**
  - hose limited
  - pump/hose limited
  - not practical
  - unsuitable
  - unsuitable
  - unsuitable
  - unsuitable
- **Injection Tanker**
  - volume limited
  - best range
  - pressure assisted
  - unsuitable
  - unsuitable
  - unsuitable
  - unsuitable
- **Sludge pump injector??**
  - not practical
  - probably best range
  - must be pumpable
  - unsuitable
  - unsuitable

Proven technologies using biosolids, suitability to material properties... worst * to ***** best

??? Unproven technologies using biosolids, est. suitability to material properties...
Liquid & Slurried Biosolids

Handling biosolids as a liquid or slurry has many advantages, not the least of which is avoiding the cost of dewatering, and is employed successfully by communities with relatively small volumes (Vernon), or short hauling distances (Calgary, Edmonton). Liquid application of trucked or re-slurried biosolids has also been used with success to overcome challenging site conditions in forestry and reclamation (GVRD, Seattle). Handling biosolids in liquid form allows the use of simple, proven - pumps, pipes, hoses and tanks, at the expense of handling ten times more material and risking messy spills. A wide variety of technologies are available for applying liquid biosolids which we have divided into spraying, spreading, and injection systems.

Surface spray

One of the simplest and most flexible ways to apply liquid biosolids is to spray it on with a high pressure nozzle. Depending on the pressures available biosolids can easily be sprayed 30-60 m, allowing large areas to be applied quickly, even over difficult terrain. Application rates are easily controlled for quantity and uniformity, but are limited to light applications at one time by leaching and run-off concerns. Other limitations of spray application are visual impact, vegetation fouling, odours, over spray, and aerosol concerns.

A variety of spray application equipment is available, ranging from hose and nozzle systems to vehicle mounted spray tankers. For small scale and research applications in a rugged forestry setting we have used hand-held fire hoses quite effectively. Larger sludge-gun and hose-reel systems adapted from agricultural irrigation equipment are commonly used for farm applications (e.g. Blaine, Birch Bay, Linden, Wa). Seattle experimented with using a hose-reel in a forestry setting but found excessive wear and damage dragging the hose through the forest and high head losses trying to pump thick re-slurried biosolids. For hose systems, the solids concentration should generally be less than 10%, and be reduced further as the hose is lengthened.

Tanker systems come in a variety of shapes and sizes, ranging from on-highway trucks to off-road vehicles. Tacoma, Wa for example uses a number of tandem axle truck tankers equipped with PTO powered pumps and remote controlled monitors to apply some of their biosolids to farm land. However, use of highway trucks on farm land is limited by poor traction during wet weather and soil compaction. Seattle used off-road Ag-Chem type vacuum/pressure tankers with remote monitors in their Silvigrow forestry program for many years and we borrowed one of their vehicles for one of our projects. This equipment can effectively apply biosolids in some pretty rugged terrain, but can require an extensive road or trail system and support equipment to apply large volumes of biosolids.

We have also used conventional hydroseeding equipment successfully to apply biosolids to steep slopes at a mine site. Hydroseeders are not designed for handling biosolids, so we had difficulty loading dewatered biosolids in through the small top hatch. One advantage is that hydroseeders have their own mixing system, so the slurry could be mixed enroute to the application site. We found there was no rock guard protecting the pump, and no easy way to get rocks out of a tank full of biosolids. None-the-less we found that the sprayed biosolids adhered well to the slope, sticking to everything like biosolids to a blanket, and showing promise as a substitute for the mulch and tackifiers normally used in hydroseeding. Further testing needs to be done to see whether seeds will germinate if applied with the biosolids.

Surface spreading

Another common method of applying liquid biosolids is by surface spreading from some sort of tanker. Tankers can range from the ubiquitous farm honey wagon, to highway and off-road tankers. Vernon, BC uses a tandem axle tanker truck with a spray bar to apply their biosolids from right out of the digesters to surrounding rangeland. Portland, Or. uses a fifth wheel dolly behind a large tractor to pull large highway tankers across rangeland at the Madison Ranch. Spray bars or splash plates are commonly used to achieve an even distribution of the biosolids. For slurries too thick for spray bars and splash plates, there are rear-discharge and side-cast manure spreaders designed for sloppy materials. Spreading reduces over spray, aerosol, and odours to some extent over high pressure spray application but is limited by the need for equipment to traverse the whole site.

