DE BEERS
A DIAMOND IS FOREVER

28 February 2003

Mackenzie Valley Environmental Impact Review Board (MVEIRB)
Box 938, 5102 – 50th Avenue
Yellowknife, NT X1A 2N7

Attention: Glenda Fratton, Environmental Assessment Coordinator

Dear: Glenda

SUBJECT: Meeting Minutes: Phosphorus Loading and Algal Modeling for the Snap Lake Project

Please accept the attached minutes from a meeting with intervenors held on 10 February 2003 for submission to the Public Registry. This meeting was held in response to phosphorus loading and algal modeling concerns raised during the MVEIRB Technical Sessions.

Should you have any questions, please feel free to contact the undersigned.

Sincerely,
SNAP LAKE DIAMOND PROJECT

ORIGINAL SIGNED BY

Robin Johnstone
Senior Environmental Manager

DE BEERS CANADA MINING INC.

#300 – 5102 50th AVENUE
YELLOWKNIFE NT X1A 3S8 CANADA
TEL (867) 766-7300 FAX (867) 766-7347

625

DE BEERS
A DIAMOND IS FOREVER

File:

MINUTES OF MEETING

TIME: 9:00 am – 3:30 pm

DATE: 10 February 2003

LOCATION: De Beers Boardroom, 3rd Floor Scotia Center

SUBJECT: Phosphorus Loading and Algal Modeling for the Snap Lake Project

DESCRIPTION: The purpose of this meeting was to reach consensus on the modelling of additional phosphorus loading scenarios. The meeting was not intended to address the environment impact implications of changes in phosphorus concentrations, as this has been covered in a memo titled, "Potential Effects of Phosphorus Enrichment on the Productivity of Snap Lake". Discussion focused on the concentrations and bioavailability of different forms of phosphorus in the treated water discharge. The results of an algal model sensitivity analysis and recalibration were presented and discussed.

* Meeting presentations titled, "Phosphorus Loading – Algal Modeling" and "Algal Modeling in Snap Lake: Sensitivity Analysis" are attached.

ATTENDEES: Neil Hutchinson (GLL/MVEIRB), Dave Balint (DFO), Marc Lange (DFO, morning only), Julie Dahl (DFO, morning only), Anne Wilson (EC), Gavin More (GNWT), Sevn Bohnet (INAC, morning only), Francis Jackson (INAC, morning only), Laurie Cordell (MVLWB), Mark Digel (Golder), Colleen English (DBCMI)
Conference call: Tim Byers (BES for YDFN), Steve Wilbur (Entrix for Dogrib Treaty 11), Don McDonald (MESL for INAC), Kenn Raven (Intera for INAC, morning only), Bob Shelast (Stantec for NSMA, afternoon only)

DISTRIBUTION: Attendees plus: Public Registry

ITEM	DESCRIPTION	ACTION
1.0	**Where does the other 1/3 of the water collected go if not accounted for in the working face contribution?** The greatest concentration change is in the recent or active mining areas. Other water does not come in contact with the active face. **Is the water that runs back through the paste backfill not accounted for?** The paste is very tight and would actually be releasing water, so water would tend to flow around these areas. We didn't want to assume just clean groundwater coming in, so the groundwater inflow in contact with mining areas was assumed to have an increase in phosphorus concentrations.	De Beers to contact project geochemists and mining engineers in order to provide a rationale for how "Working Face Contributions" of groundwater were estimated.
2.0	**Are you using a representative average concentration, or changing concentrations?** The model does a week-by-week concentration, but for illustrative purposes today, I have used the average for Years 15-22, which is very	See Item 10.0.

DE BEERS

A DIAMOND IS FOREVER

ITEM	DESCRIPTION	ACTION
	representative of maximum loadings. Changes in concentration over time are included in the EA, and the model does account for total loading over time. **Will there be spikes in the phosphorus concentration that the water treatment plant (WTP) will have to handle over time, ie: how uniform is the phosphorus concentration in the groundwater?** Groundwater inflow comes through the mine, so yes, there is variability is the WTP source water to a certain extent, but it is not a "spikey" process. Phosphorus loadings tend to gradually increase over time. There is a limit to what we can predict with models, with respect to short-term variability, so we have to focus on the intent of modeling, ,which is to predict the long-term response of Snap Lake to nutrient loadings, which was done in the EA using a very sophisticated approach. As an example of the long-term loading focus, Diavik has shifted to an annual loading limit versus a daily or monthly criteria. **Respecting the uncertainties with the model, perhaps we use Don McDonald's suggestion from the Technical Session Breakout Session of running a standard deviation?** This is a possibility, but it should be kept in mind that standard deviation (SD) is an approach usually taken for toxic substances and one SD is a very unlikely circumstance. SD's do not deal with variability, we would have to use an average and then a SD on top of that, so this addresses a different issue than short-term variability.	
3.0	**What is the specific concentration of orthophosphate (OP)?** The WTP does not remove orthophosphate so we assume no reduction and 10 ug/L is a blended concentration of all sources of water. Diavik OP concentrations in the groundwater are 95% of 300 ug/L. Snap is 10 ug/L, from a combination of sources. There is a decrease in this concentration over time due to lower amounts of connate water entering the mine. **So the depth of groundwater sampling is adequate to estimate the concentrations and you are not expecting an increase with depth?** Correct. If this is still a question, I can provide you with a more explicit explanation of how this was done. **What is the modeled OP concentration of groundwater recharge from Snap Lake in Year 15-22?** 6 ug/L, as stated in the last table of the presentation. This is a conservatively high estimate because it does not account for any algal uptake of OP.	De Beers to provide a memo that: 1) clarifies the distribution and concentration of phosphorus forms in connate water with depth, and 2) substantiates that phosphorus does not increase with depth.
4.0	**Table 1 provides minewater discharge concentrations for dissolved phosphorus (DP), but Appendix IX of the EA does not have concentrations that high. Are we to ignore the numbers is Appendix IX (DP = 10 ug/L)?** The EA did not look at DP because we did not think that it was in a form that contributed to algal growth in the lake, so we focused on OP. I would suspect that the concentration you speak of is OP, but I would have to re-visit Appendix IX before providing you with a response on this.	De Beers to confirm that the DP value in Appendix IX (Table IX.1-12) is mostly OP.
5.0	**Where does the DP originate from if there is no relation to PP?** Within a proportion of the groundwater and dissolution at the active mine face results in fine colloidals with no relation to TSS as there is no filtration. **If we extrapolate the graph of DP vs. TSS to 0 TSS, you would have 20 ug/L DP remaining. Is the other incremental level beyond 20ug/L colloidal?** Yes, it would be in some form that is adsorbed. **So you don't assume more of the very fine form is adsorbed into the water?** Correct.	De Beers to provide statistical significance (p-value) on DP-TSS relationship in underground mine water from AEP samples.
6.0	**There is a range of TSS values without treatment?** Correct. **If we assume DP is truly DP and eliminate the colloidal (11ug/L or 8%), this is most likely bioavailable?** It is most likely to be dissolved, but not necessarily bioavailable.	

