Golder Associates Ltd.

2390 Argentia Road
Mississauga, Ontario, Canada L5N 5Z7
Telephone: (905) 567-4444
Fax: (905) 567-6561

REPORT ON

WATER CONSUMPTION STUDY

Submitted to:

Ontario Stone, Sand & Gravel Association
365 Brunel Road, Unit 2
Mississauga, Ontario, Canada
L4Z 1Z5

DISTRIBUTION:

5 Copies - OSSGA
2 Copies - Golder Associates Ltd.

August 2006 04-1112-059

EXECUTIVE SUMMARY

Background

The Ontario Ministry of Environment (MOE) is committed to implementing a wide range of measures designed to ensure the safety of Ontario's drinking water supplies and the sustainability of aquatic ecosystems. These include recent and ongoing changes in the Ontario legislative framework, such as an overhaul to the Permit To Take Water (PTTW) process, Source Water Protection initiatives, and Bill 133 – Environmental Enforcement Statute (water quality). The MOE is also currently promoting fees for water takings.

In reviewing water taking permits in the Province, the MOE has noted that the aggregate industry appears to have the third largest permitted volume of water taking in the Province, exceeded only by the power industry (e.g., dams/reservoirs, cooling water) and municipalities (e.g., drinking water sources). While it is generally understood that PTTWs do not reflect actual water taking quantities, no reliable estimate of actual water taken by the aggregate industry has been available to date. Also, the Ontario Stone, Sand & Gravel Association (OSSGA) believes it is important to differentiate the actual water taking quantities into "handled water" and "consumed water" quantities, and therefore commissioned the following study.

The Study

A team of hydrologists, hydrogeologists and materials engineers at Golder Associates Ltd. (Golder) were retained by the OSSGA to conduct an evaluation of water use at four sites considered as representative of typical aggregate operations in Ontario. The four sites selected by the OSSGA consisted of an above water table pit with aggregate washing, a below water table pit with aggregate washing, a partially below water table quarry with aggregate washing and a below water table quarry without aggregate washing.

The study was conducted to quantify typical "handled" and "consumed" volumes of water in aggregate production operations. A key component of this evaluation was the collection of aggregate material samples for laboratory determination of residual water content to assess quantities of water shipped off site with the product. Site operators provided valuable information relating to quantities of various aggregate products produced, estimates of water quantities used in dust control operations and records of water quantities pumped. Average annual site specific precipitation volumes were determined to provide a context for the magnitude of the water handled and consumed.

Water Handling

Aggregate washing operations are one of the primary water handling activities on a typical aggregate site. Also, in quarries below the water table where dewatering is required to maintain dry working conditions, water is removed from the site with discharge to adjacent surface water drainage features. Water is also used in aggregate operations for dust control on haul roads and, as required in the process to control fugitive dust.

With regard to aggregate washing, water is taken from a freshwater pond for supply of a wash plant to remove fines from the aggregate. The water carrying the fines is directed through a series of ponds where the fines settle out, and the clean water is then recycled through the wash plant. Some wash water is retained within the washed aggregate that is subsequently stockpiled and shipped off site.

Quarries are typically dewatered to maintain dry working conditions. A significant portion of the pumped water originates from direct precipitation into the quarry with the balance derived from groundwater seepage and off-site storm water inflow. This water is stored onsite to allow settling of fines and then discharged to adjacent surface waters with some water recycled through wash plants where present.

Water Consumption

The primary pathways for water loss from a site are considered to be: 1) retained moisture on aggregate product that is shipped from the site, 2) water applied directly on haul roads and stockpiles for dust control, which typically evaporates before being able to infiltrate into the ground, and 3) wash water evaporation from stockpiled materials. The majority of consumed water originates onsite and is accounted for by water takings (i.e., PTTW), but will also include precipitation that falls directly onto stockpiled materials and natural in-situ water that is then evaporated or shipped off site.

Conclusions

The key findings developed from the assessment of water use at the study sites are as follows:

1) Actual water taking quantities relative to the PTTW maximum permitted amount ranged from 1% to 37% for the studied sites. This demonstrates that the PTTW maximum permitted amount is not a reliable estimate of water “taken” at an individual aggregate site, even though the higher PTTW maximum permitted amounts are necessary to handle peak water taking that may occur from time to time.

2) Consumed water (water not returned to the local surface water and/or groundwater system) was found to be a minor portion (1% to 12% at the study sites) of the PTTW maximum permitted amount and thus the PTTW maximum permitted amount should not be used to reflect the amount of consumed water. Consideration should be given to the purpose of the PTTW (wash plant make-up, wash plant recirculation, quarry dewatering) in order to interpret the representative fraction of consumed water at an individual site.

3) Depending on the studied site, consumed water was only 2% to 8% of the handled water; i.e., water consumed in aggregate operations is only a small portion of the handled water. It can therefore be concluded that the sites that were studied, and the aggregate industry in general, are primarily handlers of water, with the bulk of handled water returned to the local hydrologic system (dewatering and infiltration) or recycled repeatedly through the wash plant.

4) Consumed water was 12% or less of the amount of precipitation which falls on the site for the studied cases. Consumed water was 4% to 10% of site dewatering for studied cases with site surface water discharges (quarries). It can therefore be concluded that the consumed water at the studied sites is a minor component of the site's surplus water.

5) Between 50% to 100% of the water shipped off-site with aggregate products was attributed to natural in-situ water. The remainder was wash water and/or rainwater that adheres to the product.

TABLE OF CONTENTS

TABLE OF CONTENTS cont'd

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by the Ontario Stone, Sand & Gravel Association (OSSGA) to conduct a Water Consumption Study for four aggregate operations. The Terms of Reference for the study are provided in Appendix A. The four sites selected by the OSSGA include a pit above the water table with washing operations, a pit below the water table with washing operations, a quarry partially below the water table with washing operations, and a quarry below the water table without washing operations.

1.1 Background

There has been an increasing focus on water management and protection in the Province of Ontario, mainly through the Ministry of the Environment (MOE), but also through Conservation Authorities and other regulatory agencies. This was initially realised through province wide groundwater studies. Recent and ongoing changes in the Ontario legislative framework, such as an overhaul to the Permit To Take Water (PTTW) program, Source Water Protection initiatives, and Bill 133 – Environmental Enforcement Statute (water quality), has continued and strengthened the focus on water protection and management.

The Final Water Taking and Transfer Regulation (O.Reg. 378/04) has included amendments that: requires the holder of a Permit To Take Water (PTTW) to record the volumes of water taken daily; considers water use, water availability and whether the full permitted quantities are actually required; encourages water conservation; and highlights the need to protect the natural functions of the watershed. In addition, the MOE introduced the idea of charging fees for water taking in its 2004 Source Water Protection White Paper (White Paper) and Bill 43.

Through this process, the MOE categorised the PTTW quantities by industry and identified the major industries involved in water taking in Ontario. The PTTW records show that up to 770 billion L/year are permitted to be taken by 235 permits granted to the aggregate industry. This is the third largest amount of permitted water taking in the province following only the power industry (e.g., dams/reservoirs, cooling water) and municipalities (e.g., drinking water). Water used by other industries, such as bottled water, agriculture and golf courses, has also been highlighted by the MOE. However, the permitted withdrawal volume for the aggregate producers is notably higher by comparison (i.e., water bottlers are currently permitted for 7.5 billion L/year) due to double handling/recycling of water, dewatering, etc.

The OSSGA recognises that, unlike many of the other major industries, aggregate producers do not "consume" their permitted water taking volume. The PTTW permitted water taking volume represents a peak or ultimate demand, and is not the actual/typical amount of water taken by the industry in its processes. Also, the actual water taking amount is not the amount of water that is consumed and not returned to local hydrological systems. The aggregate producers would be more accurately described as "handlers of water", not "consumers of water".

To respond to the MOE comments, The OSSGA provided feedback to the MOE on the draft Source Water Protection Plan White Paper outlining how the industry is not a major consumer but rather a handler of water. The OSSGA recognises that it is important to be involved in the ongoing changes in the Ontario legislative framework that may affect licensing of sites, obtaining water taking and discharge permits, and result in charging for water taking. To this end, the OSSGA has proactively commissioned this Water Consumption Study.

It should be noted that licence applications under the Aggregate Resources Act are required to complete a detailed hydrogeological assessment of pit and quarry operations to ensure off-site impacts are minimal.

1.2 Purpose and Objectives

This report provides the details and results of the OSSGA's Water Consumption Study. The study was conducted to quantify typical "handled" and "consumed" volumes of water in aggregate production operations. This information will provide defensible data to educate the general public and support comments to regulatory agencies regarding the ongoing changes to the Ontario legislative framework involving water protection and management.

Project specific objectives in support of development of the Water Consumption Study were to:

- Document and define water usage and related aggregate production processes;
- Measure water content properties for a range of aggregate products;
- Quantify water handled and water consumed in typical aggregate production processes; and
- Calculate site precipitation volumes to provide context for the magnitude of the water handled and water consumed quantities.

The study includes a strong focus on the water content of the aggregate products which may represent a pathway for water "consumption" or "export" from the site.

1.3 Overview of Aggregate Industry Water Related Processes

Prior to presentation of the study results, the following important background concepts have been presented in the next sections:

- Definitions of terms to define the types of water usage related to aggregate operations (e.g., handled water and consumed water);
- Water processes related to aggregate operations such as aggregate washing, dust control and dewatering/site discharge; and
- PTTW considerations.

1.3.1 Definitions

Maximum Permitted Amount: The maximum (daily) amount that can be pumped, according to the Permit to Take Water (PTTW).

Handled Water: The total amount of water which is moved (pumped or hauled with aggregate) at a site to conduct aggregate operations. Examples include quarry dewatering (comprised of precipitation, upstream runoff, groundwater seepage), water applied for dust control, water used for aggregate washing (make-up water and recycled wash plant water) and water contained in stockpiles and shipped aggregate products.

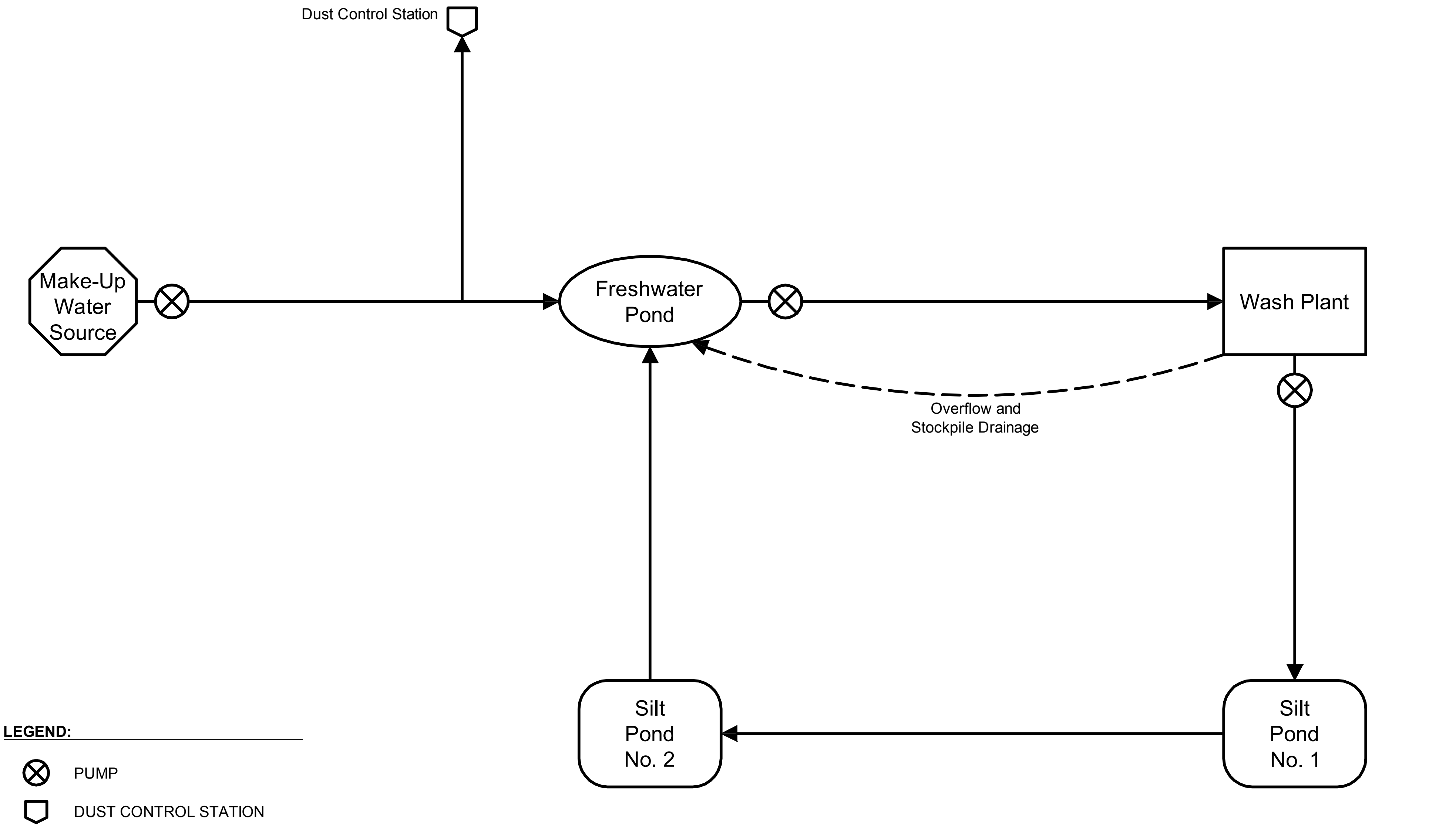
Consumed Water: The portion of handled water not returned to the local surface water and/or groundwater system. Examples include water applied for dust control, water evaporated from aggregate stockpiles and water shipped off site with final product. Consumed water is a subset of handled water.

1.3.2 Aggregate Washing

Water handling for aggregate washing is typically conducted in a closed loop system. Figure 1 is a schematic illustrating a typical aggregate washing water handling process.

Although the handling of aggregate wash water is considered a closed loop system, it must be augmented with make-up water to account for losses due to pond evaporation and leakage, water adhered to the washed product and water taken for dust control. In the case of an above groundwater table pit or quarry, the make-up water source may be a surface water feature (e.g., a river or lake), a groundwater well, or a pond excavated below the groundwater table. In the case of a below groundwater table pit or quarry, the make-up water source is typically the pond created by the portion of the pit excavated below the groundwater table, or the quarry sump. In some cases, the quarry sump or pit groundwater pond may serve as the Freshwater Pond.

Aggregate washing does not usually occur during the winter months.



Golder Associates
Mississauga, Ontario, Canada

SCALE	N.T.S.	TITLE	**SCHEMATIC OF TYPICAL AGGREGATE WASHING SYSTEM**
DATE	JULY 2006		
DESIGN	KD		
CAD	KD		
CHECK	JS		WATER CONSUMPTION STUDY
REVIEW		FIGURE	1

FILE No. 041112059BC01.dwg

PROJECT No. 04-1112-059 REV. C

1.3.3 Dust Control

Some sites use water for dust control as required. Dust control water may be withdrawn at any point in the aggregate washing system (wash plant recirculation water or make-up water), dewatering/site discharge system or a separate water source where the total suspended sediment levels are low. Dust control typically starts in April and increases in frequency until June. Dust control is typically terminated near the end of November.