Recently, a new breed of manure spreader has been developed to apply liquid manures and biosolids directly onto the soil surface below the vegetation. These systems are intended to eliminate over spray...
and aerosol concerns and greatly reduce odours. One such system is the sleigh foot applicator developed in the Netherlands. The slender sleigh foot nozzles part the grass and deposit the liquid biosolids onto the soil surface at the soil/air interface, with minimal disturbance of the soil, roots, or grass. This system was tested with biosolids at the Woodwyn Farms near Victoria, BC and worked very well. Biosolids were barely noticeable following application and odours were greatly reduced. However, this application method is only applicable to forage crops.

**Injected**

Another popular method of applying liquid biosolids is by sub-surface injection. The primary advantages of this method are reduced odour, vector attraction reduction, run-off prevention, reduced animal exposure, and improved nitrogen utilisation, i.e. less ammonia volatilisation. Injection systems are available in a variety of configurations ranging from a tractor mounted - hose fed system, to a variety of honey wagon and self-propelled vacuum/pressure tanker injection systems. Injection shanks have also been welded to the back of Cat ripper teeth for really heavy soils. All of these systems involve ripping or slicing a slot through the soil and injecting the biosolids directly into the soil below the surface under pressure through a hollow shank. They vary in the size and strength of the shank, depth of injection, and amount of surface and sub-surface soil disturbance and root damage they cause. Sub-surface injection with conventional equipment is limited to cultivated soils, and the fewer rocks the better. Calgary, AB has operated their Calgrow liquid injection based recycling program successfully for many years using a fleet of nurse tankers and Ag. Chem application vehicles.

**Re-mixing Methods**

Where a liquid application is desired using dewatered biosolids, a re-watering step is required. We have done this on a number of projects to save the cost of hauling liquid biosolids long distances. For smaller projects we have used both a tarp lined pit and a half buried cargo container as mixing basins. In both cases we used a tractor powered manure agitator (big propeller) to re-slurry the biosolids. For a larger silviculture project, we designed and built a re-watering plant patterned after Seattle's Silvigrow operation that was capable of mixing 400,000 L of slurry over 8 hours. At an average slurry concentration of 13.5% solids, this system could handle up to 54 dry tonnes per day and performed very well.

**Dewatered Biosolids**

For larger biosolids producers, the high cost of hauling and applying large volumes of liquid biosolids quickly justifies dewatering. Dewatered biosolids are semi-solid and can have very different physical properties depending on the type of treatment processes and dewatering methods used to produce it. Primary sludges tend to be more granular while biological sludges tend to be more gelatinous and more difficult to dewater. Thermophilic primary sludges tend to be more granular and dewater better than mesophilic sludges. Thermophilic biological sludges have finer particles resulting in only slightly better dewaterability. Lagoon or land-stored biosolids tend to become more friable with age.

With respect to dewatering, the percent solids achieved probably has the greatest impact on the biosolids handling characteristics. At solids concentrations less than ~25%, the biosolids become increasingly plastic, sticky, and tend to flow. As solid concentrations increase above 25%, dewatered biosolids become increasingly granular and friable in our experience. High polymer doses can reduce the viscosity of the biosolids due to the capture of more fines and the slipperyness of residual polymer.

The method of handling the biosolids following dewatering can also affect the characteristics of the final product. Sludge pumps and to a lesser extent long screw conveyors will shear the dewatered biosolids, breaking down any internal structure, and making the biosolids more plastic. Minimising the amount of shear or vibration imparted to the biosolids during handling can maintain its viscosity and help avoid problems such as shifting loads causing axle weight violations during transport.

The stickiness, viscosity, and texture of the dewatered biosolids are the key factors which need to be assessed when considering the type of application equipment best suited to a particular biosolids. Seemingly subtle differences in physical properties can make a big difference in how well a particular type of application equipment will work with your biosolids.
Surface spreading

Dewatered biosolids are typically spread onto the soil surface as a fertiliser, or subsequently incorporated as a soil amendment. As with liquid applications, conventional application methods and equipment have been adapted from agricultural manure handling.

Manure spreaders

Manure spreaders are most commonly used to apply dewatered biosolids. They come in a wide variety of shapes and sizes and differ in their configuration and internal mechanisms. These variations can make a surprising difference in how well a spreader will perform with a given biosolids on a particular site. Generally, manure spreaders can be categorised as rear-discharge or side-discharge, and can be pulled with a tractor, or self-propelled on a truck or off-road equipment chassis.

The essential elements of a spreader are a box or hopper, a means of conveying the product to the discharge point, and a mechanism to expel and uniformly distribute the product onto the soil surface. Spreader boxes are usually well designed with steep sides to prevent material hanging up or bridging, but we have experienced severe bridging in a V-box side-cast spreader while trying to spread a coarse biosolids compost. Farm spreaders typically have one of three types of internal conveyors, chain driven flights, screw conveyors, or a push-out mechanism, while some custom-built spreaders have used walking floors. We have seen all four types used on rear-discharge spreaders, but side-cast spreaders generally rely on screws. Floor chain, push-out, and walking floor style spreaders typically have a rear lift gate which prevents material falling out during loading and transport. These gates often have only two positions, up or down, unless designed to partially open to handle sloppy materials.