DE BEERS
A DIAMOND IS FOREVER

ITEM	DESCRIPTION	ACTION
	So only half of the total dissolved phosphorus (TDP) is bioavailable? Correct. We did not address the other phosphorus in the EA, so the question is how do we treat this in the modeling scenarios being discussed today? We did a literature review on phosphorus availability in groundwater but there was no information available. Groundwater is not normally considered a source of phosphorus contributing to the eutrophication of lakes. The key outcome of this meeting is agreement on what cases to look at and what they mean. **Considering what we know and what we don't know, might suggest performing a sensitivity analysis and then determining what is available from this.** This is what I was thinking. We don't know the percentage of DP not available so we run what you are comfortable with and then discuss what that means. **Sensitivity analysis is a good way to go. Run the 100% scenario. In Table 1, the recharge value for Snap is 6 ug/L – have you run the productivity model at that level, or is this the 10% zone?** The groundwater recharge from Snap Lake was calculated in the site water quality model assuming mixing in 10% of Snap Lake (this is the 10% zone).	
7.0	**What is the Diavik scenario?** 95% of the groundwater there is OP. They only considered OP as contributing to eutrophication. There was no consideration of the mining process; this is the first time this has been looked at.	
8.0	***(Suggestion of running the model using both labile and OP at 25, 50 and 100%)*** **What is the difference between running the model with labile or OP? Is one a slower process?** Yes, running the model with OP results in a more conservative approach because OP is immediately bioavailable, whereas labile phosphorus will result in a slower release of OP. In the model labile phosphorus would be included as organic phosphorus. This keeps the predictions conservative as organic phosphorus likely mineralizes more rapidly than labile phosphorus in the treated water discharge. **Could you clarify what you mean by organic phosphorus?** When algae dies, the phosphorus within it is unavailable until it is broken down to OP. It is a first order reaction that can be expressed as a half life. The decay rate in the model is 0.0072/day, so if you convert this it would take time to decay – it is a relatively slow process. This difference is what would make it worthwhile to run both scenarios.	The algal settling rate is to be run at zero sensitivity analysis for 'lower' and complete the 'higher' sensitivity analysis using the maximum algal growth rate.
9.0	**There is question surrounding the under ice pre-break up concentrations of phosphorus.** Wouldn't expect to see a seasonality with total phosphorus, and we certainly have not seen this to date. **Disagreement that De Beers has enough baseline data to make that assumption.** The model is not set up to try and account for all the variability. Trophic effects focus on average variability, which is minor when compared to the results of higher loading scenarios.	De Beers to distribute relevant sections of the RMA-11 model, showing technical details of algal production coefficients to those who wish to review them.
10.0	**If OP is low, why is the Chorophyll *a* (Chl a) so high? The net pool does not change?** Correct. OP would not stay low if we were not within a phosphorus-limited system. Within the algal model in general, there are a combination of rates that affect TP more than OP and Chl a. Settling terms and sediment release rate are the most sensitive in the model (see slide). **How is it that settling terms is the most sensitive?** Due to PO_4 adsorption and the benthic release rate. Sensitivity analysis (SA) simulations are not intended to represent reality, only changing individual parameters will affect model results. **How do the parameters of a SA affect the outcome?** We have a good range of model rates within two calibrations so we could run both calibrations. When modelling, we need to consider how changes to the lake could throw off the balance. We are not predicting a level of trophic change that would cause a shift in the net balance of phosphorus settling and release over the long-term. We can model at 1	De Beers will run the following scenarios: 1. OrthoP + a percentage of DP as OrthoP. Three percentages will be run, 25%, 50% and 100%. All runs will be at expected concentrations from the EA. 2. OrthoP + a percentage of DP as OrgP. Three percentages will be run, 25%, 50% and 100%. All runs will be at expected concentrations from the EA. 3. OrthoP + 50 percent of DP as

DE BEERS
A DIAMOND IS FOREVER

ITEM	DESCRIPTION	ACTION
	SD; this would result in higher phosphorus concentrations, but would have to recognize this represents a low probability of occurrence. **After mine start up, at what point would you get better information by continuing to calibrate the model?** All the way along. **How did you represent gradual versus threshold effects in terms of community feedback?** We do not expect threshold affects in the communities, nor do we see substantial changes in the overall ecosystem – it is expected to be more of a gradual affect. ***General discussion on which model scenarios to run.** Consensus was reached on running the modelling scenarios listed in the action column using the revised (alternate) calibration.	OrthoP, with all site water concentrations at +1 standard deviation above expected concentrations. 4. OrthoP + 50 percent of DP as OrgP, with all site water concentrations at +1 standard deviation above expected concentrations. 5. OrthoP only, but run at +1 standard deviation above expected concentrations. - The four highest priority runs will be: 1. Scenario 5 2. Scenario 2 at 100% 3. Scenario 3 4. Scenario 2 at 50% - In all scenarios orthophosphate (OrthoP) will be included, plus a proportion of dissolved phosphorus (DP). The DP will be included as either OrthoP (immediately bioavailable) or as organic phosphorus (OrgP) (i.e., labile). - Note: All terminology is consistent with the Phosphorus Loading Update - Draft Technical Memorandum, dated February 4, 2003. - All simulations will be run using the revised (alternate) calibration.

APPROVED BY:
R. Johnstone
Senior Environmental Manager

DE BEERS

Algal Modelling in Snap Lake

Sensitivity analyses

DE BEERS

Algal Model EA Predictions

- Compared to Baseline, Algal Model predicted Project water releases would:
  - increase in Chlorophyll a concentrations
  - decrease phosphorus concentrations

	Baseline	Operations	Trophic Boundary
Chlorophyll a	0.8	1.3	2 - 2.5
Total phosphorus	8	5	10 -12

- Decrease in TP concentrations resulted from a net increase in P settling due to:
  - Increased algal settling
  - Increased PO4 adsorption and settling

DE BEERS

Sensitivity Analyses

- Recalibrated model with lower settling terms
  - Sensitivity of results to different combinations of rates for model parameters
- Increased or decreased individual model parameters
  - Sensitivity of results to individual parameters

De Beers

Selected Algal Model Parameters

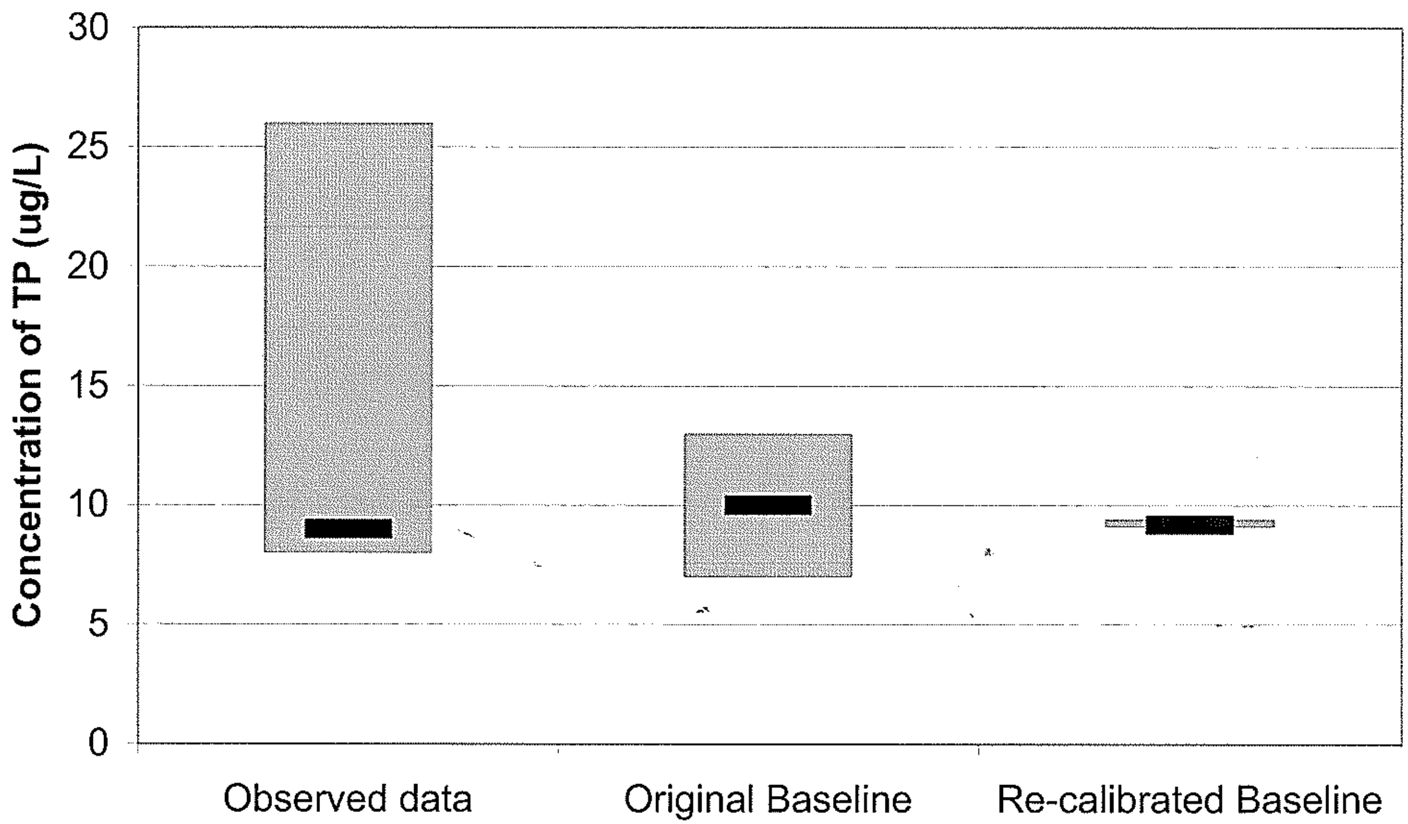
Sediment release rate	Units	Calibration		Sensitivity Analysis	
		EA	Alt.	Lower	Higher
Algae					
Maximum algae growth rate	1/d	1.87	1.75	1	3
Algal settling rate	m/d	0.08	0.01	0.1	0.6
Org-P					
Org-P mineralization rate	1/d	0.007	0.003	0.001	0.01
PO4					
Sediment release rate	$mg/m^2/d$	0.48	0	0.1	0.4
PO4-P adsorption rate	1/d	0.012	0	0.01	0.1