1.3.4 Dewatering and Site Discharge

In quarries below the groundwater table, pumping is typically required to maintain the working area in a dry state by moving the inflowing precipitation, ground water and off-site surface water from the quarry floor to the surrounding ground surface, and eventually off site. Pits below the groundwater table rarely dewater the excavation area as the soil is excavated subaqueously using a dragline. It should be noted that quarries and pits above the groundwater table may have a gravity discharge of surplus water which does not infiltrate within the site.

1.3.5 PTTW Considerations

There are typically three types of water takings which require a PTTW:

- Wash Plant Recirculation Water
- Make-Up Water
- Dewatering

Water for dust control is typically taken from a PTTW source for either the aggregate washing (wash plant recirculation water or make-up water) or dewatering. Also, some small to medium sized sites can control dust using less than 50,000 L/day (the PTTW threshold limit for requiring a PTTW).

It is important to understand the site water handling processes since they control the PTTW water quantity. Several cases are presented below to illustrate this point.

1) Wash Plant Recirculation: A PTTW may be required for withdrawal of water from the Freshwater Pond to the Wash Plant. In this case the PTTW quantity largely represents the same volume of water re-circulated in a closed loop system.

2) Make-Up Water: In a pit or quarry above the groundwater table, a PTTW would typically be required for the make-up water source to the wash plant, maintenance shops, etc. Some of the make-up water is returned to the environment through pond leakage into the ground.

3) Dewatering: In quarries below the ground water table with no washing operations, the PTTW quantity may represent the quantity of water discharged from the quarry floor. Note that pits below the groundwater table rarely dewater the excavation area as material is excavated subaqueously using a dragline.

It should be noted that licence applications under the Aggregate Resources Act are required to complete a detailed hydrogeological assessment of pit and quarry operations to ensure off-site impacts are minimal.

2.0 METHODOLOGY

2.1 Overview

The major tasks for the Water Consumption Study were:

1) Collect and review background data;
2) Visit sites and inspect how water is managed;
3) Assess aggregate water content and water retention properties;
4) Quantify consumed water for different quarry/pit types;
5) Quantify handled water for different quarry/pit types;
6) Calculate site precipitation volumes to provide context for the magnitude of the water handled and water consumed quantities.

Details of the study methodology are provided in Appendix B.

The available site specific flow rates, production data and aggregate properties were utilized to quantify water handled and water consumed at each site. Site specific precipitation volumes were then determined to provide context for the magnitude of the water handled and water consumed quantities. Details of the assessments of aggregate properties, consumed water, handled water, and precipitation volumes are provided in Sections 3, 4, 5 and 6, respectively.

2.2 Assessed Sites

This Water Consumption Study examined the following different types of aggregate operations to provide data for a representative cross-section of typical operational methods and products. The sites were selected by the OSSGA[1].

- One pit above the water table (with aggregate washing and dust control) – over 80% fine to medium sand products, minimal uniform gravel products;
- One pit below the water table (with aggregate washing and dust control) – 60% uniform gravel products and sand/gravel mix products, 40% medium sand products;
- One quarry partially below the water table (with aggregate washing, dust control operations and dewatering) sand, sand & gravel mixes and uniform gravel products; and
- One quarry below the water table (with dewatering only, low groundwater inflow) - mainly crusher run and uniform gravel products.

One of the OSSGA's site selection criteria was to provide a site that is reasonably typical of each operating condition e.g., pit below water table, pit above water table, etc.

[1] The identities and locations of the sites are confidential to preserve proprietary information regarding material specifications and quantities.

3.0 ASSESSMENT OF AGGREGATE PROPERTIES

It was determined early in the study that a key component in calculating water consumption for a site is the quantification of the water content (water trapped within the interstitial pores and/or adhered to the particle surfaces of the stockpiled aggregate products) in aggregate stockpiles. It was important to assess the water content in stockpiles containing both freshly washed aggregate, and stockpiles from which aggregate was removed and shipped off site. This water represents a primary component of water "consumption" or "export" from the site (stockpile evaporation and water shipped off-site with aggregate product).

3.1 Overview

Aggregate products and sediment laden wash water were collected during the site visit and sent to Golder's laboratory for analyses. The following properties were quantified based on the laboratory analyses or literature values for similar materials:

- in-situ natural water content of undisturbed source material (samples taken from excavation face or surge pile adjacent to screen plant);
- water content of screened/washed and screened/unwashed finished products (samples taken from product shipping piles);
- maximum potential residual (free drained) water content of screened/washed and screened/unwashed product after completion of free drainage in a stockpile with no evaporative losses (samples taken from product shipping stockpiles and tested using a Tempe Cell apparatus);
- grain size distribution of some products (samples taken from product shipping piles);
- grain size distribution of sediment in sediment laden wash water discharged to the sediment pond (i.e., the sediment that accumulates in the sediment pond); and
- maximum potential residual (free drained) water content of sediment pond fines (inferred from literature values for soils having a grain size distribution similar to that of the wash water sediment).

Details of the methodology to quantify these properties are provided in Appendix B.

3.2 Results

Table 1 provides the aggregate property values for the aggregate products present at the time of sampling. Figures 2 to 5 present the measured shipping water contents for the finished products at each site. Each site is discussed individually in the following sub-sections.

3.2.1 Pit Above Water Table/With Washing

The Pit Above Water Table produces mostly sand products. The products stockpiled at the site at the time of the site visit, that were sampled for water content are as follows:

<u>Sand/Gravel Mixes</u>

- Granular ‘A’ (Unwashed)
- Granular ‘B’ (Unwashed)

<u>Fine to Coarse Sand Mixes</u>

- Concrete Sand (Washed)
- Asphalt Sand HL-1, HL-3 (Washed)
- Masonry Sand (Washed)

<u>Uniform Fine Sand</u>

- Cable Sand (Washed)

<u>Fine Sand & Silt</u>

- Septic Sand (Washed)

The age of each product stockpile was approximately one week, except for the Granular B product which had been stockpiled for only 1 hour prior to sampling.

As shown in Table 1 and Figure 2, the measured water contents differ between products. The highest water contents (up to 16% by total weight) were obtained for the fine sand and fine sand/silt products (i.e., Cable Sand and Septic Sand, respectively). The lowest water contents (as low as 3.4%) were obtained for the sand/gravel products (i.e., Granular ‘A’ and Granular ‘B’). The higher water contents obtained for the fine sand and fine sand/silt products relate primarily to incomplete drainage of wash water from the stockpiles at the time of sampling. Both sand/gravel products are unwashed and therefore have relatively low water contents reflecting the natural, unsaturated (i.e., above water table) source material.

All of the fine to coarse sand products were washed and were stockpiled for a similar length of time as the uniform fine sand and the sand/silt products (i.e., approximately one week). Nevertheless, the fine to coarse sand products gave significantly lower water contents (e.g., 5.3% for Concrete Sand versus 16% for Septic Sand). The difference here relates in part to the larger particle sizes and hence smaller specific surface area (m^2/gm) of the Concrete Sand. The lower specific surface area for the Concrete Sand means that there is less particle surface area for adsorption/retention of the wash water, hence the lower water content. Another reason for the lower water content of the Concrete Sand compared to the Septic Sand, is that the Concrete Sand is more permeable and hence drains faster in a stockpile.

The maximum free drained water content (i.e., the water content remaining after complete gravity drainage of unbound “free” porewater from the stockpile under zero evaporative loss) is fairly similar for all products (i.e., 3% to 4% range), except for the Septic Sand. The Septic Sand product is estimated to have a maximum free drained water content of 10% based on literature values for soils of comparable grain size distribution. For all the washed products, the measured water content was much higher than the maximum free drained water content, indicating that the approximately one week old stockpiles were still draining at the time of sampling. In comparison, the unwashed sand/gravel products gave water content values essentially equal to the maximum free drained water content, indicating that the insitu source material (taken from above the water table) is at or close to the maximum free drained water content.

3.2.2 Pit Below Water Table/With Washing

The Pit Below Water Table produces uniform gravel, sand/gravel and fine to coarse sand products. The products stockpiled at the site at the time of the site visit, that were sampled for water content are as follows:

Uniform Gravels

- ¾" Concrete Stone (Washed)

Sand/Gravel Mixes

- $^{3}/_{8}$" Concrete Stone (Washed)
- ¼" Concrete Stone (Washed)

Fine to Coarse Sand Mixes

- Concrete Sand (Washed)

As shown in Table 1 and Figure 3, the measured water contents for the products (% total weight basis) range from 2.5% for ¾" Concrete Stone to 4.9% for ¼" Concrete Stone. The age of the stockpiles at the time of the sampling ranged from 2 to 3 weeks, except for the ¼" Concrete Stone which had been stockpiled for less than one week, which explains its higher water content compared to the other products sampled.

The maximum free drained water content values for the different products are similar (values ranging from 1.9% to 2.1% (total weight basis). For each product, the measured water contents of the stockpile samples were greater than the maximum free drained water content, indicating that the stockpiles were still draining, although the uniform gravel product ($^{3}/_{4}$" Concrete Stone) which had been stockpiled for approximately 3 weeks at the time of the sampling was at a water content very close to the maximum free drained value (i.e 2.5% versus 1.9%, respectively), indicating that drainage of the stockpile was nearly complete. The ¼" Concrete Stone which had been stockpiled for the least amount of time (less than one week), gave the greatest difference between measured water content and maximum free drained water content.

3.2.3 Quarry Partly Below Water Table/With Washing

The Quarry Below Water Table/with Washing, produces uniform gravel, sand/gravel mixes and sand products. The products stockpiled at the site at the time of the site visit, that were sampled for water content are as follows:

<u>Uniform Gravels</u>

- ¾" Clear Stone (Washed)

<u>Sand & Gravel Mixes</u>

- Granular 'A' (Unwashed)
- Screenings (Unwashed)

<u>Fine to Coarse Sand Mixes</u>

- Asphalt Sand (Washed)

<u>Fine Sand & Silt</u>

- Agricultural Lime (Wash Fines Excavated From Sedimentation Pond)

As shown in Table 1 and Figure 4, the measured water contents of the stockpile samples vary widely between the different products. The highest water contents (up to 9.8% total weight basis) were obtained for the asphalt sand and agricultural lime products (i.e., sand and sand/silt mixes, respectively). The lowest water content (2.0% total weight basis) was obtained for the uniform ¾" clear stone product. The relatively high water content for the washed asphalt sand can be explained by the fact that it had been stockpiled for a very short period of time (<1 day) at the time of sampling and therefore was still in the process of draining out residual wash water. The high water content for the agricultural lime, even after 6 months of stockpiling, relates to the fine grained nature of this product which imparts a high moisture retention capacity.

Except for the washed asphalt sand which had been stockpiled for less than one day, all of the sampled products were at a water content below the maximum free drained water content, indicating that they were completely drained of residual free (unbound) porewater.

3.2.4 Quarry Below Water Table/Without Washing

The Quarry Below Water Table/Without Washing produces uniform gravel and sand/gravel mixes. The products stockpiled at the site at the time of the site visit, that were sampled for water content are as follows:

<u>Uniform Gravels</u>

- ¾" Clear Stone
- HL-6 Stone

Sand & Gravel Mixes

- 2” Minus Crusher Run
- ¾” Minus Crusher Run
- Screenings

As shown in Table 1 and Figure 5, the measured water contents of the stockpile samples range from a low of 0.8% (total weight basis) for the uniform ¾” clear stone to as high as 6.5% (total weight basis) for the screenings. The relatively high water content for the screenings relates to the 15% fines content (i.e., silt/clay size content) of this product which imparts a high moisture retention capacity.

Except for the screenings, all products were at a water content equal to or less than the maximum free drained water content indicating that they were completely drained of residual free (unbound) porewater. For the screenings the measured water content of 6.5% (total weight basis) was higher than the maximum free drained water content of 3.7%, possibly due to infiltration and incomplete drainage of rainwater and snow melt during the 8 months that this product had been stockpiled.

TABLE 1
Sampled Products - Description And Water Content Results

Sample Identification	Product Description[1]	Fines Content (< 75 μm)[2]	Approximate Age of Stockpile Sampled[3]	Measured Water Content of Sample @ 110°C (% by dry wt)[4]	Measured Water Content of Sample @ 110°C (% by total wt)[5]	Potential Maximum Retainable Water Content Upon Completion of Free Drainage in Stockpile "Field Capacity" (% by total wt)[6]
Pit /Above Water Table / With Washing						
Granular A Sa.1 (Unwashed) Granular A Sa.2 (Unwashed)	Fine gravel with medium to coarse sand, trace to some fine	8% (estimated)	1 week	4.1% 3.5%	3.9% 3.4%	3.9% Tempe Cell
Granular "B" Sa.1 (4" minus) (Unwashed) Granular "B" Sa.2 (4" minus) (Unwashed)	Fine gravel with fine to coarse sand. Trace silt.	≤ 10% (OPSS std)	<1 hr	4.3% 4.4%	4.1% 4.2%	4.2% Estimated
Asphalt Sand Sa.1 HL-1 & HL-3 (washed) Asphalt Sand Sa.2 HL-1 & HL-3 (washed)	Fine to coarse sand	≤ 5% (OPSS std.)	1 week	9.7% 8.8%	8.8% 8.1%	2.6% Tempe Cell
Septic Sand Fill Sa.1 (Washed) Septic Sand Fill Sa.2 (Washed)	Fine sand (minus #50 mesh) (used for septic beds)	40% (measured)	1 week	19.4% 16.4%	16.2% 14.1%	10.0% Estimated
Cable Sand Sa.1 (washed) Cable Sand Sa.2 (washed)	Fine sand	≤10% (supplier std.)	1 week	17.4% 18.8%	14.8% 15.8%	3.2% Tempe Cell
Concrete Sand Sa.1 (washed) Concrete Sand Sa.2 (washed)	Medium sand with trace to some coarse and fine sand	≤ 3% (OPSS std)	1 week	5.6%	5.3%	3.4% Tempe Cell
Masonary Sand Sa.1 (washed) Masonary Sand Sa.2 (washed)	Fine to medium sand	≤ 5% (OPSS std.)	1 week	7.1% 7.4%	6.6% 6.9%	3.4% Estimated
Pit / Below Water Table / With Washing						
Concrete Sand Sa. 1 (washed) Concrete Sand Sa. 2 (washed)	Medium sand with trace to some coarse and fine sand	≤ 3% (OPSS std.)	2 weeks	4.0% 3.6%	3.8% 3.5%	1.9% Tempe Cell
3/4" Concrete Stone Sa.1 (washed) 3/4" Concrete Stone Sa.2 (washed)	Fine gravel with trace sand	≤ 1 % (OPSS std)	3 weeks	2.6% 2.7%	2.5% 2.6%	1.9% Tempe Cell
1/4" Concrete Stone Sa.1 (washed) 1/4" Concrete Stone Sa.2 (washed)	Fine gravel and coarse sand, with some medium sand	≤ 1% (OPSS std.)	< 1 week	5.0% 5.1%	4.8% 4.9%	2.1% Tempe Cell
3/8" Concrete Stone Sa. 1 (washed) 3/8" Concrete Stone Sa. 2 (washed)	Fine gravel with some sand	≤ 1% (OPSS std.)	3 weeks	2.9% 3.4%	2.8% 3.3%	2.0% Estimated
Quarry/Partially Below Water Table/With Washing						
3/4" Clear Stone Sa.1 (washed)	Fine gravel.		3 months	2.0%	2.0%	2.1% Tempe Cell
"Agricultural" Lime Sa.1 "Agricultural" Lime Sa.2	Wash fines excavated from sedimentation pond and stockpiled.	64% (measured)	6 months	9.8% 10.9%	8.9% 9.8%	10.0% Estimated
Granular "A" Sa.1 (Unwashed) Granular "A" Sa.2 (Unwashed)	Fine gravel with medium to coarse sand, trace to some fine	2-8 % (OPSS std.)	2 weeks	3.2% 4.0%	3.1% 3.8%	3.6% Tempe Cell
Manufactured Sand (Asphalt Sand) Sa.1 (washed Manufactured Sand (Asphalt Sand) Sa.2 (washed)	Coarse to fine sand.	≤ 5% (OPSS std)	< 1 day	8.5% 8.4%	7.8% 7.7%	2.5% Tempe Cell
Screenings Sa.1 (unwashed) Screenings Sa.2 (unwashed)	Fine gravel with fine to coarse sand, trace to some silt.	20% (measured)	< 1 day	2.8% 3.4%	2.7% 3.3%	5.4% Tempe Cell
Quarry/Below Water Table/ Without Washing						
3/4 Clear Stone Sa.1 (Unwashed) 3/4 Clear Stone Sa.2 (Unwashed)	Fine gravel.	<1% (measured)	1 month	0.8% 1.0%	0.8% 1.0%	2.0% Estimated
3/4" Minus Crusher Run Sa.1 (Unwashed) 3/4" Minus Crusher Run Sa.1 (Unwashed)	Fine gravel with medium to coarse sand, trace to some fine	11% (measured)	> 6 months	3.9% 4.8%	3.8% 4.6%	4.0% Estimated
2" Minus Crusher Run Sa.1 (Unwashed) 2" Minus Crusher Run Sa.1 (Unwashed)	Coarse to fine gravel with coarse to fine sand. Trace silt.	5% (measured)	1 week	1.7% 1.9%	1.7% 1.9%	3.0% Estimated
Screenings Sa. 1 (Unwashed) Screenings Sa. 2 (Unwashed)	Fine gravel to coarse sand, trace medium and fine sand, some silt.	15% (measured)	8 months	6.9% 7.0%	6.5% 6.5%	3.7% Tempe Cell
HL-6 Stone Sa. 1 (same as HL-8) (Unwashed) HL-6 Stone Sa. 2 (same as HL-8) (Unwashed)	Fine gravel D_{85} = 16 mm	≤ 1.7% Avg. ≤ 1.3%	> 6 months	1.9% 1.8%	1.9% 1.8%	2.0% Estimated

