Summary of Selection Criteria

Wards Island WPCP Centrifuge Replacement Project Feasibility Study

New York City / Department of Environmental Protection

per CDM Smith Report

March 2012

Background:

The purpose of the CDM Smith report was to evaluate current dewatering centrifuge technology for the replacement of 13 existing centrifuges at Wards Island, and potentially adding three additional centrifuges, for a total of 16 machines.

Five different centrifuges were evaluated for replacement of the existing Humboldt CP4-1centrifuges:

- Alfa Laval, Model G2-115
- Andritz, Model CP4-1.2 (a retrofit, using same frame)
- Andritz Model D6LX
- Centrisys Model CS26-4
- Westfalia, Model CF 7000

Per the CDM report, "*the capacity of the current centrifuges was originally specified at 250 GPM with a range of 1% to 3% solids, and a 24.5% sludge cake solids requirement.* The basis of sizing new centrifuges is to use the design capacity of the existing centrifuges, based on the premise that the ancillary components (piping, conveyors, hoppers, pumps, etc.) were designed to support the combined centrifuge throughput".

The report noted that "all models evaluated are mid-feed, counter-current design using AC variable frequency drives (VFDs) for the main drive motors. Solids conveyor (scroll) gearbox/speed reducer input shafts are driven by VFD controlled AC motors as well, with the exception of Centrisys, which uses a radial piston hydraulic motor with a VFD driven oil pump."

Criteria and Score Weighting

1. Centrifuge Features

The centrifuge features category is meant to evaluate the physical differences between the centrifuges.

- **G-Volume** Units with a higher G-volume receive a higher score
- **Back Drive Design** Direct drive and high torque receive higher scores
- **Bearing Lubrication System** Score from highest to lowest: single pass air conveyed oil, recirculated forced oil, grease.
- **Bowl Design** Duplex steel favored over carbon steel or non-duplex, wear strips are favored over grooves, lower beach angle favored due to knowledge of performance for NYC sludge.
- **Scroll Design** - A higher score is given to an open flight design, and full scroll protection.
- **Special Features** Features unique to a given model of centrifuge not included elsewhere in the matrix.

2. Performance

This category is meant to evaluate the performance of each machine. Items in this category included:

- **Power Use** Higher score corresponds to a lower power draw from the unit; a lower score corresponds to a higher power draw.
- **Cake Solids** Higher cake solids receives higher score
- **Polymer Consumption** A high score corresponds to lower polymer dose for a set solids output compared to the other units.
- **Centrate Quality** A high score corresponds to lower centrate TSS for a set solids output compared to the other units.

3. Installation

This category is meant to evaluate the comparative ease of installation of each machine. Items included in this category are:

- **Structural Considerations for Installation** - A high score indicates fewer structural modifications are needed
- **Mechanical Considerations for Installation** - high score indicates little mechanical modifications are needed, while a low score indicates that significant modifications are needed.
- **Construction Duration** - A higher score is assigned to shorter construction durations
- **Delivery Time** - A higher score is assigned to shorter anticipated time periods.

4. Operations and Maintenance

This category is meant to evaluate the availability of vendor support and the maintenance needs of each machine. Items in this category included:

- **Number of Employees/Service Staff -** Higher scores are provided to large installed equipment base and number of employees available to service.
- **Location of Major Maintenance / Parts Stocking Facility** –A higher score is assigned to maintenance centers that are closer to Wards Island WPCP.
- **Gearbox Overhaul Frequency** -A higher score assigned to gearboxes requiring less frequent overhauls.
- **Bearing Lubrication System** – From highest to lowest score are: single pass air conveyed oil, recirculated forced oil, grease.
- **Weight of Rotating Assembly/Gearbox** – High score for low weight.
- **Years the Centrifuge Model Has Been Manufactured** The longer the machine has been made, the more bugs have been worked out - longer manufacture gets higher score.