Algal Model Parameters - Effect on TP and Chl a

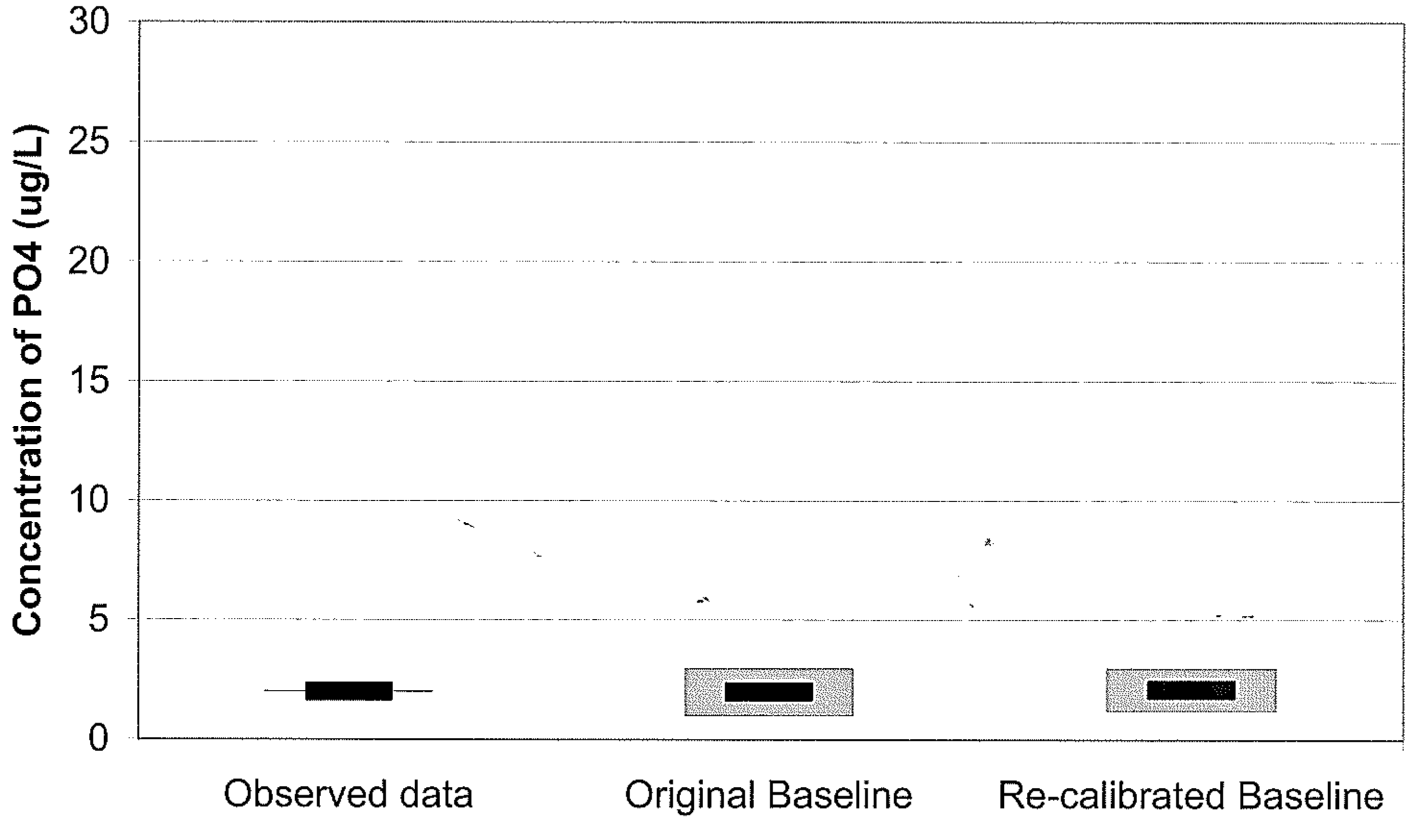
	TP & Chl a
♦ **Algae**	
– Maximum algal growth rate	⌦
– Algal settling rate	↓
♦ **Organic Phosphorus**	
– Organic P mineralization rate	↑
♦ **Orthophosphate**	
– Sediment release rate	↑
– Adsorption and settling rate	↓