Notes
1 - Product description based on Unified Soils Classification System
2 - Fines refers to silt and clay sized particles of diameter less than 75 mm. "OPSS std." - denotes Ontario Provincial Standard Specification for the product.
3 - Age of stockpile sampled by Golder Associates was provided by site personel.
4 - Measured at Golder Associates Mississauga Laboratory
5 - Water content on a total weight basis = $\frac{w}{1+w}$, where w = water content on a dry weight basis
6 - The potential maximum water content retainable upon completion of free drainage (with no evaporative loss) from an initially saturated state is commonly referred to as the "field capacity water content". Measured values were obtained using a standard Tempe Cell apparatus at 33 kPa, after initial saturation of the sample.

FIGURE 2

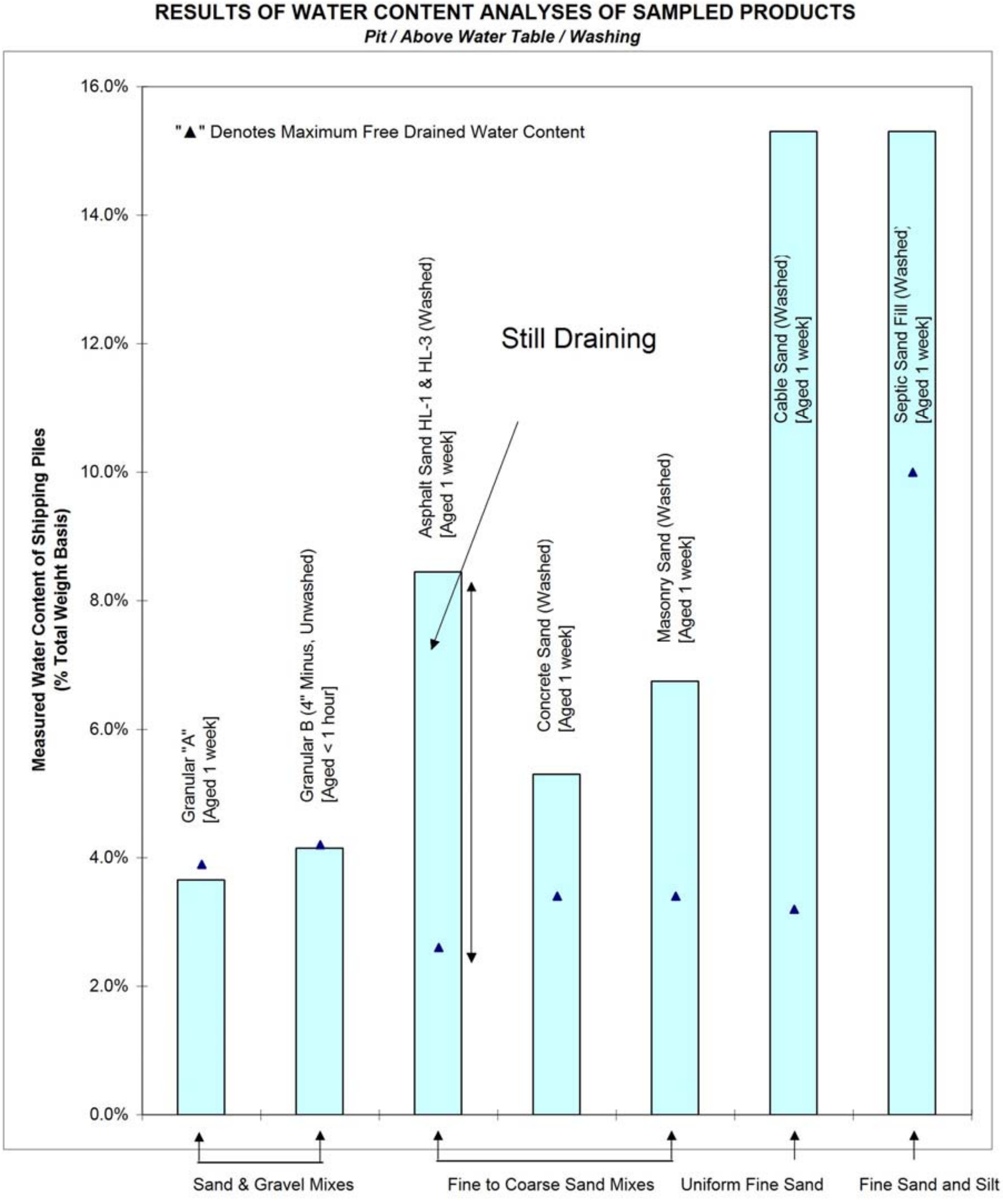

RESULTS OF WATER CONTENT ANALYSES OF SAMPLED PRODUCTS
Pit / Above Water Table / Washing
"▲" Denotes Maximum Free Drained Water Content
Measured Water Content of Shipping Piles (% Total Weight Basis)
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
Granular "A" [Aged 1 week]
Granular B (4" Minus, Unwashed) [Aged < 1 hour]
Asphalt Sand HL-1 & HL-3 (Washed) [Aged 1 week]
Still Draining
Concrete Sand (Washed) [Aged 1 week]
Masonry Sand (Washed) [Aged 1 week]
Cable Sand (Washed) [Aged 1 week]
Septic Sand Fill (Washed) [Aged 1 week]
Sand & Gravel Mixes
Fine to Coarse Sand Mixes
Uniform Fine Sand
Fine Sand and Silt

FIGURE 3

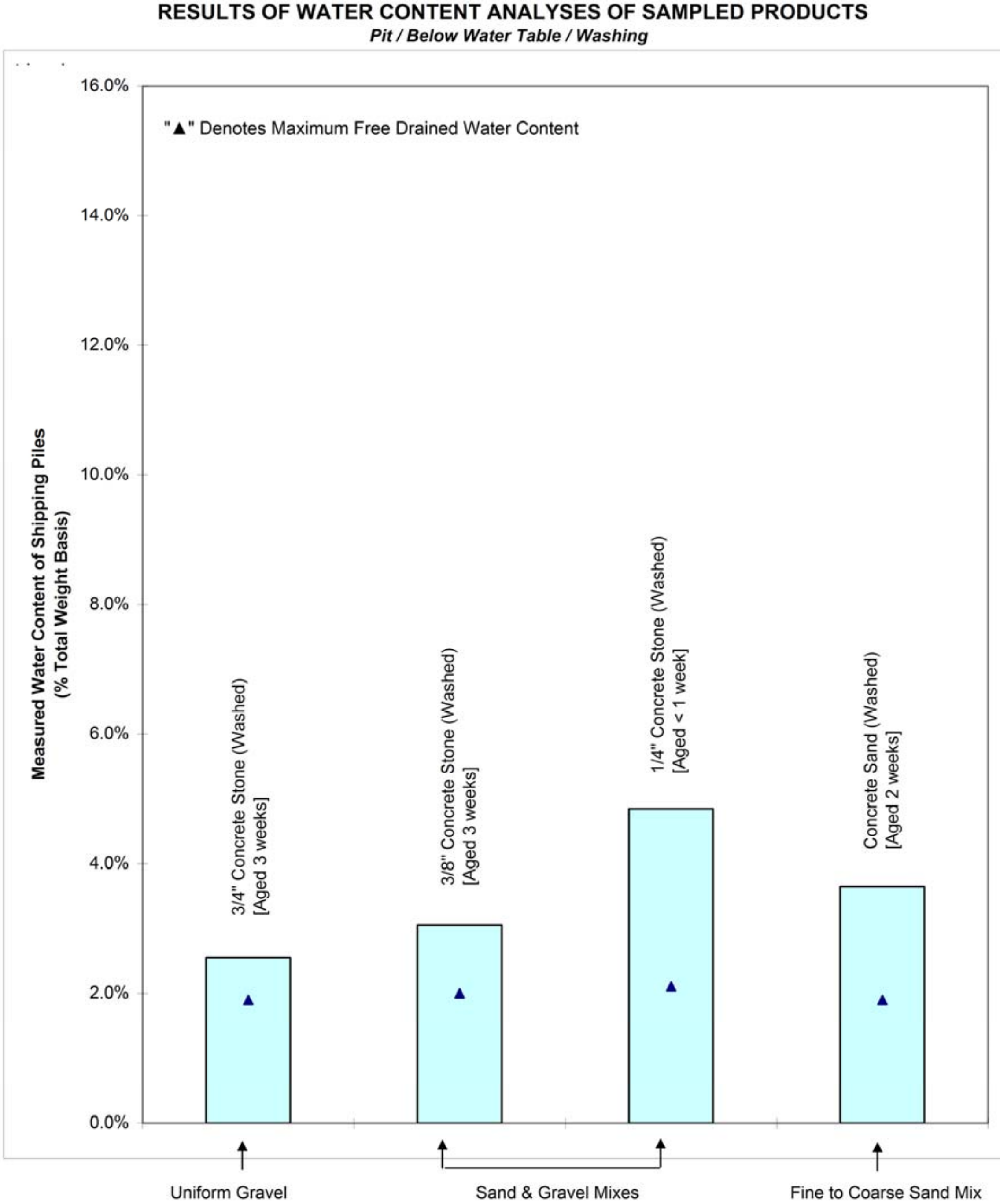

RESULTS OF WATER CONTENT ANALYSES OF SAMPLED PRODUCTS
Pit / Below Water Table / Washing
"▲" Denotes Maximum Free Drained Water Content
Measured Water Content of Shipping Piles (% Total Weight Basis)
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
3/4" Concrete Stone (Washed) [Aged 3 weeks]
3/8" Concrete Stone (Washed) [Aged 3 weeks]
1/4" Concrete Stone (Washed) [Aged < 1 week]
Concrete Sand (Washed) [Aged 2 weeks]
Uniform Gravel
Sand & Gravel Mixes
Fine to Coarse Sand Mix