5. Cost

This category evaluates the capital, operations and maintenance costs associated with each unit. Included in this category are:

- **Centrifuge Budget Cost** – This is the cost from the manufacturers for 13 units including control panels, based on 2012 delivery, lowest cost is highest score

- **Estimated Capital Project Cost** – The estimated capital project cost is provided for installation of the centrifuges, and any structural and mechanical modifications necessary to install the centrifuges, as well as replacement of the sludge feed pumps, centrate piping and polymer pumps. The lower the cost compared to the other manufacturers, the higher the score for this criterion.
- **Estimated Power and Chemical Cost** – The estimated operating cost includes polymer costs and power costs. The lower the cost compared to the other manufacturers, the higher the score for this criterion.
- **Estimated Cake Disposal Cost**- Cake disposal costs are the single largest operating cost by far, it is included here because the current technology centrifuges are expected to perform better than the retrofitted CP4-1 units. Actual pilot data would be needed to populate this category.
- **Estimated Payback Period** –The lower the payback period compared to the other manufacturers, the higher the score for this criterion

Table 5-1
Weighting of Criteria

Criteria	Maximum Score	Category Weights	Criteria Weights	Normalized Criteria Weights
Centrifuge Features		**20**		
G-Volume	5		50	10
Back Drive Type/Gearbox/Torque	5		20	4
Bearing Lubrication System	5		15	3
Bowl Design	5		5	1
Conveyor Design	5		5	1
Special Features	5		5	1
Subtotal for Category			**100**	**20**
Performance		**20**		
Power Consumption (kW)	5		40	8
Cake Solids (%)	5		60	12
Polymer Consumption (active lb/ton)	5		0	0
Centrate Quality	5		0	0
Subtotal for Category			**100**	**20**
Installation		**15**		
Structural Considerations	5		30	4.5
Mechanical Considerations	5		30	4.5
Construction Duration	5		20	3
Delivery Time	5		20	3
Subtotal for Category			**100**	**15**
Operations and Maintenance		**25**		
Service Staff	5		15	3.75
Major Parts Stock, Repair, Overhaul Location	5		15	3.75
Gearbox Overhaul Frequency	5		20	5
Bearing Lubrication System	5		15	3.75
Weight of bowl&scroll/Weight of Gearbox	5		10	2.5
Reserved	5		0	0
Years model has been Manufactured	5		25	6.25
Subtotal for Category			**100**	**25**
Cost		**20**		
Centrifuge Budget Cost	5		15	3
Estimated Facility Upgrade Capital Cost	5		20	4
Estimated Annual Power/Chemical Cost	5		10	2
Estimated Cake Disposal Cost	5		30	6
Estimated Payback Period	5		25	5
Subtotal for Category			**100**	**20**
Total Score		**100**		**100**

NOTES
Shaded cells should be equal to 100
Yellow Cells Require Input

Centrifuge Critical Parts under Consideration in Evaluation

1. Scroll

Each manufacturers design is unique based on their experience and testing.
Scroll design has evolved; the flights are stronger to handle higher torque occurring at high solids production. Flights or segments of flights in the cylindrical section are fully or partially open or "ribboned" to allow the centrate to flow to the liquid outlet more easily for mid feed designs, reducing turbulence and reducing rotating mass. Scroll pitch may be constant or varied. Scroll Pitch is an important design variable each manufacturers considers for specific applications.

2. Hydraulic Separator Plate

Another improvement is the employment of a separating plate welded to the scroll axis that creates a hydraulic differential from the operating pond to the solids beach. The cylindrical section of the bowl has a slightly greater pond depth, creating a hydraulic gradient to assist the dewatered solids to travel up the beach and discharge, rather than relying solely on scroll torque. This allows the machine to operate at deeper pond depth, and helps oppose the slippage forces discussed above, allowing use of steeper beach angles. All of the manufacturers employ some form of this feature.