All of these conveying systems work reasonably well on level ground with fairly firm biosolids. Floor chain and walking floor systems are less effective spreading on slopes, particularly down slope, and with sloppy material. With stiffer biosolids, there is the problem of biosolids sloughing into the beaters unevenly, particularly when the spreader hits a bump or is on a slope, resulting in an uneven application. A partially open rear gate can alleviate this problem with floor chain and push-out spreaders, but will back up most walking floor systems. In our experience, push-out and walking floor systems can handle large rocks, chunks of concrete, and sections of pipe and timber better than floor chain and screw conveyor equipped spreaders, but the best advice is to keep these kinds of things out of your biosolids and most definitely out of your spreaders. Push-out systems without a sliding floor or lid will tend to mound the biosolids and spill it over the sides, particularly if the biosolids exhibit plastic flow. Overall, we rate screw conveyors the best for providing positive, consistent delivery of biosolids to the discharge point regardless of biosolids consistency, slopes, and bumps. Alas, screw conveyors require about five times the horse power used by walking floor and floor chain systems, proving once again that performance has its price.

The discharge mechanisms for expelling and distributing the biosolids onto the ground typically involve spinning paddles or hammers designed to shred or break up the biosolids into fine particles and distribute them as uniformly as possible in a fan to the side or rear of the spreader. Side-cast spreaders typically have a smaller expeller which spins at a higher speed and spreads the biosolids over a width of 10-20 m, much wider than most rear-discharge units, and are particularly well suited to lower application rates. We have used a side-cast spreader with fixed paddles arranged in a horizontal reel. This unit has a very fine and even spreading pattern, but the combination of fixed paddles and high speed does not tolerate rocks very well. We expect that the swing hammer type of expeller would be much more tolerant of rocks and other surprises that find their way into biosolids.

The most common distributor for rear-discharge spreaders is one or more horizontal shafts with angled paddles, although we have seen spreaders with vertical shaft paddles, and horizontal spinners like those of sand and fertiliser spreaders. Distributors for rear-discharge spreaders typically turn more slowly and spread in a short, narrow fan behind the spreader, usually 3-5 m wide. In our experience, the resulting spread pattern is much coarser and not as even as achieved with a side-cast spreader. There are more large chunks, less evenly distributed on the ground. Most of the spreaders we have used have also had an annoying tendency to cast more material to the sides and leave the centre almost bare, resulting in a stripping effect. We attribute the poor spreading to the slower speed and crude design of the typical horizontal beater. On the positive side these beaters generally handle rocks quite well, and rear-discharge spreaders typically have a higher throughput and can spread faster or heavier than side-cast spreaders.
Recently we tried a rear-discharge spreader with opposing vertical beaters. This unit worked well when it was demonstrated spreading compost and produced an even spread pattern. However, when we tried it with our 24% dewatered biosolids, it performed miserably with biosolids bypassing the beaters on both sides and through the gap between them, resulting in huge plops of biosolids along the spreading path. This example underscores the importance of matching the design and operating details of your spreading technology to the properties of your biosolids.

We are still looking for a rear-discharge spreader that can spread dewatered biosolids as finely and evenly as a side-cast spreader, but with the higher throughput. The current crop of manure spreaders have not been optimised for spreading biosolids evenly. How about a full width set of swing hammers angled down at 30° so the odd rock doesn't hurt anyone?

**Slope Spreader**

One of our innovations has been to modify a manure spreader to apply dewatered biosolids onto steep slopes. We fitted a locking lid to the top of a push-out style spreader and converted it to all hydraulic operation. The lid ensures positive feed of biosolids to the expeller regardless of slope angle. We then plumbed a small wide-track dozer to pull and power the spreader. This combination has worked very well to apply biosolids to slopes ranging up to 28° and can apply up-slope or down.

**Flingers**

What do you do when a side-cast spreader won't throw your dewatered biosolids far enough or high enough to get it where you want it? This situation can arise in silviculture, reclamation, or agriculture where crops, terrain, or other access restrictions prevent conventional applications. One solution is to get a bigger flinger, such as the Aero-Spread. The Aero-Spread is basically a high powered fan, and we all know what happens when biosolids hit the fan.