FIGURE 4

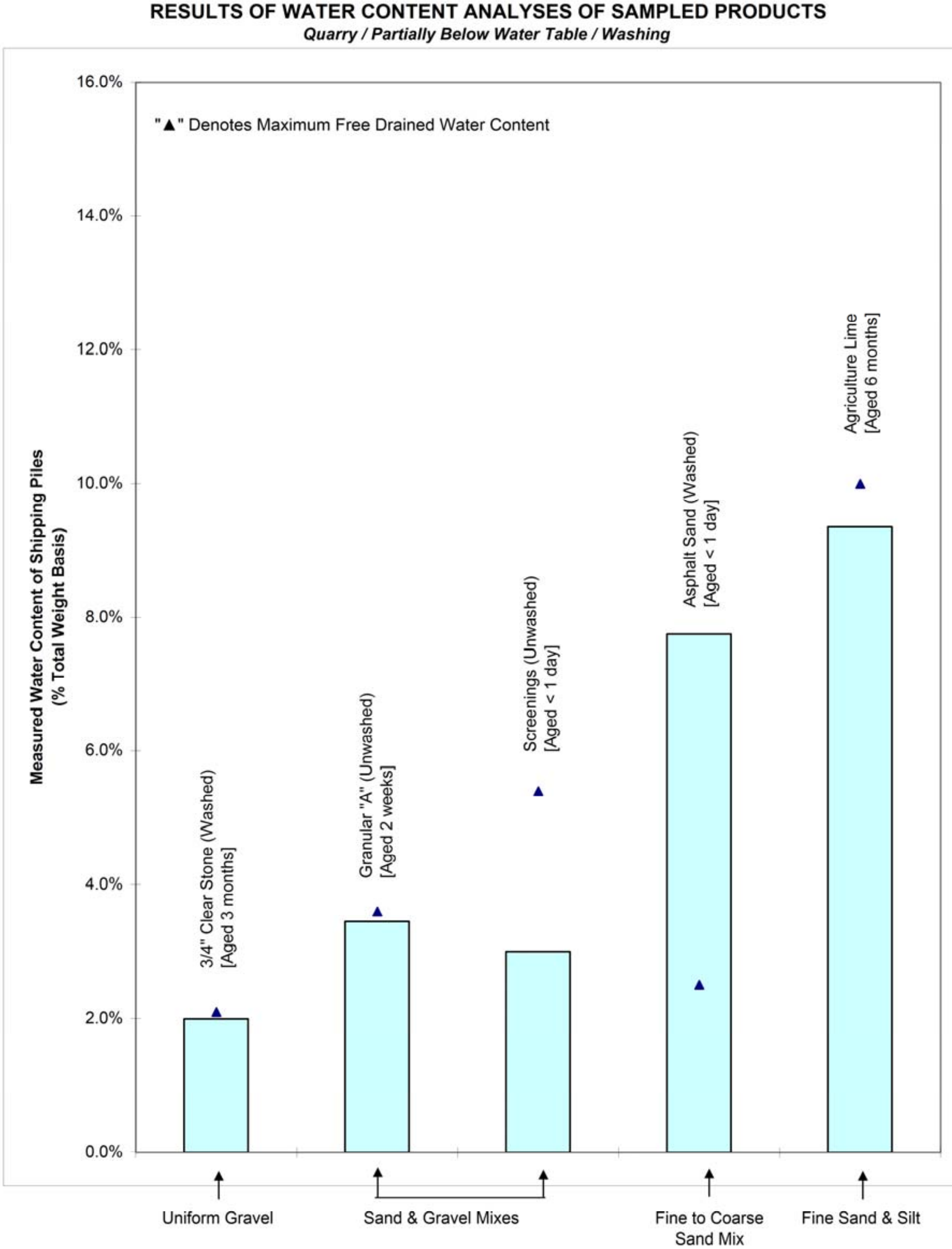
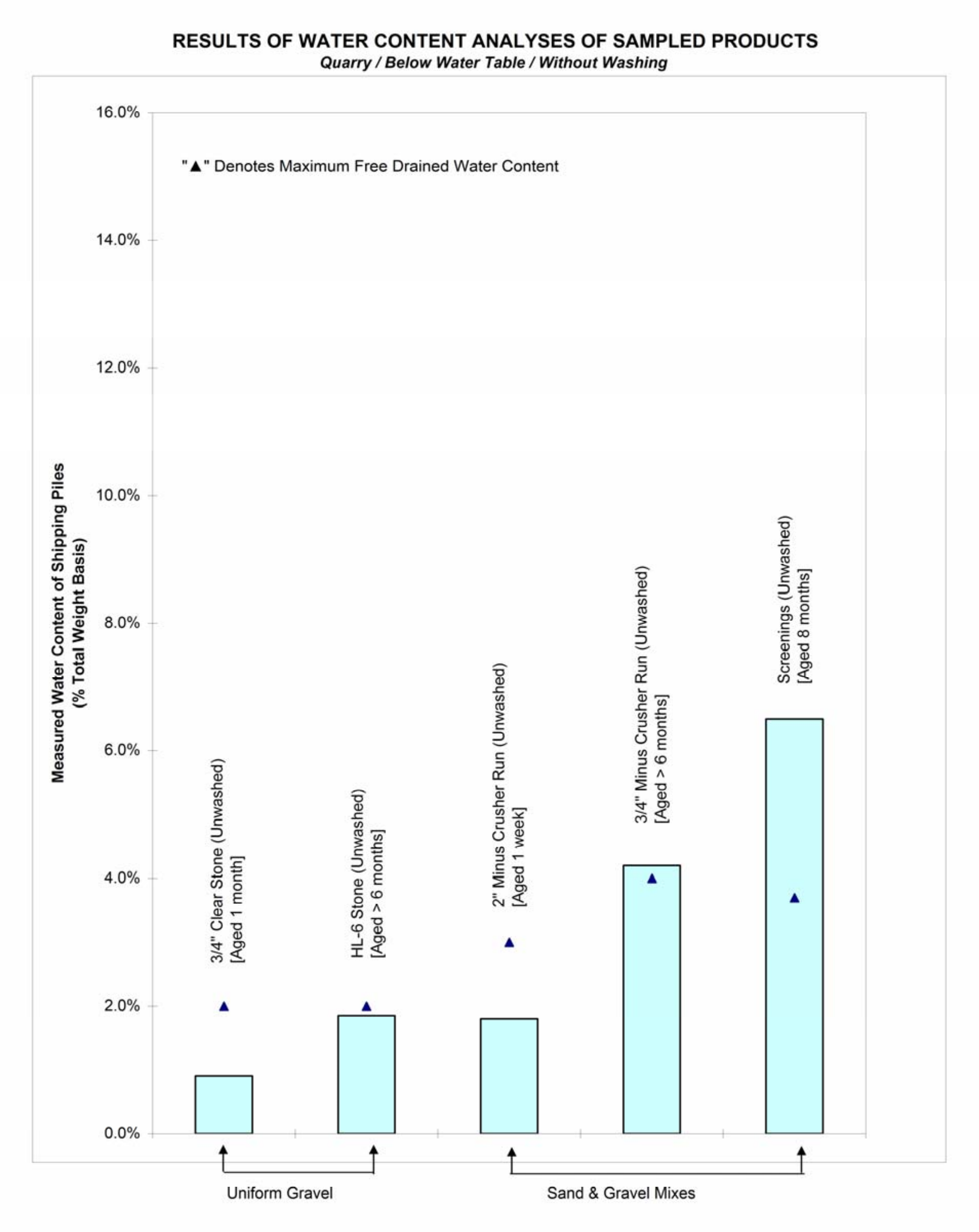

RESULTS OF WATER CONTENT ANALYSES OF SAMPLED PRODUCTS
Quarry / Partially Below Water Table / Washing
"▲" Denotes Maximum Free Drained Water Content
Measured Water Content of Shipping Piles
(% Total Weight Basis)
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
3/4" Clear Stone (Washed)
[Aged 3 months]
Granular "A" (Unwashed)
[Aged 2 weeks]
Screenings (Unwashed)
[Aged < 1 day]
Asphalt Sand (Washed)
[Aged < 1 day]
Agriculture Lime
[Aged 6 months]
Uniform Gravel
Sand & Gravel Mixes
Fine to Coarse
Sand Mix
Fine Sand & Silt

FIGURE 5


RESULTS OF WATER CONTENT ANALYSES OF SAMPLED PRODUCTS
Quarry / Below Water Table / Without Washing
"▲" Denotes Maximum Free Drained Water Content
Measured Water Content of Shipping Piles (% Total Weight Basis)
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
3/4" Clear Stone (Unwashed) [Aged 1 month]
HL-6 Stone (Unwashed) [Aged > 6 months]
2" Minus Crusher Run (Unwashed) [Aged 1 week]
3/4" Minus Crusher Run (Unwashed) [Aged > 6 months]
Screenings (Unwashed) [Aged 8 months]
Uniform Gravel
Sand & Gravel Mixes

3.3 Summary and Aggregate Properties

Table 2 and Figure 6 provide a summary of the water content results grouped by product gradation. The following summarizes the key findings.

Uniform Gravels (e.g., clear stone, concrete stone, asphalt stone)

- maximum residual (free drained) water content ranged from 1.9% to 2.1% by total weight; Golder experience indicates this number may be less than 1% for some products
- shipping pile water content (0.9% to 2.6% by total weight) were typically equal to or less than the maximum residual (free drained) water content i.e., stockpiles were fully drained of free (unbound) porewater
- air can penetrate gravel piles easier than sand piles thereby enhancing evaporation from gravel stockpiles
- shipping pile water content typically approaches maximum residual (free drained) water content in less than one week (based on Golder experience)

Fine to Coarse Sand Mixes (e.g., concrete sand, asphalt sand and masonary sand)

- maximum residual (free drained) water content ranged from 1.9% to 3.4% by total weight
- shipping pile water content (3.7% to 8.5% by total weight) after 1 day to 2 weeks of stockpiling were consistently greater than the maximum residual (free drained) water content i.e., stockpiles were still draining
- shipping pile water content typically approaches maximum residual (free drained) water content after approximately one month (based on this study and Golder experience)
- likely little further reduction in shipping pile water content after one month

Uniform Fine Sand

- only one product sampled (Cable Sand)
- shipping pile water content after one week of stockpiling was 15.3% (total weight basis) which was much higher than the maximum residual (free drained) water content of 3.2% i.e., stockpile was still draining

Sand & Gravel Mixes (e.g. crusher run, screenings, 1/4”&3/8” concrete stone, Granular ‘A’&‘B’)

- some sand and gravel products are unwashed
- maximum residual (free drained) water content ranged from 2.0% to 2.1% by total weight ($^1/_4$” and $^3/_8$” concrete stone), 3.6% to 4.2% (Granular ‘A’ &‘B’ and crusher run) and 3.7% to 5.4% (screenings)
- shipping pile water contents for unwashed sand & gravel mixes (1.8% to 6.5% total weight basis) were typically approximately equal to or less than the maximum residual (free drained) water content (3.6% to 5.4% total weight basis), i.e., stockpiles were fully drained free (unbound) porewater
- shipping pile water contents for washed sand & gravel products (3.1% to 4.9%) after up to 3 weeks of stockpiling was still above the maximum residual (free drained) water content (2.0%), even after 3 weeks of stockpiling i.e. stockpiles were still draining.

There were cases (e.g., screenings) where unwashed products demonstrated shipping pile water content greater than the maximum residual (free drained) water content. These cases imply a source of added water other than from the washing process, such as rain water, which enters the stockpile and takes time to drain away.

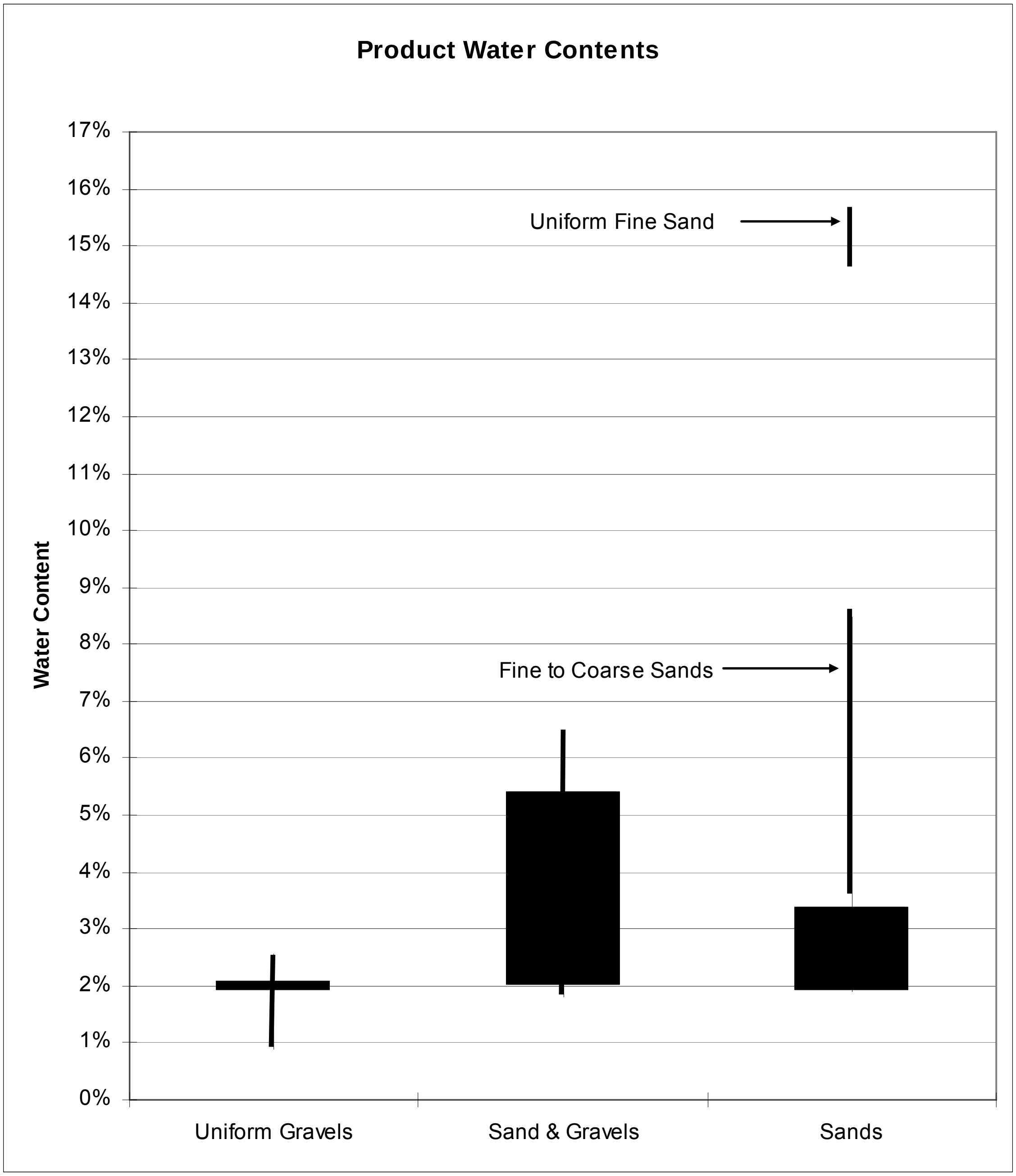
TABLE 2
Summary Of Sampled Product Water Content Results

Site[1]	Product	Approximate age of Stockpile Sampled	Water Content (total weight basis)	
			Measured[2] (average of duplicate samples)	Maximum Residual (Free Drained)
Uniform Gravels				
4	3/4" Clear Stone (Unwashed)	1 month	0.9%	2.0%
4	HL-6 Stone (Unwashed)	> 6 months	1.9%	2.0%
3	3/4" Clear Stone (Washed)	3 months	2.0%	2.1%
2	3/4" Concrete Stone (Washed)	3 weeks	2.6%	1.9%
Sand & Gravel Mixes				
4	2" Minus Crusher Run (Unwashed)	1 week	1.8%	3.0%
3	Screenings (Unwashed)	< 1 day	3.0%	5.4%
2	3/8" Concrete Stone (Washed)	3 weeks	3.1%	2.0%
3	Granular "A" (Unwashed)	2 weeks	3.5%	3.6%
1	Granular "A" (Unwashed)	1 week	3.7%	3.9%
1	Granular "B" (Unwashed)	< 1 day	4.2%	4.2%
4	3/4" Minus Crusher Run (Unwashed)	> 6 months	4.2%	4.0%
2	1/4" Concrete Stone (Washed)	< 1 week	4.9%	2.1%
4	Screenings (Unwashed)	8 months	6.5%	3.7%
Fine to Coarse Sand Mixes				
2	Concrete Sand (Washed)	2 weeks	3.7%	1.9%
3	Asphalt Sand (Washed)	< 1 day	7.8%	2.5%
1	Concrete Sand (Washed)	1 week	5.3%	3.4%
1	Masonary Brick Sand (Washed)	1 week	6.8%	3.4%
1	Asphalt Sand (Washed)	1 week	8.5%	2.6%
Uniform Fine Sands				
1	Cable Sand (Washed)	1 week	14.8% - 15.8%	3.2%
Fine Sands with Silt				
1	Septic Sand (Washed)	1 week	15.2%	10.0%
3	Agricultural Lime (Washed)	6 months	9.4%	10.0%

Notes:

1 Site 1 = Pit Above Water Table
Site 2 = Pit Below Water Table
Site 3 = Quarry Partially Below Water Table
Site 4 = Quarry Below Water Table

FIGURE 6



Legend:

- range of measured stockpile water content
- range of maximum residual (free drained) water content

4.0 CONSUMED WATER

The objective of the water consumption calculations was to determine the proportion of water consumed in typical aggregate production processes. It was recognised that consumed water at aggregate sites may have various components that need to be considered.

The methodology for calculation of the required quantities is presented in Appendix B, Section B.3.

Water consumed by site operations may typically be broken down into the following components:

- Water shipped with aggregate products (comprised of natural in-situ water, precipitation and wash water);
- Water evaporated from the final product stockpiles; and
- Dust control.

Altered evaporation rates due to land use changes (e.g., farmland to a pond) are not consumed water as defined and in the context of the PTTW process. The rationale for this characterization is that:

- Altered evaporation rates are applicable to all urban/rural development (e.g., widening your driveway) i.e., they are not an industry specific issue; and
- An increase in evaporation due to change in land use (for any industry) does not require a PTTW.

Extraction activities in sand and gravel pits that extend below the water table may cause a temporary lowering of groundwater levels locally as groundwater flows inward to the excavation to replace the solid matrix of aggregate materials removed. This event depends on rate of extraction and local site conditions. Water of this type is not considered consumed water, since it is still available to the local environment.

The following provides a summary of the consumed water calculations for the study sites.

4.1 Water Shipped With Aggregate

Tables 3 and 4 present the results of the calculations for volume of water shipped with aggregate products.

Table 3 presents the annual shipped tonnage and (stockpile) shipping water content for each product sold at each site. Multiplication of these two numbers calculates the volume of water shipped off-site for each product at each site.