3. Conical Beach Angle

The beach angle affects the performance of the machine. For a given size machine, a steeper beach angle provides a shorter conical section and a longer cylindrical section. This results in greater residence time for clarification. For a given rotational speed, the steeper the beach angle, the greater the downward force vector (slippage force) acting on the dewatered solids. This results in higher torque on the scroll and/or reduces the net solids transport rate out of the machine. There is a critical beach angle for a given sludge consistency beyond which the solids will not be reliably conveyed. Also, increased wear is imparted on the scroll as the torque requirements increase.

- Centrisys and Westfalia machines offered have a standard beach angle of 15 degrees.
- Andritz does not have experience with beaches steeper than 12 degrees on municipal sludge in the US.
- Alfa Laval has over 100 installations on municipal sludge with a 20 degree beach, and has been unsuccessful testing 15 and 20 degree beaches on other municipal sludge installations with a high grit content that usually manifests in the spring season.
- Alfa Laval offers a 10 degree cone angle for this project due to performance concerns of applying a 20 degree beach without knowledge of the range of sludge characteristics or opportunity to pilot.

4. Strips vs. Grooves

The centrifuge bowls have either grooves or strips running axially along the entire bowl length. Their primary function is to create friction between solids and bowl to keep the layer of solids between the bowl wall and the scroll flight tip rotating with the bowl. If this layer slips and rotates with the scroll, plugging occurs. Per the CDM report, practical evaluation indicates that strips are less costly to install, less costly to renew, and will have a lower lifecycle cost.

5. Scroll Drive

There are advantages and disadvantages of the various drive mechanisms, and they are all similar in efficiency. Hydraulic back drive systems provide more precise differential speed control - since scroll speed is directly caused by a low speed radial piston hydraulic motor bolted to the bowl housing with output shaft attached to the scroll shaft. Torque maintenance and differential speed control are directly measured by pressure and flow. Current hydraulic motors are more compact, offer high torque capabilities at much lower pressure, and have low internal component speeds to minimize wear. The oil pumps are controlled with AC variable speed motors, controlling scroll speed by changing the flow rate to the hydraulic piston motor and eliminating the bleed back loop. Torque is directly proportional to system pressure, and because the drive system uses oil, there is no backlash.

Summary of Findings:

Using an evaluation matrix, the centrifuge manufacturers / proposed products were ultimately ranked as follows, from highest score to lowest:

1) *Centrisys CS26-4*, receiving the highest score due to:
   - Second highest G volume
   - Highest torque capacity
   - Second lowest operating costs
   - Minimal structural and mechanical modifications needed for installation.

2) *Alfa Laval G2-115*, receiving the second highest score due to :
   - Comparatively smaller G volume.

3) *Westfalia CS 7000*, ranked lower due to:
   - Proposed new model had no operating track record
   - Installation requires centrifuge opening structural modifications.

4) Andritz D6LX, ranked lower due to:
   - It carries the second highest power consumption estimate
   - It has the second highest capital cost
   - Installation requires centrifuge opening structural modifications.

5) *Andritz CP4-1.2.*
The re-fitted Andritz CP4-1.2 has the largest capacity of all the machines evaluated. It was not recommended, however, for the following reasons:
   - The design capacity is 250 GPM, not 300 GPM as Andritz indicates the re-fitted unit is capable.
   - Accommodating 300 GPM unit design flow would include upsizing polymer pumps, sludge feed pumps and centrate piping.
   - Existing carbon steel frames are to remain in service, cost estimate includes new SS cladding, however the frames are over 20 years old, and the extent of metal fatigue is not known.
   - Highest estimated capital cost
   - Highest estimated maintenance cost
   - Largest connected electrical load
   - Highest energy consumption
   - Carbon steel bowl, vs. duplex SS for all other units considered

Background on the Centrisys Corporation Model CS26-4

The CS 26-4 energy efficient design preceded all models in USA installations:

- The beach angle is 15 degrees
- The bowl diameter/solids discharge diameter/bowl cylinder length is 26/15.3/89.6 inches. The CS 26 bowl length is the longest of the units evaluated.
- The scroll is a closed flight design near the feed section to maximize solids transport and open near the centrate end to promote settling/capture, as indicated by Centrisys.
- The scroll is cast duplex and 316 SS to protect against corrosion and wear protection is provided by tungsten on the full length of the flights, using tiles in the feed zone and spray applied tungsten in the effluent zone. Replaceable tungsten carbide inserts are provided at the feed and discharge ports.
- The scroll design does not use a separator disc to raise the pond depth but incorporates a solids baffle on the beach which Centrisys claims affects the driest solids to be discharged from the machine.
- The main drive system consists of a VFD controlled main motor that rotates the bowl via an in-line belt and pulley arrangement. The scroll drive is a radial piston motor, manufactured by Viscotherm AG. This hydraulic conveyor drive has several differences from the hydraulic drives installed on the original NYCDEP centrifuges. The new piston motor and oil pump unit are more compact than the components of the original drives. The radial piston motor is of smaller diameter and weighs less than the planetary and cyclo boxes utilized by other manufacturers, while producing more torque at the scroll.

- The scroll speed is controlled by a gear pump remotely located in an oil reservoir driven by a variable speed AC motor. Changing the motor speed changes the oil flow, directly affecting scroll speed. This provides for an extremely controllable differential speed not affected by variations in load on the conveyor. In addition, unlike a sealed, oil filled speed reducer, the hydraulic oil flowing to the motor is constantly filtered to remove contamination from machine wear or condensation. This prolongs the life of the drive system. An external cooling water flow of 3 GPM is required to cool the hydraulic oil. Air cooling is also an option. Centrisys indicates the water supply can be plant effluent.
- The radial piston hydraulic motor is mounted outboard of the main bearings. The motor is bolted to the scroll and the output shaft is connected to the scroll shaft, rotating the scroll at a low rpm independently of the bowl speed. This arrangement allows the motor to drive the scroll whether the bowl is rotating or not, and has advantages of cleaning solids out of the bowl.
- The bearings are oil lubricated using an air conveyed single pass oil system. This system is simple in that oil drips from a reservoir into an air stream and sprays into the bearing. This is a favored method of lubricating high speed bearings from a bearing life standpoint, in that the oil is not recycled, there is no potential for contamination and viscosity breakdown.

The ***Centrisys CS26-4*** utilizes a hydraulic motor scroll drive motor manufactured by Viscotherm AG. The radial piston motor (Rotodiff) is directly bolted to the bowl, and performs the work of a gearbox and electric motor. The Rotodiff rotates at very low speed, and the output shaft is directly coupled to the scroll shaft, controlling scroll speed independently of the bowl speed.

The advantages to this hydraulic backdrive include:

1. The motor is compact with low rotating mass and a large torque capacity. This reduces energy consumption and provides plenty of power to handle solids feed fluctuations.
2. Since the scroll is driven independently, the hydraulic piston motor can drive the scroll with the bowl stationary, without fixing the bowl to the frame via special tools, a maintenance convenience for cleaning solids out of the bowl.
3. Motor shaft output speed is directly controlled by oil flow rate, and oil pressure is directly proportional to scroll torque, this allows precise control of differential speed by varying the oil pump speed. Since the radial piston motor does not have mechanical gearing, there is a very low system spring rate (no backlash).

The disadvantages to this hydraulic backdrive include:

1. The disadvantages to this system are primarily the additional maintenance of an oil pump and reservoir with required filter/oil changes, high pressure system with the potential for hydraulic leaks, and hydraulic line routing requirements.