DE BEERS

Recalibration Results - Total phosphorus

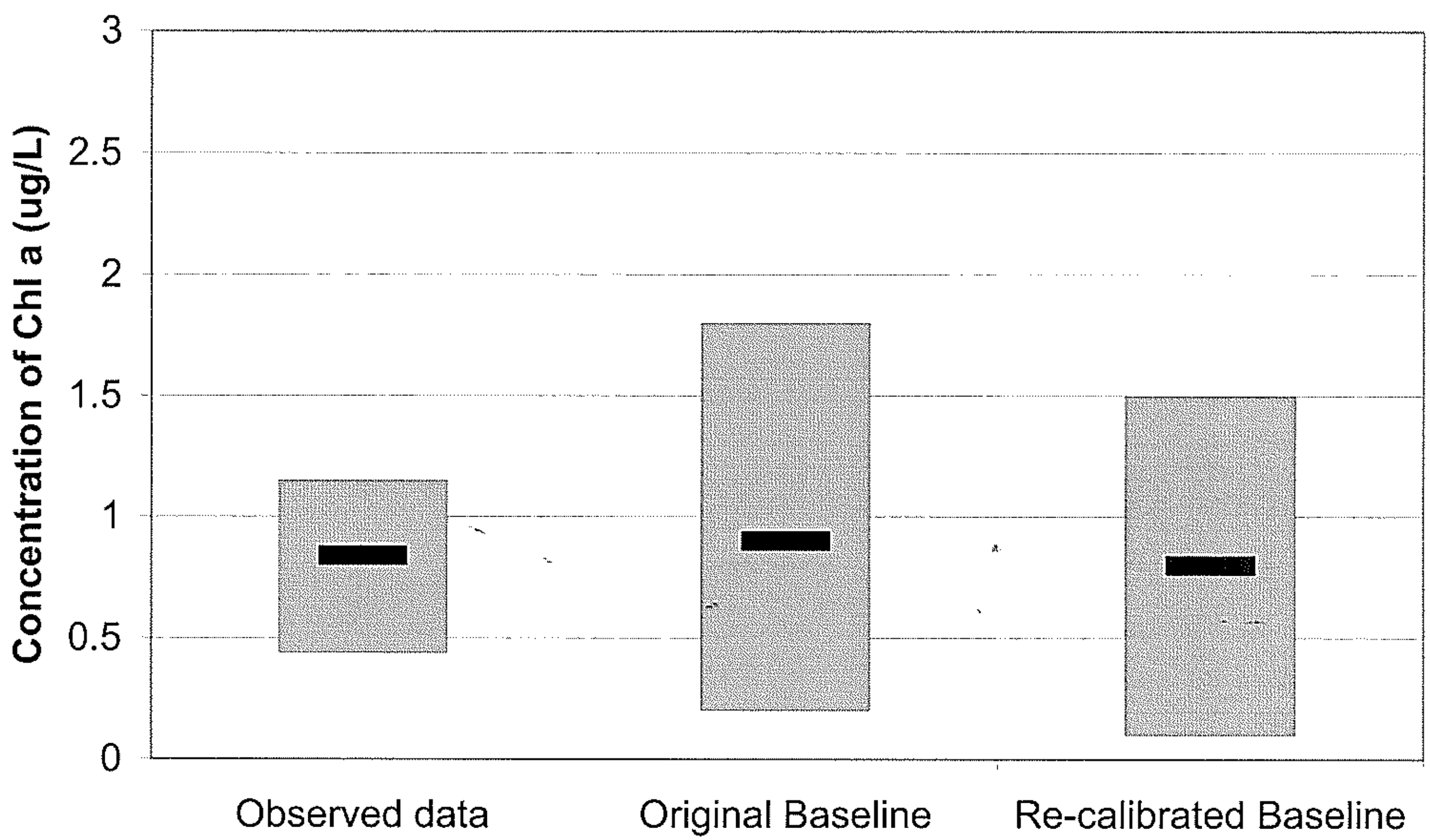


Recalibration Results - Orthophosphate



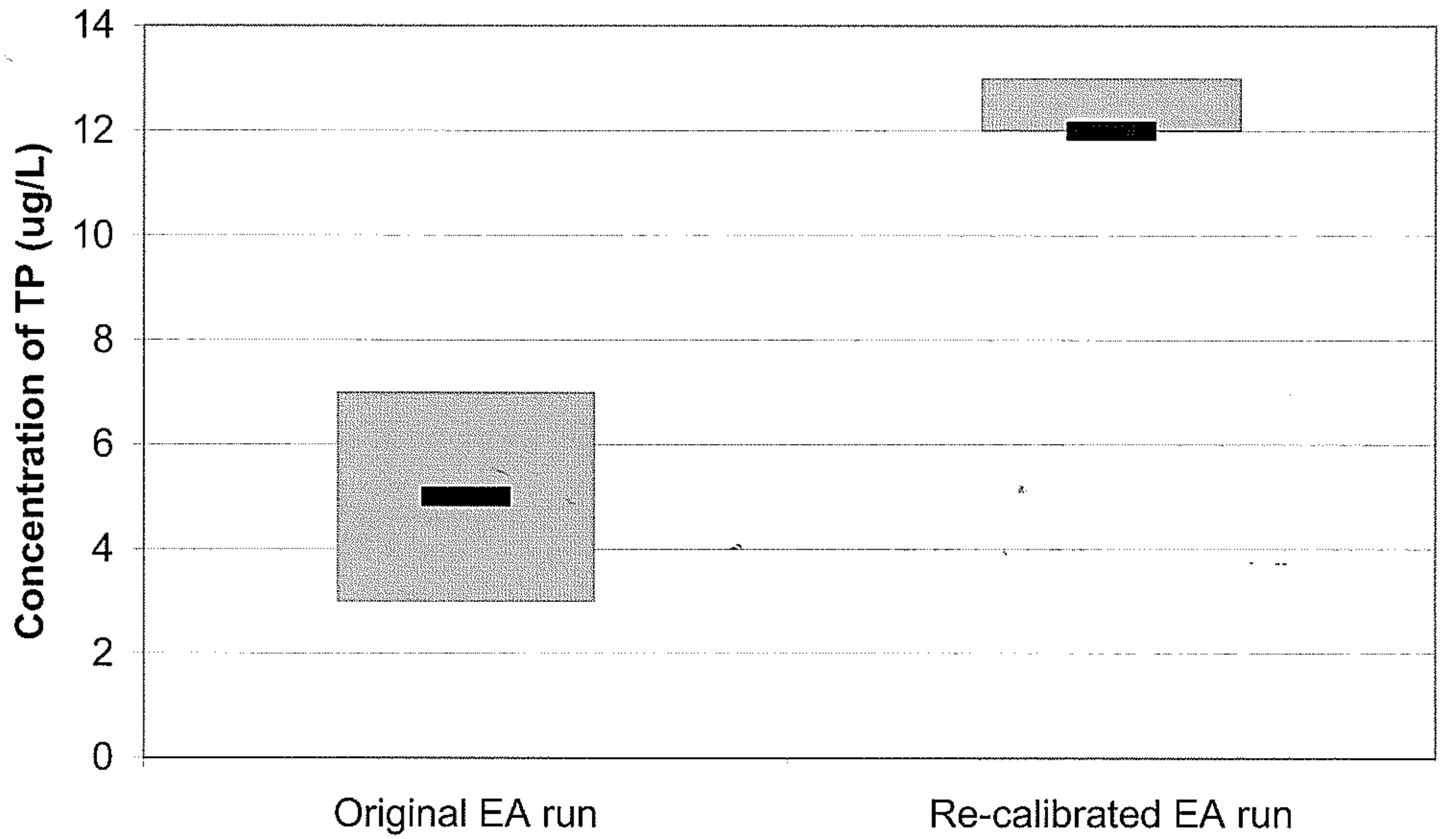
De Beers

Recalibration Results - Chlorophyll a



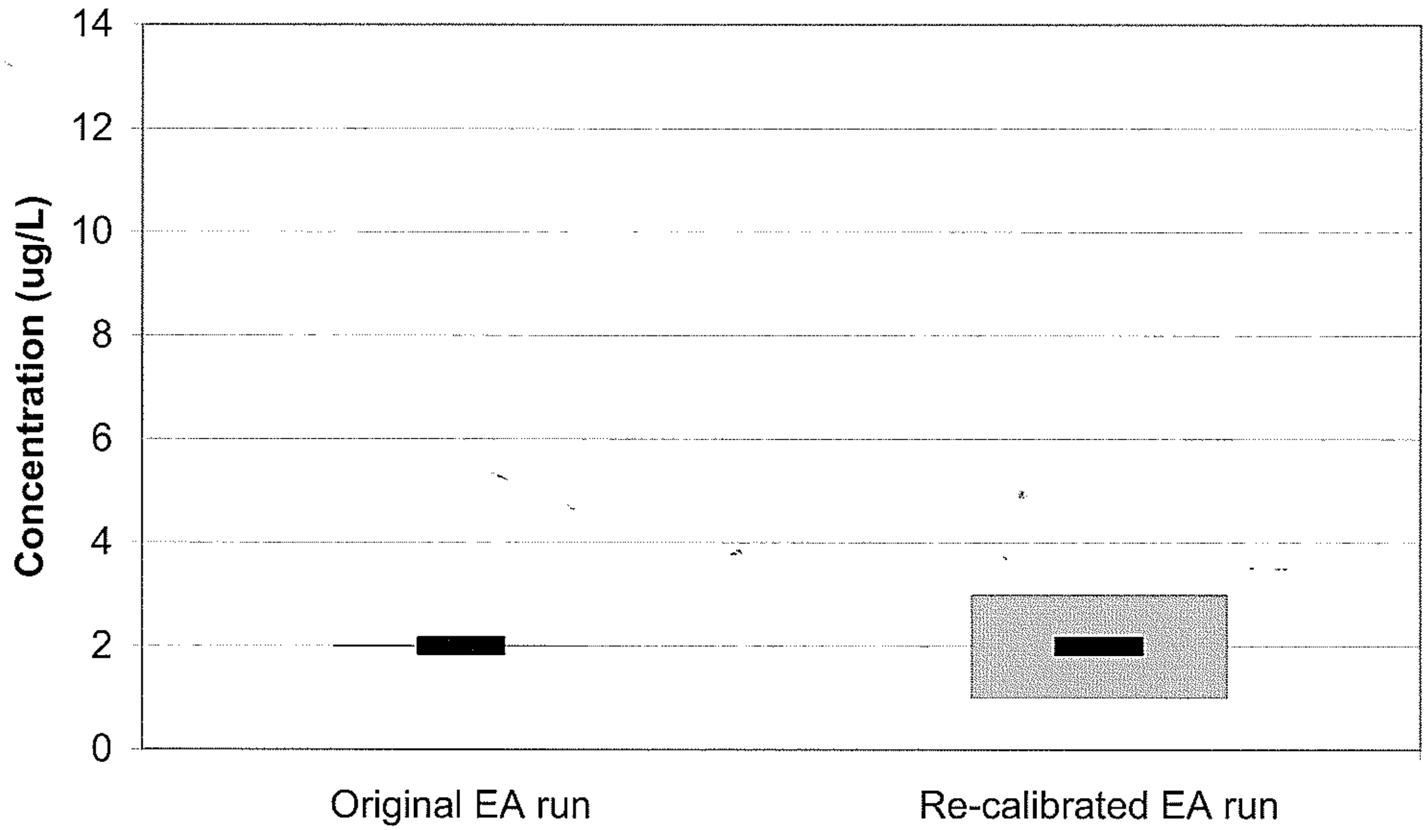
De Beers

EA Results - Total phosphorus



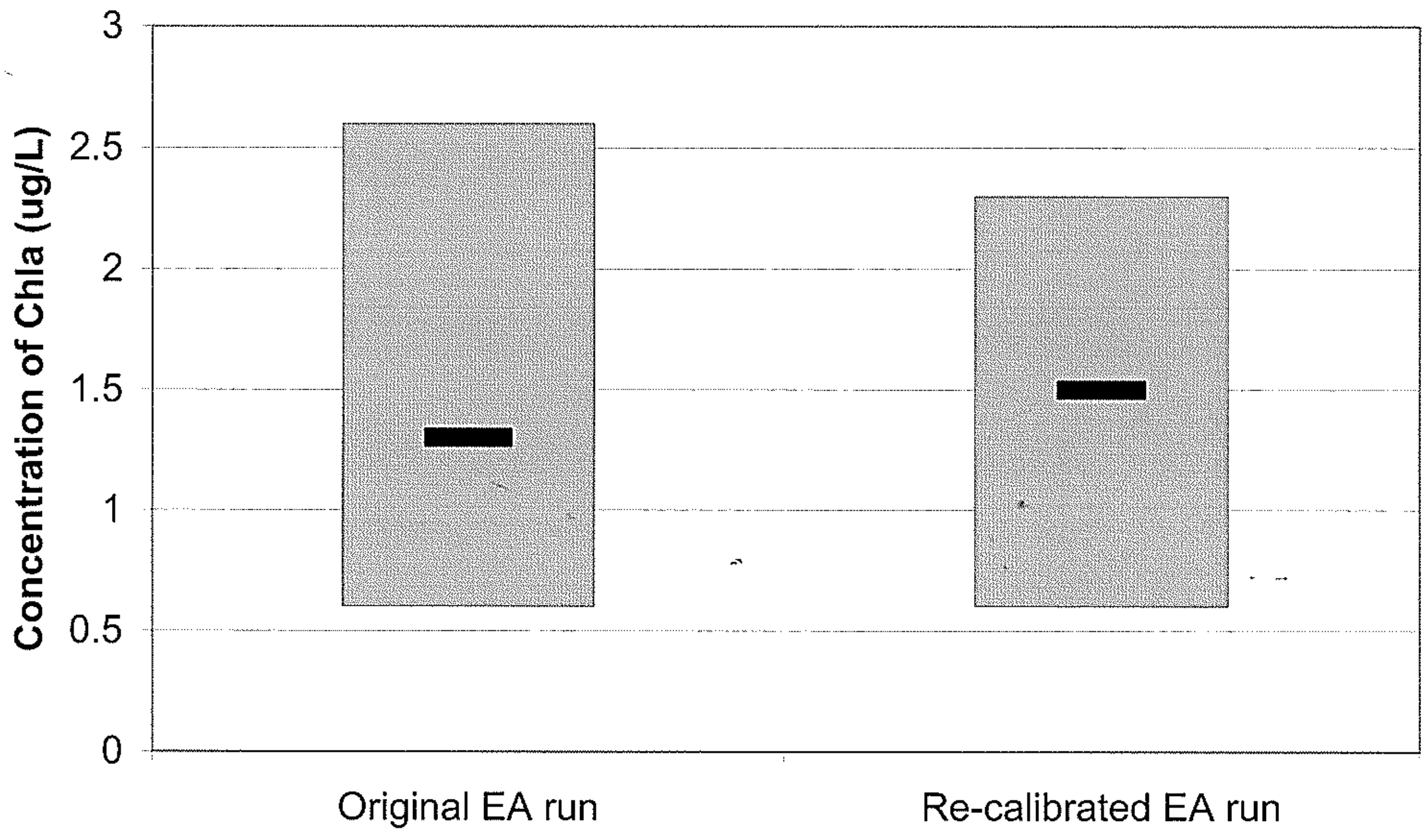
DE BEERS

EA Results - Orthophosphate



DE BEERS

EA Results - Chlorophyll a