Table 3 also provides the average in-situ moisture content for each site (prior to the material being separated into individual sizes and products). The average in-situ moisture content multiplied by the annual shipped product tonnage calculates the amount of water shipped off site that was original in-situ water. Subtraction of this number from the total volume of water shipped off site per site provides the amount of water that was shipped off site that was added to the material through the washing process and/or by precipitation onto the product stockpiles.

Based on the test results for this study (see Figure 6), as well as Golder's experience, the range in average water shipped off-site was estimated to be approximately:

- Fine to coarse Sand mixes = 35 to 85 L/tonne of product (total weight basis)
- Sand & Gravel Mixes = 15 to 65 L/tonne of product (total weight basis)
- Uniform Gravels = 5 to 30 L/tonne of product (total weight basis)
- Uniform Fine Sands = 150 L/tonne

The amount of water shipped off-site in washed aggregate products depends on the type of product (sand, gravel or sand & gravel mix). As discussed in Section 3, the amount of water shipped off-site in washed aggregate products also depends and the age of the stockpile.

Unwashed gravels and sand & gravel mixes typically had a moisture content near their maximum residual (free drained) water content.

Table 4 provides the same information as Table 3, but summarises on a per site basis (as opposed to Table 3 which provides information on an individual product basis). Three of the four (all but the pit above the water table) had water volumes shipped off site in the range of 35 L/tonne. The pit above the water table was 62 L/tonne. The pit above the water table produces mostly sand products which retain more water than gravels.

Water shipped off-site ranged from 55% to 72% of the total consumed water at each site.

As can be seen in Table 4, the portion of water shipped off-site that is attributed to natural (in-situ) water (assuming no drying prior to processing) was approximately:

- Sand Pit below water table = 100%: The product goes into wash plant saturated and therefore the water shipped off-site is attributed to natural (in-situ) water.
- Sand Pit above water table = 60%: This site produces mostly sand products which retain more water than gravels (i.e., sites with more gravel products may be greater than 60%).
- Quarries = 50% to 65%: Quarries crush bedrock material resulting in more voids, surface area and fines for water to adhere to in the final product as compared to the consolidated in-situ rock material.

4.2 Stockpile Evaporation

Table 5 presents a summary of water consumed due to all items, including stockpile evaporation, for each site.

An estimate of the total annual volume of water evaporated from the product stockpiles was obtained by multiplying the stockpile surface areas by an average annual evaporation depth taken from Environment Canada water budgets for the local area. Average stockpile sizes were determined based on the annual shipped product tonnages and site photos. Surface areas were then quantified for the stockpiles sizes.

Stock pile evaporation ranged from 15% of the total consumed water (pit above water table, mostly sands) to a high of 29% of the total consumed water (quarry below water table, mostly stone products).

Site observations indicated that only a thin layer at the surface of the aggregate stockpile was dried out, more so for sands than gravels. It is speculated that although precipitation may soak through the entire stockpile, the evaporative effects of the sun can not penetrate very far into the stockpile. Gravel stockpiles generally have a larger void between the aggregate, and thus air may be able to penetrate deeper into gravel stockpiles, thus providing additional evaporation.

4.3 Dust Control

Table 5 presents a summary of water consumed due to all items, including dust control, for each site.

Water consumed by dust suppression was generally calculated from site records of the number of water trucks per day which apply water, and the volume of water per truck.

Dust control usage varied from site to site, ranging from approximately 4% to approximately 26% of the total consumed water.

4.4 Total Water Consumed

Table 5 presents a summary of water consumed due to all items (dust control, stockpile evaporation, and shipping off-site with product) for each site. **Consumed water per tonne of products (all products combined) ranged from 45 L/tonne to 89 L/tonne (4.5% to 8.9%) on a total (shipping) weight basis, depending on the site i.e., less than 0.1 m^3/tonne of product.**

Section 7 - Comparison of Consumed Water Quantities, compares the consumed water to the handled water quantities (Section 5) and precipitation quantities (Section 6) to provide context to the magnitude of the consumed water quantities.

TABLE 3
Consumed Water - Shipped Off-Site

Product	Washed / Unwashed	Annual Shipped Tonnage[1]	In-Situ Moisture Content[2]	In-Situ Water Tonnage	Product Shipping Moisture Content[3,4]	Product Dry Tonnage	Trucked Off Site Water Total Volume[4]	Trucked Off Site Water Added to In-Situ Water	
		tonnes	*%*	*tonnes*	*%*	*tonnes*	*m^3*	*m^3*	*% of Tot*
Pit /Above Water Table / with Washing									
5-1 Sand Salt[6]	Part washed	1,854	na	na	4.0%	1,779	74		
80-20 Golf Course Mix[6]	Unwashed	43	na	na	3.4%	42	1		
Granular "A"	Unwashed	88,818	na	na	3.7%	85,576	3,242		
Granular "B"	Unwashed	22,125	na	na	4.2%	21,207	918		
Processed Sand Fill [6]	Unwashed	87	na	na	4.0%	84	3		
Cable Sand	Washed	17,468	na	na	15.3%	14,795	2,673		
Filter Sand[6]	Washed	5,006	na	na	4.2%	4,798	208		
Concrete Sand	Washed	318,127	na	na	5.3%	301,266	16,861		
Septic Sand Fill	Washed	42,528	na	na	15.2%	36,085	6,443		
Masonry Sand	Washed	22,943	na	na	6.8%	21,394	1,549		
Drainage Stone[5]	Washed	125	na	na	2.0%	123	3		
Washed Subtotal		**408,049**				**380,240**			
Total		**519,122**	**4.0%**	**19,486**		**487,147**	**31,974**	**12,488**	**39%**
Pit / Below Water Table / With Washing									
Concrete Sand	Washed	646,700	na	na	3.7%	623,095	23,605		
3/4" Stone	Washed	380,180	na	na	2.6%	370,485	9,695		
1/4" Stone	Washed	402,200	na	na	4.9%	382,693	19,507		
3/8" Stone	Washed	242,000	na	na	3.1%	234,619	7,381		
Washed Subtotal		**1,671,080**				**1,610,893**			
Total		**1,671,080**	**14%**	**225,525**		**1,610,893**	**60,187**	**0**	**0%**
Quarry/Partially Below Water Table/with Washing									
6” Crusher Run[7]	Unwashed	5,483	na	na	3.5%	5,294	189		
2” Crusher Run[7]	Unwashed	52,563	na	na	3.5%	50,749	1,813		
Gran A – 3/4” Crusher Run	Unwashed	130,791	na	na	3.5%	126,279	4,512		
Gran M – 1/2” Crusher Run[7]	Unwashed	31,893	na	na	3.5%	30,792	1,100		
Screenings	Unwashed	5,944	na	na	3.0%	5,766	178		
Armour Stone B	Unwashed	3,424	na	na	2.0%	3,355	68		
Rip Rap	Unwashed	13,109	na	na	2.0%	12,847	262		
Gabion Stone	Unwashed	5,648	na	na	2.0%	5,535	113		
Shot Rock	Unwashed	6	na	na	3.0%	6	0		
(R) 2” Crusher Run	Unwashed	10	na	na	3.5%	9	0		
FILL	Unwashed	306	na	na	9.0%	278	28		
Salt Only (Winter Sand)	Unwashed	2,044	na	na	5.0%	1,942	102		
Mixing New Sand	Unwashed	13,835	na	na	5.0%	13,143	692		
Agricultural Lime	Washed	8,669	na	na	9.4%	7,859	811		
1 1/2” – 2” Clear Stone[8]	Washed	2,325	na	na	2.0%	2,278	46		
3/4” Clear Stone	Washed	54,974	na	na	2.0%	53,874	1,099		
1/2” Clear Stone[8]	Washed	2,495	na	na	2.0%	2,445	50		
3/8” Clear Stone[8]	Washed	799	na	na	2.0%	783	16		
1/4” Clear Stone[8]	Washed	45,390	na	na	2.0%	44,482	908		
3/4” Concrete Stone[8]	Washed	174,254	na	na	2.0%	170,769	3,485		
3/8” – 1/4” Blend (NJC) [8]	Washed	141	na	na	2.0%	138	3		
1 1/2" Concrete Stone[8]	Washed	1,336	na	na	2.0%	1,310	27		
HL8 [8]	Washed	1,508	na	na	2.0%	1,477	30		
HL3 Stone[8]	Washed	46,286	na	na	2.0%	45,360	926		
1/8” Chip Stone[8]	Washed	3,245	na	na	2.0%	3,180	65		
Class 1[8]	Washed	9,796	na	na	2.0%	9,600	196		
Winter Sand	Washed	18,690	na	na	5.0%	17,755	934		
HL3 Sand	Washed	137,795	na	na	7.8%	127,047	10,748		
Sand Waste	Washed	1,693	na	na	6.5%	1,583	110		
Washed Subtotal		**509,394**				**489,940**			
Total		**774,448**	**2.0%**	**14,919**		**745,935**	**28,513**	**13,594**	**48%**
Quarry/Below Water Table/ Without Washing									
HL-6	Unwashed	115,179	na	na	1.9%	113,048	2,131		
3/4" clearstone	Unwashed	47,558	na	na	0.9%	47,130	428		
2" clear stone	Unwashed	13,663	na	na	0.9%	13,540	123		
Screenings	Unwashed	14,740	na	na	6.5%	13,781	958		
19mm crusher run	Unwashed	257,064	na	na	4.2%	246,267	10,797		
50 mm crusher run [6]	Unwashed	81,835	na	na	1.8%	80,361	1,473		
Washed Subtotal		**0**				**0**			
Total		**530,038**	**2.0%**	**10,283**		**514,128**	**15,910**	**5,627**	**35%**

Notes:
1) Average of the 2002 and 2003 shipping tonnages (total weight basis).
2) Moisture content expressed on a dry weight basis.
3) Moisture content expressed on a total weight basis.
4) Based on moisture content measured at time of sampling.
5) No data available. Assumed the same water content as 3/4" clear stone for quarry partially below water table.
6) No data available. Assumed the same average water content as concrete sand.
7) No data available. Assumed the same water content as unwashed Granular "A".
8) No data available. Assumed the same water content as 3/4" clear stone.

TABLE 4
Consumed Water - Shipped Off-Site Summary

Product	Annual Shipped Tonnage[1]	Water Volumes Shipped Off Site			Rain Water & Wash Water Added to In-Situ Water In Stockpiles[3]			
	tonnes	*m^3/year*	*L/day [(2)]*	*L/tonne*	*m^3/year*	*L/day [(2)]*	*L/tonne*	*%*
Pit Above Water Table With Washing	519,122	32,000	182,900	62	12,500	71,400	24	39%
Pit Below Water Table With Washing[4]	1,671,080	60,200	344,000	36	0	0	0	0%
Quarry Partially Below Water Table With Washing	774,448	28,500	162,900	37	13,600	77,700	18	48%
Quarry Below Water Table Without Washing[5]	530,038	15,900	90,900	30	5,600	32,000	11	35%

Notes
1) Average of the 2002 and 2003 shipping tonnages (total weight basis).
2) Assumes an 8 month production year (April 1 to November 31), 5 day working week
3) Calculated as the annual water volume shipped off-site minus the annual water volume associated with the in-situ source material.
4) No water added to in-situ water since in-situ water content is greater than that shipped off-site.
5) Water Content of Quarry Below Groundwater Table Without Washing had rain water added to stockpiles i.e., shipping moisture content was greater than in-situ water content for screenings and crusher run products even though not washed.

TABLE 5
CONSUMED WATER

Item	Pit Above Water Table With Washing	Pit Below Water Table With Washing	Quarry Partially Below Water Table With Washing	Quarry Below Water Table No Washing
PTTW Annual Volume(m^3/year)	400,000	2,740,000	7,880,000	2,170,000
Production (tonne/year)	519,000	1,671,000	774,000	530,000
CONSUMED WATER				
1) Shipped off Site (m^3/yr)	32,000	60,000	29,000	16,000
2) Evaporated from Product Stockpiles(m^3/yr)	7,000	20,000	10,000	7,000
3) Dust Control (m^3/yr)	7,000	3,000	14,000	1,000
CONSUMED WATER TOTAL (m^3/yr)	**46,000**	**83,000**	**53,000**	**24,000**
CONSUMED WATER TOTAL (L/tonne)	**89**	**50**	**68**	**45**
CONSUMED WATER TOTAL (% of PTTW)	**12%**	**3%**	**1%**	**1%**

5.0 HANDLED WATER

Handled water is defined as the total amount of water which is moved (pumped or hauled with aggregate) at a site to conduct aggregate operations. Examples include quarry dewatering (comprised of precipitation, upstream runoff, groundwater seepage), water applied for dust control, water used for aggregate washing (make-up water and recycled wash plant water) and water contained in stockpiles and shipped aggregate products.

Quarry dewatering and water used for aggregate washing (make-up water and recycled wash plant water) were obtained from site records. Sources of other quantities are described in the consumptive use calculations.

The methodology for calculation of the handled water quantities is presented in Appendix B, Section B.4.

5.1 Site Descriptions

Figures 7 to 10 present the quarry dewatering, dust control, and wash plant water (make-up and recycled) annual volumes. The following sections describe each site.

<u>Pit Above Water Table With Washing</u>

The Pit Above Water Table is a sand and gravel pit that is located above the water table and performs washing operations. Its water handling components include a wash plant, two silt ponds, one freshwater pond, a well make up source, a dust control station, and various pumps. Aggregate is washed in the wash plant with water pumped from the freshwater pond. Wash plant effluent is pumped to silt pond 1, where it then flows to silt pond 2. Water from silt pond 2 is pumped back to the freshwater pond to complete the cycle. Should the wash plant experience overflow, water will bypass the silt ponds and be directed back to the freshwater pond. As required, the freshwater pond is replenished with water drawn from the source well, via a pump. Water used by the dust control station is also drawn from the source well. No surface water is discharged off-site.

<u>Pit Below Water Table With Washing</u>

The Pit Below Water Table is a sand and gravel pit that extracts below the water table and has a wash plant. Its water handling components include a wash plant, one silt pond, one freshwater pond, various pumps, and a dust control station. Aggregate is washed at the wash plant with water supplied from the freshwater pond. The freshwater pond is the pond created by excavation of aggregate. Wash plant effluent is discharged to the silt pond, where it is in turn pumped back to the freshwater pond. In the event of wash plant overflow, effluent bypasses the silt pond and is directed back into the freshwater pond. The dust control station draws water from the freshwater pond. There is no surface water discharged from this site.

Quarry Partially Below Water Table With Washing

Water related components include a wash plant, two silt ponds, a freshwater pond, one sump, a dust control station, and various pumps. Aggregate is washed in the wash plant with water pumped from the freshwater pond. Wash plant effluent is pumped to silt pond 1, where it then flows to silt pond 2. Water from silt pond 2 flows back to the freshwater pond to complete the cycle. As required, the freshwater pond is replenished with water drawn from the quarry sump. Water used by the dust control station is drawn from the freshwater pond. Intermittent overflow from the freshwater pond is discharged off-site.

Quarry Below Water Table Without Washing

Aggregate washing is not carried out at this site. Water handling components on-site include one sump, a dust control station and a pump. Surface water and groundwater is collected on the quarry floor in a sump. Water captured within the sump is pumped to a local creek. A nearby surface water body is used to supply the dust control with water.

5.2 Summary

Handled water is the sum of wash water, make-up water, dewatering, and consumed water (dust control, shipped off-site and evaporated from stockpiles). The following observations are drawn from a review of Figures 7 to 10 and from Table 6 (in Section 7):

1) The total handled water at the studied sites varied from approximately 600,000 m^3/year to approximately 3,500,000 m^3/year.