Table 5-2

Centrifuge Evaluation Matrix

Basis for Analysis, assumed the same for all vendors:

Inlet Sludge Rate per unit	250 gpm @ 1.7%
Capture Efficiency	Greater than 95%
Centrate Quality	1000 mg/l
Polymer Use	32 lb/ton (active basis), diluted to a 0.25% solution
Noise	85 dba

Green background means the score was calculated using the standard deviation procedure

If the criteria doesn't have a green background, that means the score is a subjective input

Notes:

Shaded cells should be equal to 100

Yellow Cells Require Input

Manufacturer					Alfa Laval			Andritz			Andritz			Centrisys			Westfalia		
Model					ALDEC G2-115			CP4-1.2			D6LX			CS 26			CF7000		
Criteria	Maximum Score	Category Weights	Criteria Weights	Normalized Criteria Weights	Value	Score	Weighted Score	Value	Score	Weighted Score	Value	Score	Weighted Score	Value	Score	Weighted Score	Value	Score	Weighted Score
Centrifuge Features		20																	
G-Volume	5		50	10	310,601	1.69	16.87	453,183	4.40	43.96	363,529	2.69	26.93	402,598	3.43	34.35	368,639	2.79	27.90
Back Drive Type/Gearbox/Torque	5		20	4	Direct/ 2 stg planetary/ 20kNm	2.83	11.31	Regen/ 1 stg cylcoid/20 kNm	2.83	11.31	Regen/ 1 stg cylcoid/20 kNm	2.83	11.31	Direct-hydraulic/radial piston moto/ 25kNm	4.63	18.54	Direct/4 stg planetary/17.4kNm	1.89	7.55
Bearing Lubrication System	5		15	3	Grease	4	12.00	Recirculated forced oil	3	9.00	Recirculated forced oil	3	9.00	single pass oil	5	15.00	single pass oil	5	15.00
Bowl Design	5		5	1	CC Duplex, 10 deg, wear strips	3	3.00	CS, 10 deg, grooves	2	2.00	CC Duplex, 11 deg, grooves	3	3.00	CC Duplex, 15 deg, strips	4	4.00	CC Duplex, 15 deg, grooves	3	3.00
Conveyor Design	5		5	1	open, progressive	3	3.00	open, progressive	3	3.00	open, progressive	3	3.00	open, constant	3	3.00	open, progressive	3	3.00
Special Features	5		5	1	power plates, direct torque measurement	2	2.00	None	0	0.00	None	0	0.00	solids evac stationary bowl, reverse rotation possible, direct torque measurement	3	3.00	None	0	0.00
Subtotal for Category			100	20			48.18			69.26			53.23			77.88			56.44
Performance		20																	
Power Consumption (kW)	5		40	8	67	3.48	27.83	115	1.22	9.80	72	3.24	25.95	67	3.48	27.83	65	3.57	28.58
Cake Solids (%)	5		60	12	28%	3	36.00	28%	3	36.00	28%	3	36.00	28%	3	36.00	28%	3	36.00
Polymer Consumption (active lb/ton)	5		0	0	30	3.45	0.00	32	1.21	0.00	30	3.45	0.00	30	3.45	0.00	30	3.45	0.00
Centrate Quality	5		0	0			0.00			0.00			0.00			0.00			0.00
Subtotal for Category			100	20			63.83			45.80			61.95			63.83			64.58
Installation		15																	
Structural Considerations	5		30	4.5	minor	4	18.00	None required	5	22.50	new support beams, new chutes	3	13.50	no support issues, new chutes	4	18.00	new support beams, new chutes	3	13.50
Mechanical Considerations	5		30	4.5	feed at opp end, new chute transition fittings	2	9.00	None required	5	22.50	feed same end, new chute transition fittings	4	18.00	feed opposite end, but piping included on skid, new chute transition fittings	3	13.50	feed opposite end, new chute transition fittings	2	9.00