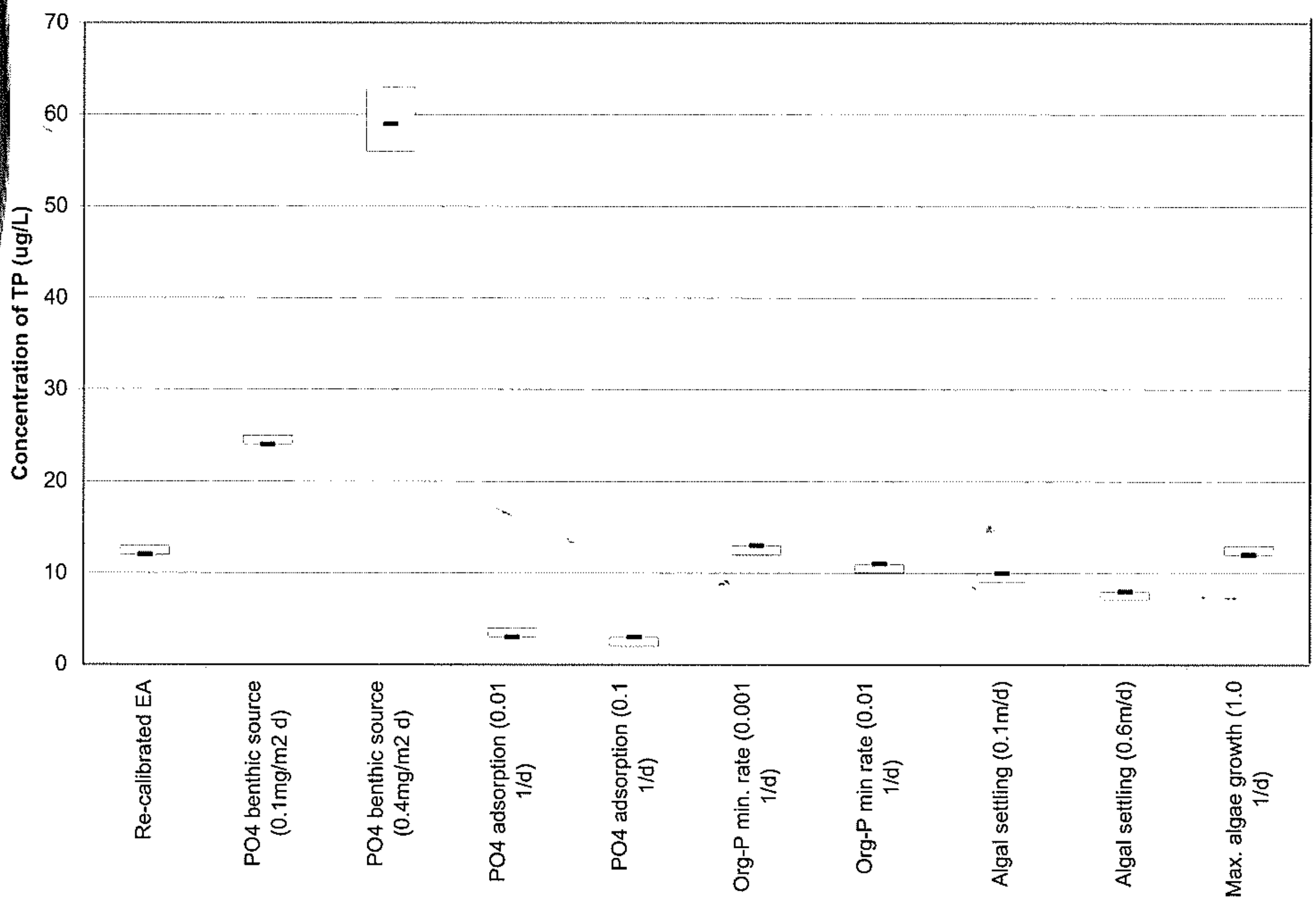
De Beers

Conclusions of Sensitivity Analyses

- There is no unique combination of model parameters rates for baseline calibration
  - EA: higher algal and OrthoP settling balanced by sediment OrthoP release and Org P mineralization
  - New: all rates lower but still balanced
- TP results are sensitive to different calibrations
- Chl a and OrthoP results are not sensitive to different calibrations