2) Depending on the site, wash plant water varied from approximately 1,000,000 m^3/year to approximately 2,700,000 m^3/year. For sites without dewatering (both pits), wash water was 92% of the total handled water. For sites with dewatering and wash water volumes (quarry partially below water table), wash water was approximately 80% of the total handled water. For the site without washing (quarry below water table), dewatering was approximately 96% of the handled water.

3) Depending on the site, wash plant water varied from 0.6 m^3/tonne to 5.4 m^3/tonne of washed product (all site products combined, on a total weight basis).

4) Site dewatering (which only occurred at quarries for the studied cases) varied from approximately 540,000 m^3/year to approximately 600,000 m^3/year. For the quarry with washing, dewatering water was 16% of the total handled water. For the quarry without washing, dewatering water was 96% of the total handled water.

5) Make-up water to compensate for consumed water and water returned to the local hydrologic system was approximately 110,000 m^3/year (for the pit above the water table and the quarry partially above the water table). This corresponds to 0.2 m^3/tonne to 0.3 m^3/tonne of washed product and 3% to 6% of the total handled water.

6) Consumed water (total of dust control, water shipped off-site and water evaporated in stockpiles) varied from 24,000 m^3/year to 83,000 m^3/year. This corresponds to less than

0.1 m^3/tonne of product (all site products combined, on a total weight basis) and 2% to 8% of the total handled water.

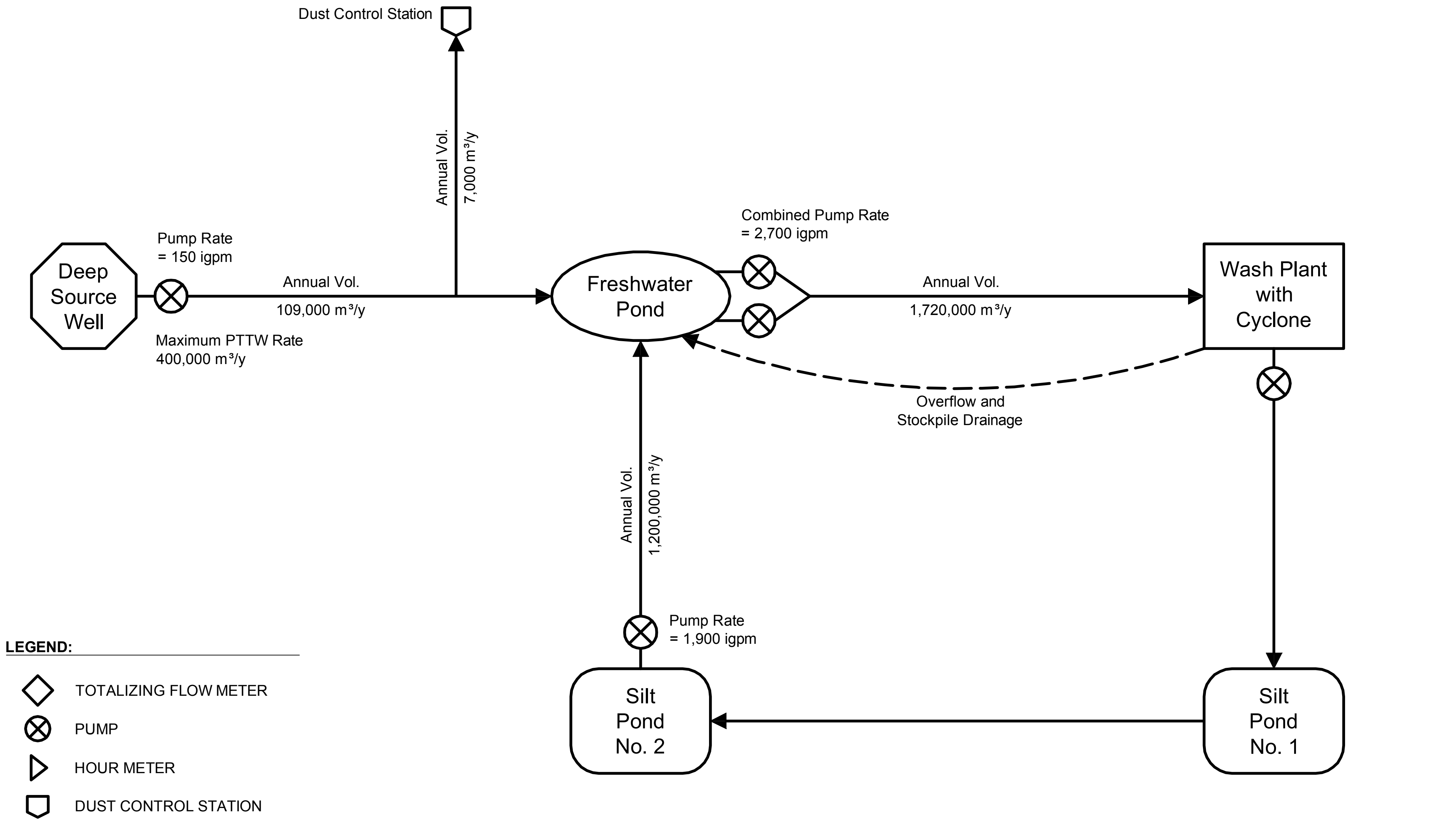
As can be seen from the above, for all sites, consumed water was the smallest water handling component, although make-up water was comparable.

Typically, at sites above the water table, the largest water handling component was wash plant water. It should be noted that the amount of water in the washing recycling system is actually much smaller, but is pumped over and over again through the wash plant.

Typically, at sites below the water table, dewatering can be the largest water handling component (particularly when there is no washing). However, wash water can be the largest water handling component if large quantities of groundwater and surface water inflow do not occur at the site. Dewatering amounts are reflective of the amount of water returned to the hydrologic system through site surface water discharge.

Further interpretation of the above water handling quantities is provided in Section 7 – Comparison of Consumed Water Quantities.

PLOT DATE: July 11, 2006
FILENAME: T:\Projects\2004\04-1112-059 (APAO, Ontario)\-BC- FINAL\041112059BC07.dwg



Golder Associates
Mississauga, Ontario, Canada

SCALE	N.T.S.
DATE	JULY 2006
DESIGN	KD
CAD	KD
CHECK	JS
REVIEW	
FILE No.	041112059BC07.dwg
PROJECT No.	04-1112-059
REV.	C

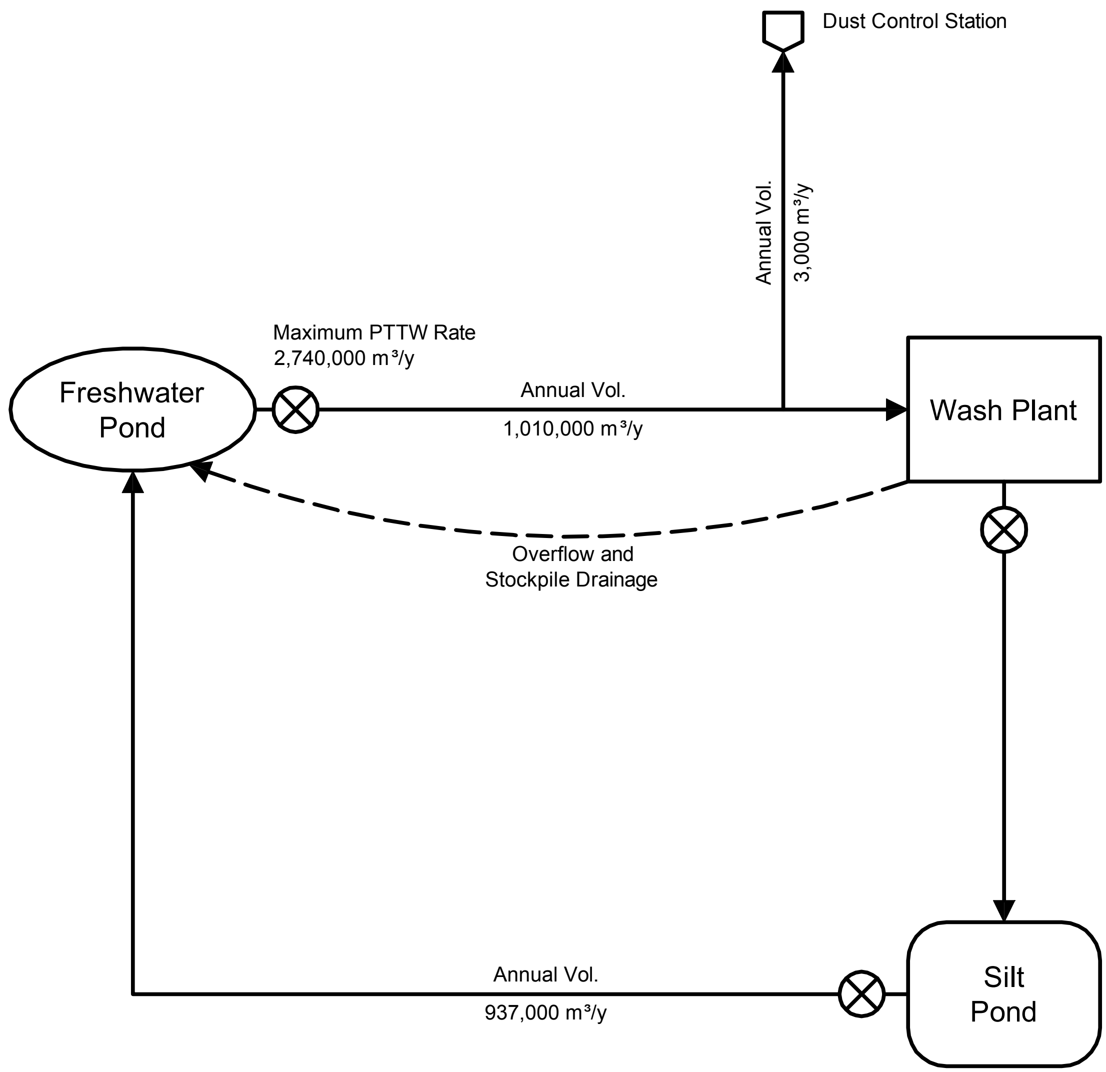
TITLE

SCHEMATIC OF HANDLED WATER
PIT ABOVE WATER TABLE WITH WASHING

WATER CONSUMPTION STUDY

FIGURE 7

PLOT DATE: July 11, 2006
FILENAME: T:\Projects\2004\04-1112-059 (APAO, Ontario)\-BC- FINAL\041112059BC08.dwg



LEGEND:

- TOTALIZING FLOW METER
- PUMP
- HOUR METER
- DUST CONTROL STATION

Golder Associates
Mississauga, Ontario, Canada

SCALE	N.T.S.
DATE	JULY 2006
DESIGN	KD
CAD	KD
CHECK	JS
REVIEW	
FILE No.	041112059BC08.dwg
PROJECT No.	04-1112-059
REV.	C

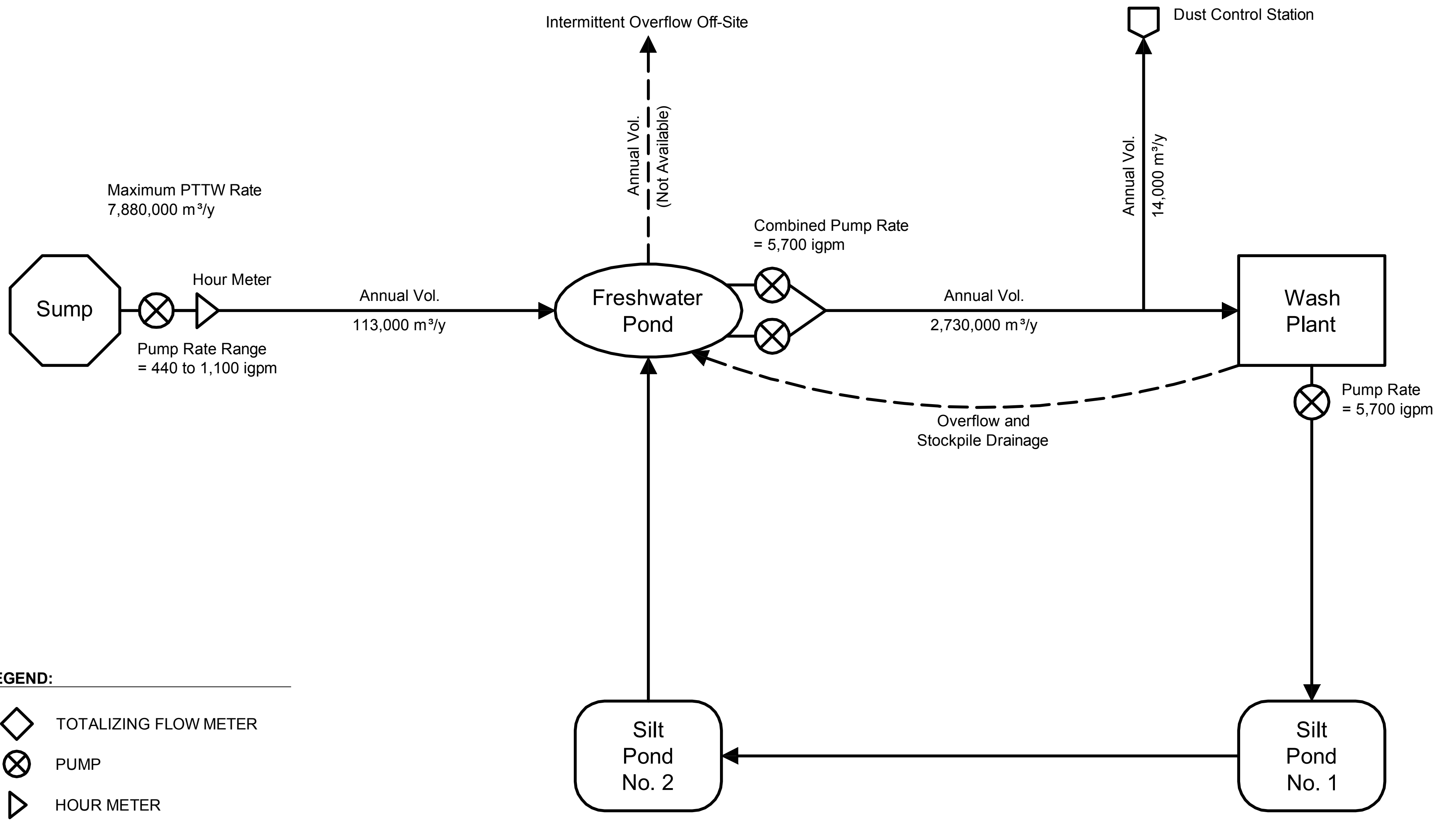
TITLE

SCHEMATIC OF HANDLED WATER PIT BELOW WATER TABLE WITH WASHING

WATER CONSUMPTION STUDY

FIGURE 8

PLOT DATE: July 11, 2006
FILENAME: T:\Projects\2004\04-1112-059 (APAO, Ontario)\-BC- FINAL\041112059BC09.dwg



LEGEND:

- TOTALIZING FLOW METER
- PUMP
- HOUR METER
- DUST CONTROL STATION

Golder Associates
Mississauga, Ontario, Canada

SCALE	N.T.S.
DATE	JULY 2006
DESIGN	KD
CAD	KD
CHECK	JS
REVIEW	

FILE No. 041112059BC09.dwg
PROJECT No. 04-1112-059 REV. C

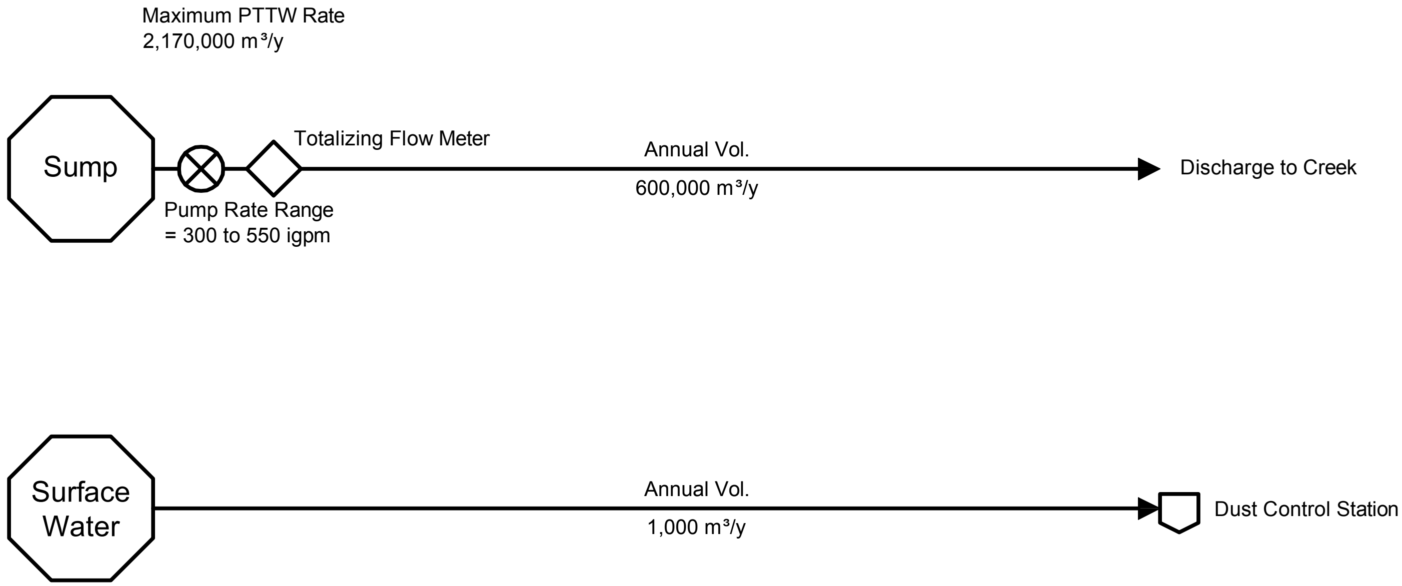
TITLE

SCHEMATIC OF HANDLED WATER QUARRY PARTIALLY BELOW WATER TABLE WITH WASHING

WATER CONSUMPTION STUDY

FIGURE 9

PLOT DATE: July 11, 2006
FILENAME: T:\Projects\2004\04-1112-059 (APAO, Ontario)\-BC- FINAL\041112059BC10.dwg



LEGEND:

- TOTALIZING FLOW METER
- PUMP
- HOUR METER
- DUST CONTROL STATION

Golder Associates
Mississauga, Ontario, Canada

SCALE	N.T.S.	TITLE	SCHEMTIC OF HANDLED WATER QUARRY BELOW WATER TABLE WITHOUT WASHING
DATE	JULY 2006		
DESIGN	KD		
CAD	KD		
CHECK	JS		WATER CONSUMPTION STUDY
REVIEW		FIGURE	10

FILE No. 041112059BC10.dwg

PROJECT No. 04-1112-059 REV. C

6.0 PRECIPITATION VOLUMES

Average annual site specific precipitation volumes were determined to provide context for the magnitude of the water handled and water consumed quantities.

It is important to reference an appropriate gauge based on distance from site, record length and suitability (e.g., elevation difference and local climate) issues. Monitoring locations were screened for the various issues. The site’s footprint and total drainage area to the site’s point of discharge were delineated. Precipitation volumes were calculated by multiplying the average annual precipitation depth by the delineated area.

The calculated amount of consumed water was found to be 12% or less of the site’s precipitation onto each of the studied sites (see Table 6).

7.0 COMPARISON OF CONSUMED WATER QUANITIES

Table 6 compares the consumed water quantities for each site (see Section 4) to quantities of handled water (e.g., dewatering, wash plant make-up, recirculation water, etc., see Section 5), precipitation quantities (see Section 6), and PTTW maximum permitted amounts. Each are discussed below.

As discussed in Section 4, the consumed water per tonne of products (all products combined, on a total weight basis) ranged from 45 L/tonne to 89 L/tonne (4.5% to 8.9% water content) on a total (shipping) weight basis, depending on the site i.e., less than 0.1 m^3/tonne of product (all site products combined, on a total weight basis).

For the studied cases, consumed water was only 2% to 8% of the total handled water (water used for washing, make-up, dewatering, dust control, shipped off-site and evaporated from stockpiles). Thus, water consumed in aggregate operations is only a small portion of the handled water.

Depending on the site, consumed water was only 2% to 8% of the water recycled in a wash plant. Consumed water is only a small portion of the wash water. The bulk of wash water is returned to the local hydrologic system (evaporation, infiltration and dewatering) or recycled repeatedly through the wash plant.

Consumed water was 4% to 10% of site dewatering for studied cases with site surface water discharges (quarries). This demonstrates that the consumed water is a minor component of the site's surplus water.

The calculated amount of consumed water was found to be 12% or less of the amount of precipitation which falls on the site for the four studied cases. This again demonstrates that the consumed water is a minor component of the site's available water.

Consumed water was found to be 1% to 12% of the PTTW maximum permitted amount in the studied cases. Consideration should be given to the purpose of the PTTW (wash plant make-up, wash plant recirculation, and/or quarry dewatering) in order to interpret the representative fraction of consumed water at an individual site.

Actual water taking quantities relative to the PTTW maximum permitted amount ranged from 1% to 37% for the studied sites. This demonstrates that the PTTW maximum permitted amount is not a reliable estimate of water "taken" at an individual aggregate site, even though the higher PTTW maximum permitted amounts are necessary to handle peak water taking that may occur from time to time.

TABLE 6
Consumed Water Ratios

Item	Pit Above Water Table With Washing	Pit Below Water Table With Washing	Quarry Partially Below Water Table With Washing	Quarry Below Water Table No Washing
Aggregate Production (tonne/year, wet wt. basis)	519,000	1,671,000	774,000	530,000
Washed Product (tonne/year, wet wt. basis)	408,000	1,671,000	509,000	0
Precipitation Volume (m^3/year)	810,000	680,000	1,310,000	650,000
PTTW Volume (m^3/year)	400,000	2,740,000	7,880,000	2,170,000
Water Taken / PTTW Limit (%)	28%	37%	1%	28%
Make-Up Water (m^3/year)	110,000	Not Applicable	113,000	Not Applicable
Make-Up Water (m^3/tonne of washed product)	0.3	Not Applicable	0.2	Not Applicable
Make-Up Water Volume / PTTW Volume (%)	28%	Not Applicable	Not Applicable	Not Applicable
Make-Up Water Volume / Handled Water Volume (%)	6%	Not Applicable	3%	Not Applicable
Wash Water (m^3/year)	1,720,000	1,010,000	2,730,000	Not Applicable
Wash Water (m^3/tonne washed product)	4.2	0.6	5.4	Not Applicable
Wash Water Volume / PTTW Volume (%)	Not Applicable	37%	35%	Not Applicable
Wash Water Volume / Handled Water Volume (%)	92%	92%	79%	Not Applicable
Dewatering (m^3/year)	Not Applicable	Not Applicable	540,000	600,000
Dewatering Volume / PTTW Volume (%)	Not Applicable	Not Applicable	Not Applicable	28%
Dewatering Volume / Handled Water Volume (%)	Not Applicable	Not Applicable	16%	96%
Handled Water (m^3/year)[1]	1,876,000	1,093,000	3,436,000	624,000
Consumed Water (m^3/year)	46,000	83,000	53,000	24,000
Consumed Water (L/tonne)	89	50	68	45
Consumed Water / PTTW (%)	12%	3%	1%	1%
Consumed Water / Precipitation (%)	6%	12%	4%	4%
Consumed Water / Handled Water (%)	2%	8%	2%	4%
Consumed Water / Make-Up Water (%)	42%	Not Applicable	47%	Not Applicable
Consumed Water / Wash Water (%)	3%	8%	2%	Not Applicable
Consumed Water / Site Discharge (%)	Not Applicable	Not Applicable	10%	4%

Notes
1) Sum of wash water, make-up water, dewatering and consumed water (dust control, shipped off-site and evaporated from stockpiles)

8.0 CONCLUSIONS

Based on the preceding analysis, the following are concluded:

1) The shipping pile water content for washed fine to coarse sand mixes (3.7% to 8.5% total weight basis) was greater than the maximum residual (free drained) water content (1.9% to 3.4% total weight basis) i.e., the stockpiles were still draining. Stockpile water contents for these sand products typically approach the maximum residual (free drained) water content in one month, with likely no further reduction after one month.

2) The shipping pile water content for uniform gravel products at the studied sites (0.9% to 2.6% total weight basis) was approximately equal to or less than the maximum residual (free drained) water content (1.9% to 2.1% total weight basis, for studied cases; Golder experience indicates this number may be less than 1% for some products). Free water can drain much faster from uniform gravel stockpiles than from sand stockpiles. The stockpile water content typically approaches the maximum residual (free drained) water content in less than one week.

3) The shipping pile water content for unwashed sand & gravel mixes at the studied sites (1.8% to 6.5% total weight basis) was typically approximately equal to or less than the maximum residual (free drained) water content (3.6% to 5.4% total weight basis). Washed sand & gravel products had shipping pile water contents (3.1% to 4.9%) above the maximum residual (free drained) water content (2.0%), even after 3 weeks of stockpiling.

4) The amount of water shipped off-site in aggregate products (component of consumed water) depends on the grain size distribution of product, the age of the stockpile and whether or not the product is washed.

5) The average water shipped off-site was 35 L/tonne to 85 L/tonne of product for fine to coarse sand mixes, 150 L/tonne for uniform fine sand, 15 L/tonne to 65 L/tonne of product for sand & gravel mixes, and 5 L/tonne to 30 L/tonne of product for uniform gravel. Water contents above 100 L/tonne (0.1 m^3/tonne) were only found in washed uniform fine sand and fine sand/silt stockpiles which had not drained yet.

6) Between 50% to 100% of the water shipped off-site with aggregate products was attributed to natural in-situ water. The remainder was wash water and/or rainwater that adheres to the product.

7) At the studied sites with washing, the largest water handling component was wash plant water.

8) Depending on the studied site, consumed water was only 2% to 8% of the handled water i.e., water consumed in aggregate operations is only a small portion of the handled water. It can therefore be concluded that the sites that were studied, and the aggregate industry in general, are primarily handlers of water, with the bulk of handled water returned to the local hydrologic system (dewatering and infiltration) or recycled repeatedly through the wash plant.

9) Consumed water was 12% or less of the amount of precipitation which falls on the site for the studied cases. Consumed water was 4% to 10% of site dewatering for studied cases with site surface water discharges (quarries). It can therefore be concluded that the consumed water at the studied sites is a minor component of the site's surplus water.

10) Consumed water (water not returned to the local surface water and/or groundwater system) was found to be a minor portion (1% to 12% at the study sites) of the PTTW maximum permitted amount and thus the PTTW maximum permitted amount should not be used to reflect the amount of consumed water. Consideration should be given to the purpose of the PTTW (wash plant make-up, wash plant recirculation, quarry dewatering) in order to interpret the representative fraction of consumed water at an individual site.

11) Actual water taking quantities relative to the PTTW maximum permitted amount ranged from 1% to 37% for the studied sites. This demonstrates that the PTTW maximum permitted amount is not a reliable estimate of water "taken" at an individual aggregate site, even though the higher PTTW maximum permitted amounts are necessary to handle peak water taking that may occur from time to time.

12) The accuracy of aggregate properties, product volumes and water shipped off-site is considered high since they are based on measured quantities. The accuracy of estimates for water consumed by evaporation is good since they are based on aggregate properties and product volumes. The dust control quantities are estimates based on site operator observations. Accuracy of flows (wash plant, make-up water) varies from site-to-site, and within each site.

GOLDER ASSOCIATES LTD.

Original signed by:

John A. Sinnige, P.Eng.
Senior Water Resource Engineer

Original signed by:

Frank S. Barone, P.Eng
Associate, Senior Geotechnical Engineer

Original signed by:

Sean McFarland, P.Geo.
Principal, Senior Hydrogeologist

JAS/FSB/JP/SM/spc/wlm
n:\active\2004\1112\04-1112-059 apao water consumption study ontario\reports\final report\04-1112-059 final wtr consumption study aug 2006.doc

APPENDIX A

TERMS OF REFERENCE

Aggregate Producers' Association of Ontario
Water Consumption Study
Terms of Reference

Summary
In response to the Source Water Protection White Paper presented by the MOE earlier this year and the associated perception of our industry being one of the largest water consumers within the Province, the APAO has decided to assess the actual consumption of water at four typical types of aggregate operations. The APAO Board endorsed a request for information from the membership and to date, 45 sites have reported. The Environment subcommittee has met and is proposing that a Consultant be retained to produce complete water balances for four operations consisting of one quarry below water (washing and dewatering), one quarry above water (just washing or if not volunteered a quarry with dewatering only), one sand and gravel pit above water (just washing) and one sand and gravel pit below water (just washing). These typical operations would then be compared to the submitted information to verify and augment the findings of the water budgets.

Details
Producing members will be asked to supply the 4 suitable sites and existing information. The Consultant will be required to provide one paper and one electronic (in Word format) copy of a proposal outlining their research approach and cost estimate for carrying out each water balance individually. The Consultant should consider the following requirements:

1/ A review and site visit will be required to determine the current status of each of the four sites within a four hour drive of Toronto for the purpose of recommending appropriate flow and water level monitoring methods and requirements for the preparation of a water balance. The Consultant will identify all relevant points of water transfer for metering and water level monitoring at all relevant points of standing water.

2/ After the acceptance of flow and water level monitoring requirements, the recommended flow metering devices will be installed by the Producer, while the Consultant will be responsible for the installation of the recommended water level measuring devices. The Consultant will also be required to determine the appropriate duration and frequency of monitoring for the meters and standing water levels at each of the sites for the purpose of this study.

3/ The Consultant will complete water balances for each of the four sites to determine the actual water consumption at each site. To assist in creating these water balances, the Producer would provide copies of all relevant site plans, production data, dust control and aggregate washing information, in confidence, to the Consultant. The Consultant should be prepared to obtain samples of raw and washed products to determine fines removal, moisture content etc. The Consultant should assume that lab testing would be completed at a lab of their choice (i.e. internal or contract) in order to obtain all information in a timely manner.

4/ The Consultant will develop a report of the water budgets for the four sites. In addition, they will develop a simplistic presentation depicting the Province wide use of water by the Aggregate industry and comments on its significance and environmental effects. This presentation will be suitable for use with the APAO Board, the MOE, politicians and the general public.
Upon completion of the water balances, the Consultant will, in conjunction with the APAO Environmental Committee, develop a defensible definition for "water consumption" for typical aggregate operations.

5/ The proposals should be submitted to the APAO by Friday, July 30, 2004

6/ The proposal will be awarded at 3:00pm August 4, 2004.

7/ The project must be completed by October 15, 2004.

Please direct any questions or requests for clarification to Peter White, Environment and Resources Manager at (pwhite@apao.com) or 905 507 0711

APPENDIX B

DETAILED METHODOLOGY

B.1 WORK PLAN OVERVIEW

The major tasks were:

1) Collect and review background data;
2) Visit and inspect sites;
3) Assess aggregate properties;
4) Quantify water consumed at different types of process and quarry/pit types;
5) Quantify water handled at different types of process and quarry/pit types;
6) Calculate site precipitation volumes to provide context for the magnitude of the water handled and water consumed quantities.