Construction Duration	5		20	3	Installation estimate 4 weeks for 3 machines. Estimated 18 month total duration.	5	15.00	Long lead on first unit. Installation estimate 4 weeks for 3 machines. Estimated 24 month total duration.	4	12.00	Structural modifications required. Installation estimate 8 weeks for 3 machines. Estimated 24 month total duration.	3	9.00	Long lead on first unit. Installation estimate 4 weeks for 3 machines. Estimated 24 month total duration.	4	12.00	Structural modifications required. Installation estimate 8 weeks for 3 machines. Estimated 24 month total duration.	3	9.00
Delivery Time	5		20	3	First unit in approximately 9 months (includes submittals). 2 units per week thereafter.	4	12.00	First unit in 12 months (includes submittals). 2 Units per month thereafter	2	6.00	First two units in 10 months (includes submittals), 2 - 4 units per month thereafter	3	9.00	First unit in 12 months (includes submittals). 2 Units per month thereafter	2	6.00	First two units in 8-10 months (includes submittals). 2 units each week thereafter	4	12.00
Subtotal for Category			100	15			54.00			63.00			49.50			49.50			43.50
Operations and Maintenance		25																	
Service Staff	5		15	3.75	7 field/ 30 in VA	3.25	12.19	30	3	11.25	30	3	11.25	x	2	7.50	22 Northvale/ 100 cust service	5	18.75
Major Parts Stock, Repair, Overhaul Location	5		15	3.75	Chesapeake, VA (Approximately 350 miles)	3.39	12.72	Scott Depot, WV (Approximately 560 miles)	2.71	10.17	Scott Depot, WV (Approximately 560 miles)	2.71	10.17	Wisconson (Approximately 860 miles)	1.74	6.52	Northvale (Bergen County), NJ (Approximately 25 miles)	4.45	16.67
Gearbox Overhaul Frequency	5		20	5	20000 hr	4.51	22.54	12000 hr	2.10	10.48	12000 hr	2.10	10.48	15000 hr	3.00	15.00	16000 hr	3.30	16.51
Bearing Lubrication System	5		15	3.75	auto greaser, 1 qt	2	7.50	forced oil, large reservoir	3	11.25	forced oil, large reservoir	3	11.25	single pass oil, 1 qt	4	15.00	single pass oil, 1 qt	4	15.00
Weight of bowl&scroll/Weight of Gearbox	5		10	2.5	4400/660 lb	4	10.00	5500/993 lb	2	5.00	7100/993	3	7.50	8050/375 lb	5	12.50	??	1	2.50
Reserved	5		0	0			0.00			0.00			0.00			0.00			0.00
Years model has been Manufactured	5		25	6.25	10	4.21	26.29	5	2.84	17.72	7	3.38	21.15	10	3.11	19.44	0	1.46	9.15
Subtotal for Category			100	25			91.24			65.87			71.79			75.96			78.58
Cost		20																	
Centrifuge Budget Cost	5		15	3		2.83	8.49		1.60	4.80		2.75	8.26		4.29	12.88		3.52	10.57
Estimated Facility Upgrade Capital Cost	5		20	4	$40,022,000	2.76	11.02	$42,779,000	1.74	6.95	$40,393,000	2.62	10.48	$35,567,000	4.40	17.61	$38,048,000	3.49	13.94
Estimated Annual Power/Chemical Cost	5		10	2	$4,024,000	3.47	6.94	$4,390,100	1.22	2.43	$4,050,400	3.31	6.62	$4,024,000	3.47	6.94	$4,013,400	3.54	7.07
Estimated Cake Disposal Cost	5		30	6	$18,466,000	3	18.00	$18,466,000	3	18.00	$18,466,000	3	18.00	$18,466,000	3	18.00	$18,466,000	3	18.00
Estimated Payback Period	5		25	5	16.2	3.43	17.14	23.0	1.32	6.62	17.7	2.96	14.79	14.5	3.94	19.68	16.4	3.36	16.78
Subtotal for Category			100	20			61.60			38.80			58.14			75.11			66.36
Total Score		100		100			318.84			282.72			294.62			342.29			309.47