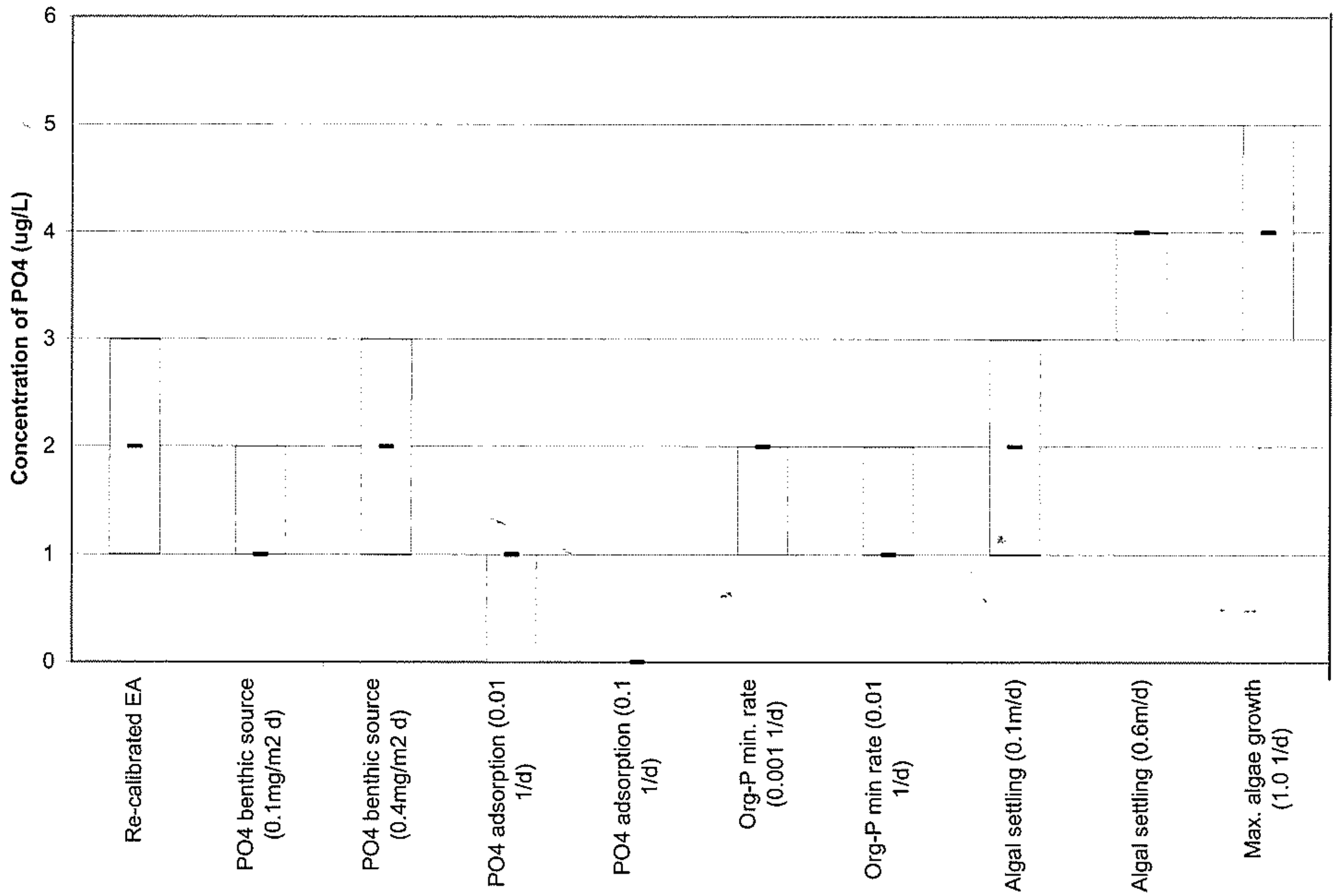
De Beers

Sensitivity Analysis Results - Total Phosphorus



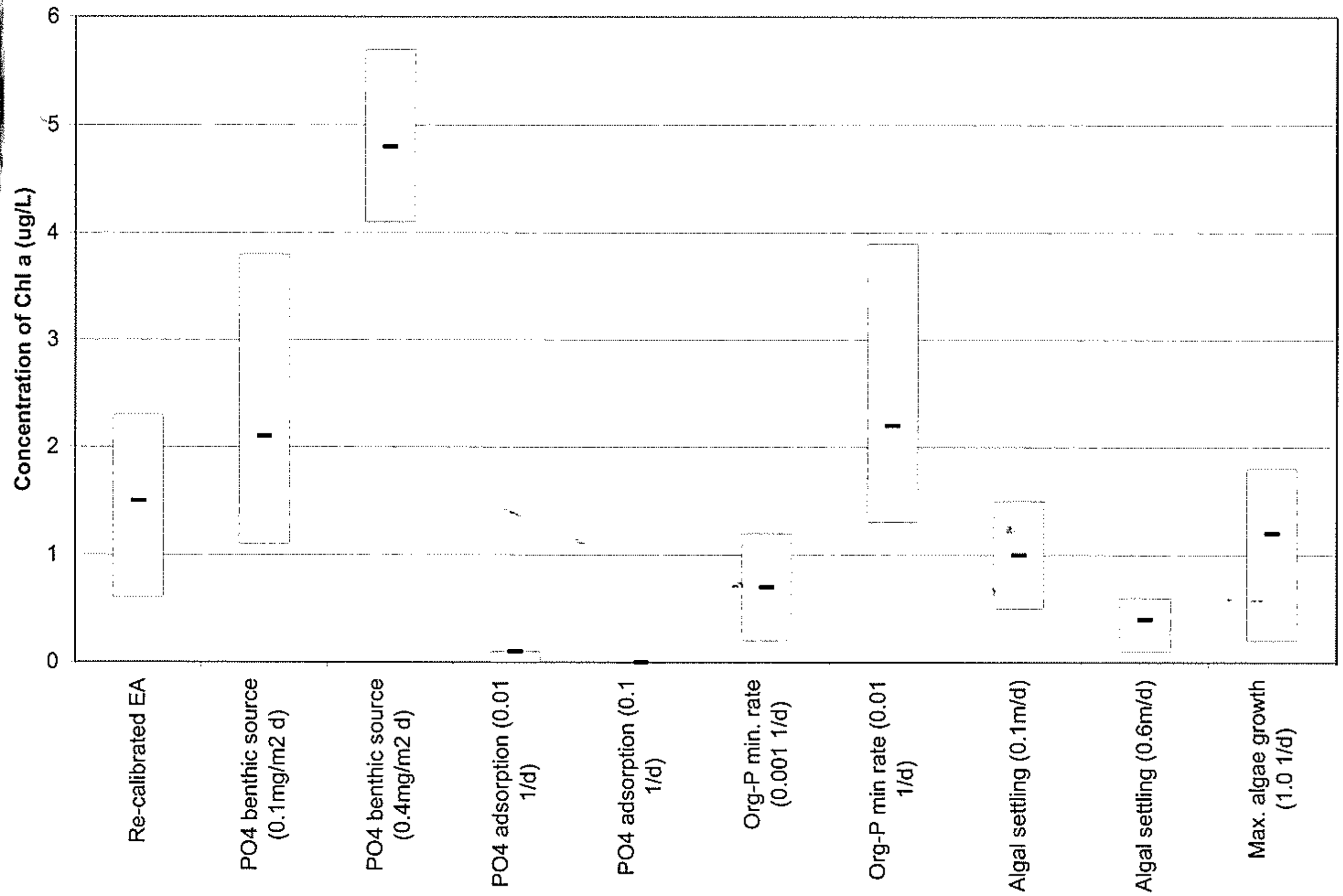
De Beers

Sensitivity Analysis Results - Orthophosphate



DE BEERS

Sensitivity Analysis Results - Chlorophyll a



De Beers

Phosphorus Loading - Algal Modelling

Objectives:

- Reach consensus on forms of phosphorus in water discharge that could affect algal concentrations in Snap Lake
- Define additional modelling requirements to satisfy concerns regarding the effect of the Snap Lake Diamond Project on algal concentrations in Snap Lake
- Define the path forward between now and the MVEIRB hearing

DE BEERS

Proposed Agenda

- Phosphorus Loading