A review of background information was undertaken to assess existing conditions and identify any data gaps which required further work. The information obtained during the background information review (where available) includes:

- Permits To Take Water and supporting documentation;
- Certificate of Approval (OWRA Section 53) and supporting documentation;
- MNR Aggregate Resources Act Site Plans;
- 1:10,000 Ontario Base Mapping and site specific mapping;
- site mapping and air photos;
- flow monitoring data and dust control;
- aggregate products produced at each site;
- washed and unwashed shipping tonnages;
- previously completed site specific studies; and
- other relevant information.

An initial site visit was conducted to determine the current status of each of the four sites. The following tasks were conducted:

- sampling of source material (where possible);
- sampling of stockpiles of finished product;
- sampling of wash water;
- inspection of site pumps and flow metering equipment;
- development of flow schematic with points of water intake, conveyance, storage and discharge;
- assessment of dust suppression methods, frequency and equipment; and
- assessment of data gaps and requirements for the installation of any required monitoring instrumentation (e.g. flow meters) and additional testing requirements.

If sample collection did not occur during the initial site visit, a second site visit was undertaken. The source material, aggregate (for different product lines) and wash water samples collected during the site visit were sent to Golder's laboratory for analysis (details provided in Section B.2).

The following properties were quantified from lab tests and literature:

- in-situ natural water content of undisturbed source material;
- shipping (product stockpile) water content of screened/washed and screened/unwashed product (where applicable);
- maximum potential residual (free drained) water content of screened/washed and screened/unwashed product (where applicable);
- fines content of products;
- grain size analysis of wash water sediment; and
- residual water content of wash water sediment.

The proceeding tasks provided the required information to complete the water consumption task. Details of the tasks to quantify the amount of water consumed at the site are provided in Section B.3. In summary, quantities of water consumed by dust control, stockpile evaporation and water shipped off site with final product were quantified. The quantity of natural in-situ water associated with the mined aggregate was quantified also. Quantities of water stored in sediment pond fines and the void created by excavation of source material in below water table pits were also calculated.

The amount of water handled at a site was calculated to provide context for the consumed water quantities, as discussed in Section B.4.

Average annual site specific precipitation volumes were calculated to provide context for the handled and consumed water quantities, as discussed in Section B.5.

B.2 ASSESSMENT OF AGGREGATE PROPERTIES

B.2.1 Sampling of Product Shipping Stockpiles

The product shipping stockpiles at each site were sampled by Golder on one event in the fall of 2004. The sampling procedure involved the use of a front-end loader to prepare a standard sample pad, as is normally carried out for quality control sampling. The loader excavated approximately 1.5 m into the side of the stockpile at one or two locations and laid the material in a single sample pad adjacent to the toe of the stockpile. The top of the sample pad was back-bladed and samples were then collected in duplicate using a hand spade. Each of the duplicate samples consisted of five or six sub-samples taken from various locations along the top and sides of the sample pad. Each sample was placed in double polyethylene bags, which were tightly sealed to prevent loss of moisture.

At the time of sampling, information was obtained from site staff on the age of each stockpile and whether or not the product was washed.

B.2.2 Laboratory Measurement of Water Content on Shipping Stockpile Samples

Water content measurement on the samples collected from the shipping stockpiles was carried out in accordance with ASTM Method D2216, which involves drying the sample at 110ºC. The results are presented in Table 1 (Section 3.2).

B.2.3 Determination of Potential Maximum Residual (Free Drained) Water Content for the Products

To assess the extent to which a shipping stockpile has undergone drainage of free (unbound) porewater at the time of sampling, the measured water content values for the stockpile samples were compared to the potential maximum residual (free drained) water content. The latter is defined as the residual water content of a loosely packed/initially saturated product which has undergone complete gravity drainage of all free unbound porewater (i.e., porewater not bound by capillary and/or adsorption forces onto the soil solids) with zero evaporative loss. Considering that the shipping piles are not tarped to prevent evaporative losses, the water content of a shipping pile that has undergone full drainage of free porewater should be comparable to or less than (reflecting evaporative loss) the potential maximum residual (free drained) water content.

Measurement of potential maximum residual (free drained) water content was carried out at Golder Associates' laboratory on samples from the product shipping piles. The procedure involved the use of a standard Tempe Cell apparatus (Fredland and Rahardjo, 1993) equipped with a 100 kPa ceramic "high air entry" disk. Each test sample was initially saturated in a tri-axial cell under a water pressure of 500 kPa, which results in complete saturation of all pores between particles as well as the interstitial pores within individual stone particles. After saturation, the sample was removed from the tri-axial cell and loosely packed into the Tempe Cell. An air pressure of 33 kPa (1/3 atmosphere pressure) was then applied to the cell to expediate drainage of free unbound porewater (Coleman, 1947). This air pressure was maintained until no further drainage occurred from the sample. Note that the ceramic "high air entry" disk allows the porewater to drain through it but not air. Therefore, there is no air flow through the sample which would otherwise lead to evaporative losses. The time for completion of drainage from the samples typically ranged from 20 hours for uniform gravel materials to 60 hours for fine sand materials. The residual water content of the samples after free drainage under the 33 kPa air pressure (i.e., the potential maximum residual free drained water content) was then measured by drying the test samples at 110ºC as per ASTM Method D2216. The results are given in Table 1 (Section 3.2).

B.2.4 Assessment of Insitu Water Content of Natural "Bank Material”

Pit Above Water Table

At the above water table pit, duplicate samples of fresh "bank material” were obtained for analysis of natural in-situ water content. The samples were collected from the screen plant surge pile (i.e., the output stockpile of the 4 inch jaw crusher). The timeframe between excavation at the pit working face and collection of the samples at the surge pile was quite short (4 hours) and therefore the measured water contents are considered representative of the natural in-situ water content of the bank material.

The measured natural in-situ water contents (by ASTM Method D2216) obtained for the duplicate "bank material” samples are 4.3% and 4.4% (dry weight basis):

Pit Below Water Table

Measurement of in-situ natural water content of the source material at the below water table pit would require advancing boreholes below the water table immediately adjacent to the pit and collection of undisturbed saturated samples of material representative of the aggregate source material. As a borehole investigation was outside the scope of this study, the in-situ natural (saturated) water content for the source material at the below water table pit was estimated using the following equation:

$$w_{sat} = \frac{S \bullet e}{G_s} \qquad \text{[Eqn. B.2-1]}$$

where w_{sat} = saturated water content (dry wt. basis)

S = degree of saturation

= 1.0 for fully saturated soil

e = void ratio

$\underset{\sim}{}$ 0.38 for dense sand and gravel having an in-situ dry density of $\underline{\sim}$ 2.0 Mg/m^3

G_s = specific gravity of solids
= 2.7 (for soil comprised of mostly quartz and calcite minerals)

Substituting into the above equation, an in-situ saturated water content of 14% (dry wt. basis) is estimated for the below water table pit.

Quarries

The natural in-situ water content of the mined rock at the quarry sites was taken as the undisturbed/saturated rock matrix water content. This water content was calculated using Equation B.2-1 (above) assuming G_s = 2.7 and e = 0.06 (based on Golder database for similar rock formations). The resulting natural in-situ rock matrix water content is 2.0% (dry wt. basis).

B.2.5 Sampling/Analysis of Wash Plant Discharge Water

At one of the sites, the pit below water table, a sample of the wash plant discharge water was obtained for grain size analysis of the suspended sediment. The sample (approximately 20L volume) was collected in a plastic pail at the wash plant, from the tank where the sediment ladden wash water is pumped out to the sedimentation pond. The sample was transported to Golder's laboratory and the suspended solids were allowed to settle within the pail. The clear water supernatant was carefully decanted and the sediment removed and oven dried at 110ºC. Upon oven drying, the sediment was analyzed for grain size distribution using a hydrometer (ASTM Method D422-63). The results are presented in Figure B.1 and indicate that the wash sediment is comprised primarily of silt sized particles (0.075 mm – 0.002 mm diameter range) with some clay size material (<0.002 mm diameter).

B.3 CONSUMPTIVE USE CALCULATIONS

The objective of the water consumption calculations is to determine the proportion of water consumed in typical aggregate production processes. The consumed water may be compared to PTTW quantities, handled water quantities and/or precipitation volumes to provide context.

Water consumed by site operations may typically be broken down into the following:

- aggregate processing – water shipped with aggregate products including the portion of natural in-situ water versus wash water in shipped product (i.e., how much wash water is added to shipped aggregate products);
- aggregate processing – water evaporated from the final product stockpiles; and
- dust control

The following provides an overview of the methodology to calculate the above quantities.

B.3.1 Aggregate Processing

B.3.1.1 Volume of Water Shipped with Aggregate Products

As described in Section B.2, shipping stockpiles of screened/washed and screened/unwashed product were sampled on one event in the fall of 2004 and analyzed for water content.

The total annual volume of water shipped with aggregate products was calculated by multiplying the measured shipping stockpile water content (total wet weight basis) by the annual shipped tonnage of the product recorded at the scale house. Note that this assumes that the measured water content values for the individual shipping piles (obtained from one sampling event in the Fall of 2004) reflect the annual average water content of the shipped products. This is considered a reasonable assumption for this study.

B.3.1.2 Volume of Wash Water Added to Shipped Aggregate Products

Water is added to the aggregate during the washing process and by precipitation on product stockpiles. The amount of water added on an annual basis was assumed to be the difference between the total water volume shipped with the products (Section B.3.1.1) and the in-situ water volume associated with the mined aggregate source material (see Section B.2.4). The results of this calculation are presented in Table 3 in the main report. Note that the there is a potential for in-situ water to be lost by evaporation at the extraction face and during storage in the surge pile prior to screening and washing. However, site observations regarding the time between extraction and processing indicated that this time was typically minimal and thus the amount of evaporation would be small to negligible.

B.3.1.3 Volume of Water Evaporated from the Washed Final Product Stockpiles

An estimate of the total annual volume of water evaporated from the product stockpiles was obtained by multiplying the stockpile surface areas by an average annual evaporation depth taken from Environment Canada water budgets for the local area. Average stockpile sizes were determined based on the annual shipped product tonnages and site photos. Surface areas were then quantified for the stockpile sizes.

B.3.2 Dust Control

Water consumed by dust suppression was generally calculated from site records of the number of water trucks per day which apply water, and the volume of water per truck.

B.4 WATER HANDLING

Water handled at the site is water which is moved (pumped or hauled with aggregate) to conduct aggregate operations. Examples include quarry dewatering (comprised of precipitation, upstream runoff, groundwater seepage), water applied for dust control, water used for aggregate washing (make-up water and recycled wash plant water) and water contained in stockpiled and shipped aggregate products.

For above groundwater table sites, a source of water (well, river, lake, etc.) is required for site operations. A portion of the extracted water is returned to the environment with the site's stormwater runoff through surface water discharge or infiltration to groundwater.

For below groundwater table quarries, dewatering is required to maintain dry working conditions. The sources of dewatering water are precipitation on the site, upstream runoff which flows into the site and groundwater seepage.

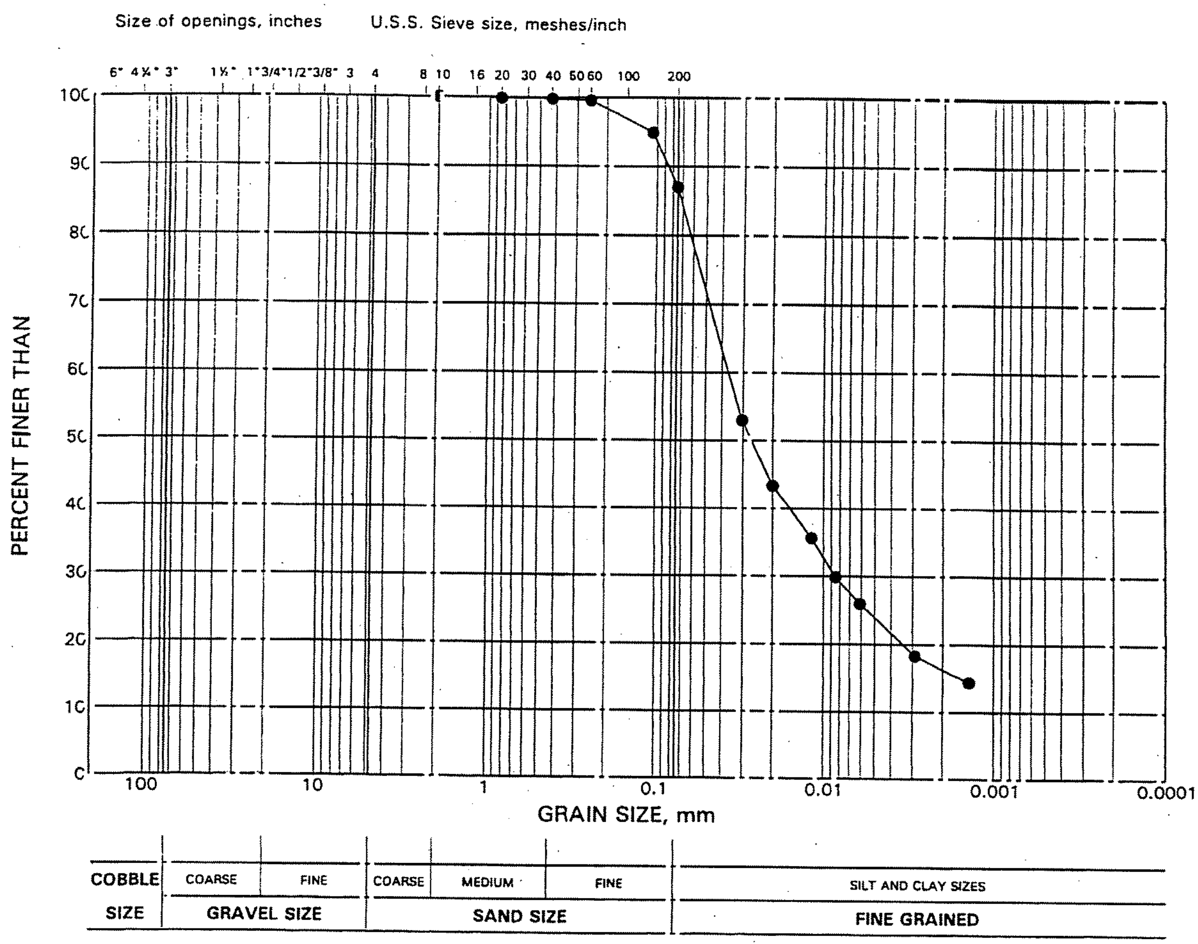
Quarry dewatering and water used for aggregate washing (make-up water and recycled wash plant water) were obtained from site records. Other quantities are described above in consumptive use calculations.

B.5 PRECIPITATION VOLUMES

Average annual site specific precipitation volumes were calculated to provide context for the handled and consumed water quantities. It is important to reference an appropriate gauge based on distance from site, record length and suitability (e.g., elevation difference and local climate) issues. Monitoring locations were screened for the various issues. The site's footprint and total drainage area to the site's point of discharge were delineated. Precipitation volumes were calculated by multiplying the average annual precipitation depth by the delineated area.

GRAIN SIZE DISTRIBUTION

FIGURE B.1



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)
●		Wash Plant Sediment (Pit / Below Water Table)	

Date 10/13/2004

Project 04-1112-059

Golder Associates

Prepared by LG

Checked by ________