Seattle graciously lent us one of their Aero-Spread units to test at a mine reclamation project applying to steep 37° slopes. We found that from the bottom of the slope flinging up-slope, we were able to apply up 20-30 m with a very even spreading pattern. Flinging down-slope, we could easily triple that distance. With its wide spreading pattern, the Aero-Spread just crawls along for anything but the lowest of application rates. Re-positioning between loads and adjusting to inside or outside curves are key to even application, so an experienced operator is an asset. To increase throughput, a nurse system for biosolids transfers to the Aero-Spread units should be considered.

The following year, a contractor suggested trying a tractor powered agricultural silage blower to accomplish the same task. Dewatered biosolids were conveyed into the silage blower positioned at the top or bottom of the slope. The silage blower also proved capable of flinging the biosolids quite a distance, about 15-20 m up slope and 30-45 m down slope, but the evenness of the application was hampered by the lack of directional control on the blower and its tendency to dribble biosolids within the first 3-5 m. This idea needs a bit more work, but shows what you can do with improvisation.

Perhaps the most important thing we learned about flingers is that they really do not like rocks. We kept a welder very busy during both flinger trials. The contractor using the silage blower eventually had two, so that one could work while the other was being repaired.

**Squirters**

One of the many unconventional ideas we have come up with for applying biosolids to difficult sites involved the use of a concrete pumper truck with a long placement boom. These units are available with boom lengths up to 55 m, that can reach a long way up or down a slope or over a forest site. Sludge cake pumps are just modified concrete pumps, so pumping through the boom should not be a problem. All we needed was a means to project the biosolids from the end of the boom. Coincidentally, we were contacted by a sludge pump manufacturer, and a plot to test this idea was soon hatched.

The pump manufacturer suggested that we first try simply squirting the biosolids from the end of the boom, and set to work rigging up a variety of different shaped nozzles. When these were first tested at their facility using dewatered secondary sludge approximately 20-22% solids, the results exceeded our expectations. We were able to squirt the dewatered biosolids up to 30 m beyond the end of the boom, and depending on the type of nozzle achieve either a splatter or a blob on the ground. Subsequently we tested the pump at our Annacis plant with 28% primary biosolids and were able to squirt the biosolids up...
to 55 m horizontally from the nozzle. We then tested the pump system without the boom truck at a forest application and were able to squirt the biosolids just as far into the forest as our liquid applicator vehicle.

We have not developed this idea any further, but the idea may yet have potential for specialised applications. This sludge pump idea could also be adapted to subsurface inject dewatered biosolids if someone can come up with a reason to. It is certainly exciting to operate with the sludge pump operating near maximum speed, line pressures of 800+ psi and the pipe surging with every stroke of the pump. It is even more exciting when the nozzle plugs. Limitations are the high cost of the sludge pump and boom truck, and uncertainty about operating a sludge pump at high stroke rates for extended periods of time.

Sprayers

We have also toyed with the notion of pneumatically conveying and spraying dewatered biosolids. One idea we haven't yet tried is to test shotcrete equipment as a means of applying biosolids. Shotcrete is sprayed on concrete, and is used extensively to shore building excavations, mines, and tunnels. Systems vary, but most involve pumping a high-slump or runny concrete mix to an ejector nozzle where the concrete is expelled with compressed air. Conceptually, this equipment should work quite well to spray finely distributed biosolids at least 10 to 20 m, and could easily be combined with the pumper truck idea described above to extend the range. If anyone else has tried this, we would like to hear from them how it worked.

In the same vein, we recently had the opportunity to test a bark blower with our biosolids. Bark blowers are specially equipped trucks designed to pneumatically convey and apply bark mulch and compost quickly and easily, and are revolutionising landscaping. Designed for lighter, dryer, and more friable materials, we were sceptical about how this machine would work with dewatered biosolids. We were surprised to find that the machine we tested was capable of conveying and spraying our dewatered biosolids very effectively through 30 m of hose. We finally plugged up the hose when we fed it some 15-18% slop, but with our regular dewatered biosolids at 23-25% solids it performed quite well. The machine can spray the dewatered biosolids as a finely divided stream of particles up to 20 m, and is controlled by a single operator at the end of the hose. We plan to test this machine in an operational setting this year.

SUMMARY AND CONCLUSION

We like to think that there is a best biosolids application technology or approach for every situation. For some of our applications such as on very rocky mine sites, we are still looking for a better technology. For some of our technologies such as the sludge squirter, we are still looking for an application. Further development of many new and old technologies is required to optimise them for biosolids spreading. We believe that as biosolids applicators, we need to place greater emphasis on selecting and optimising application methods and equipment to the physical properties of our biosolids and the site conditions. We need to actively develop and test new methods and technologies, rather than simply using what is readily available. The payoff is better application results, improved efficiency, and better acceptance of biosolids recycling by the client and the public. We encourage others to innovate and share their ideas and application experiences. That is how we all improve.