  - Presentation on sources, forms, concentrations and loadings
  - Discussion
- Algal Modelling
  - Presentation on results of sensitivity analyses
  - Discussion
- Wrap-up
  - Consensus on phosphorus loading scenarios
  - Additional model run(s)

DE BEERS

Phosphorus in water discharged to Snap Lake

Sources

Forms

Concentrations

Loading

DE BEERS

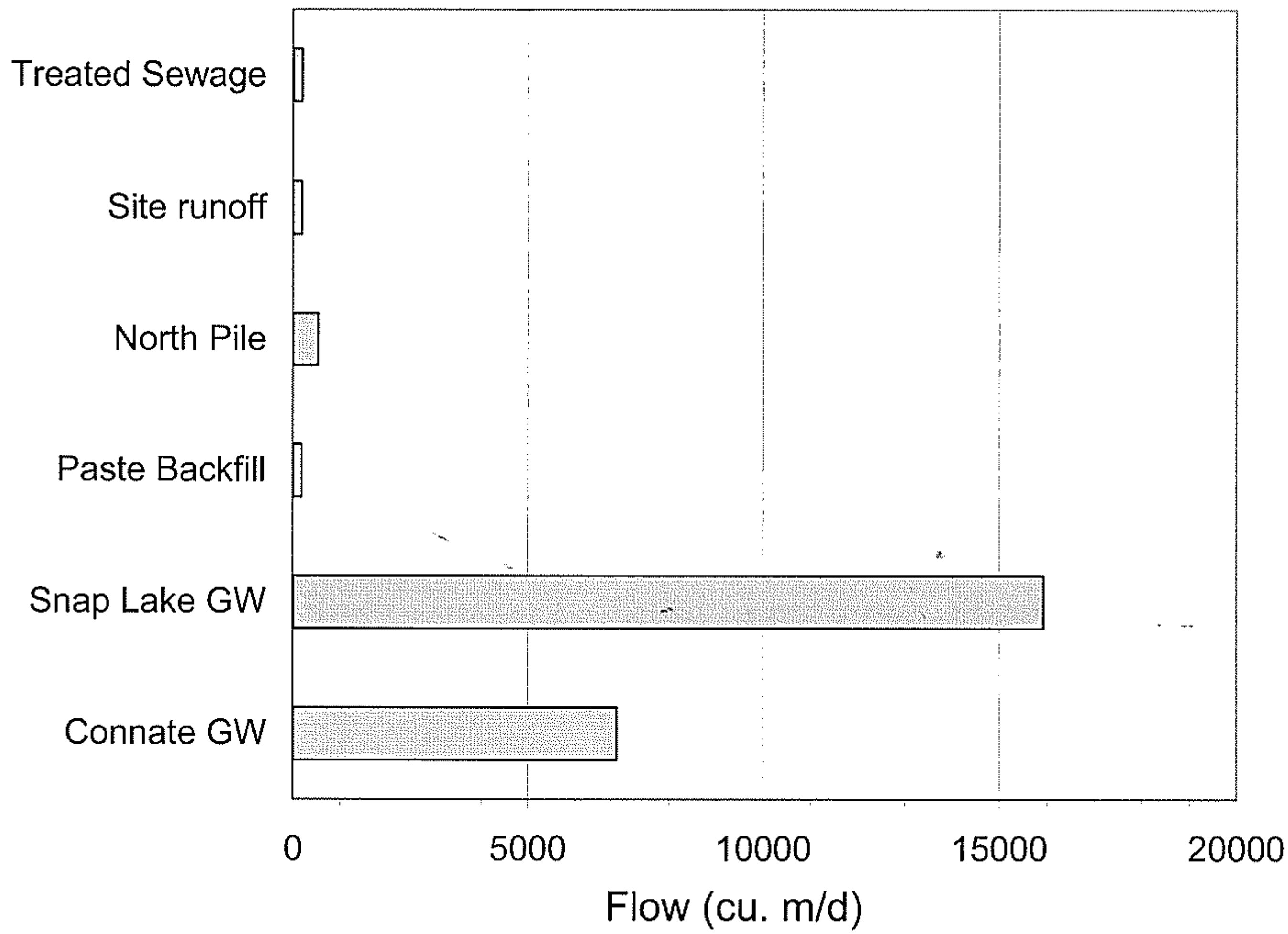
Phosphorus - Sources

- Underground
  - Connate groundwater inflow
  - Snap Lake recharged groundwater inflow
  - Increase in mine water concentrations at active working face
  - Paste backfill consolidation
- Surface
  - North pile seepage and runoff
  - Runoff from developed and undeveloped areas
  - Sewage treatment plant

DE BEERS

Flow contributions to water release

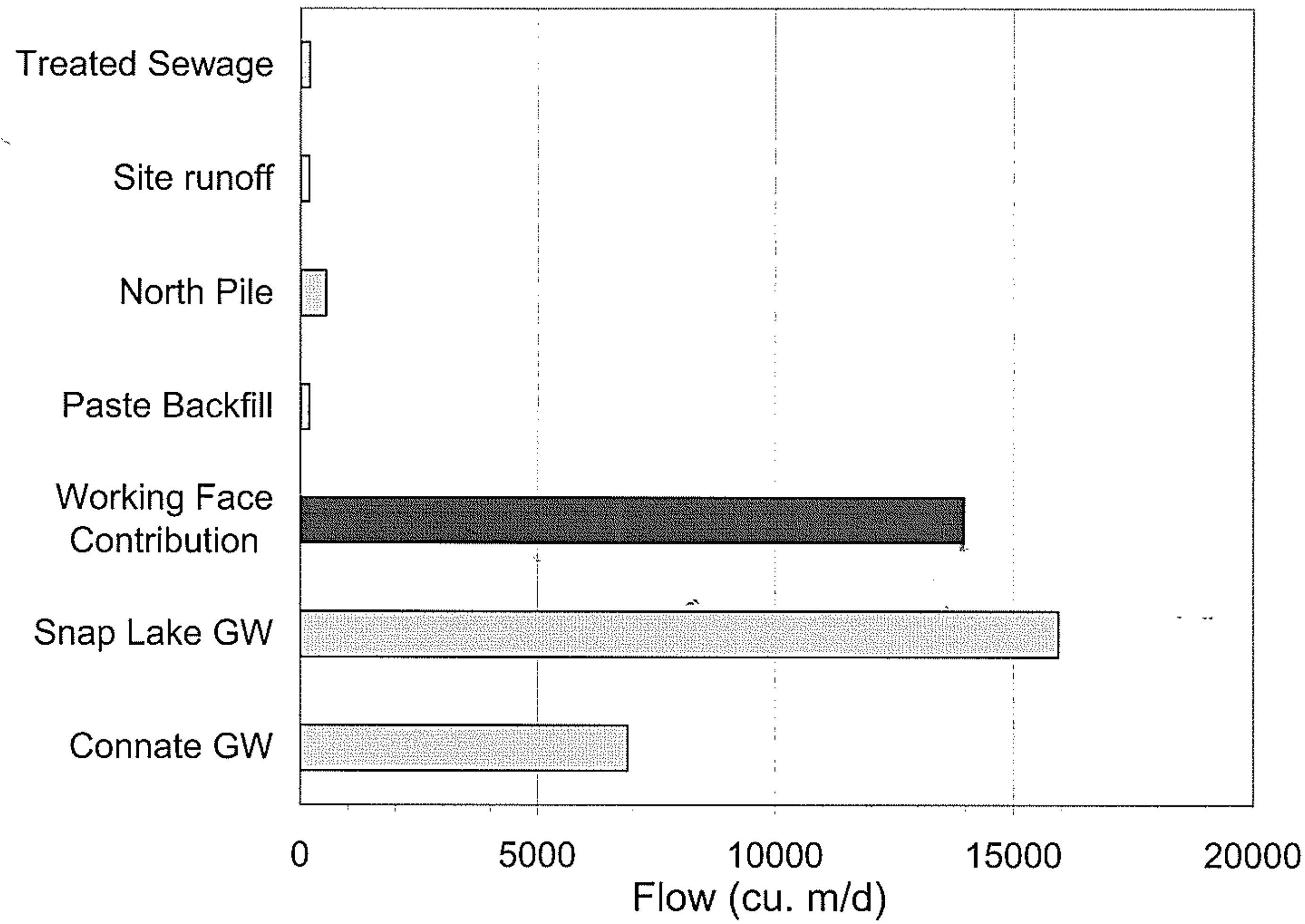
Average for years 15 - 22



DE BEERS

Working face contribution

Average for years 15 - 22



De Beers

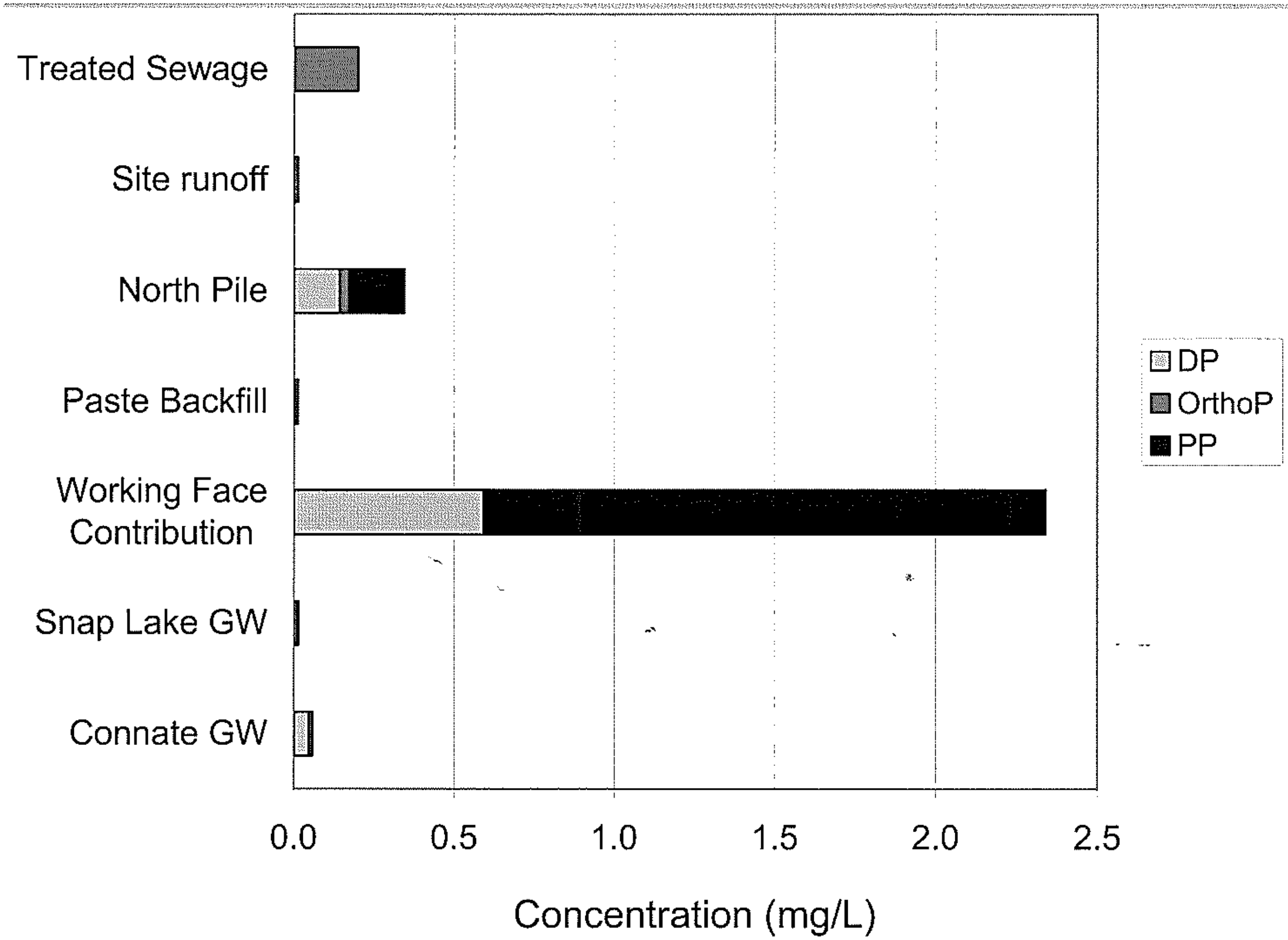
Phosphorus - Forms

- Total Phosphorus in Groundwater/Minewater
  - Particulate
    - Mineral (PP)
  - Dissolved
    - Orthophosphate (OrthoP)
    - Dissolved mineral phosphates & Colloidal phosphorus (DP)

DE BEERS

Phosphorus - Concentrations (pre-treatment)

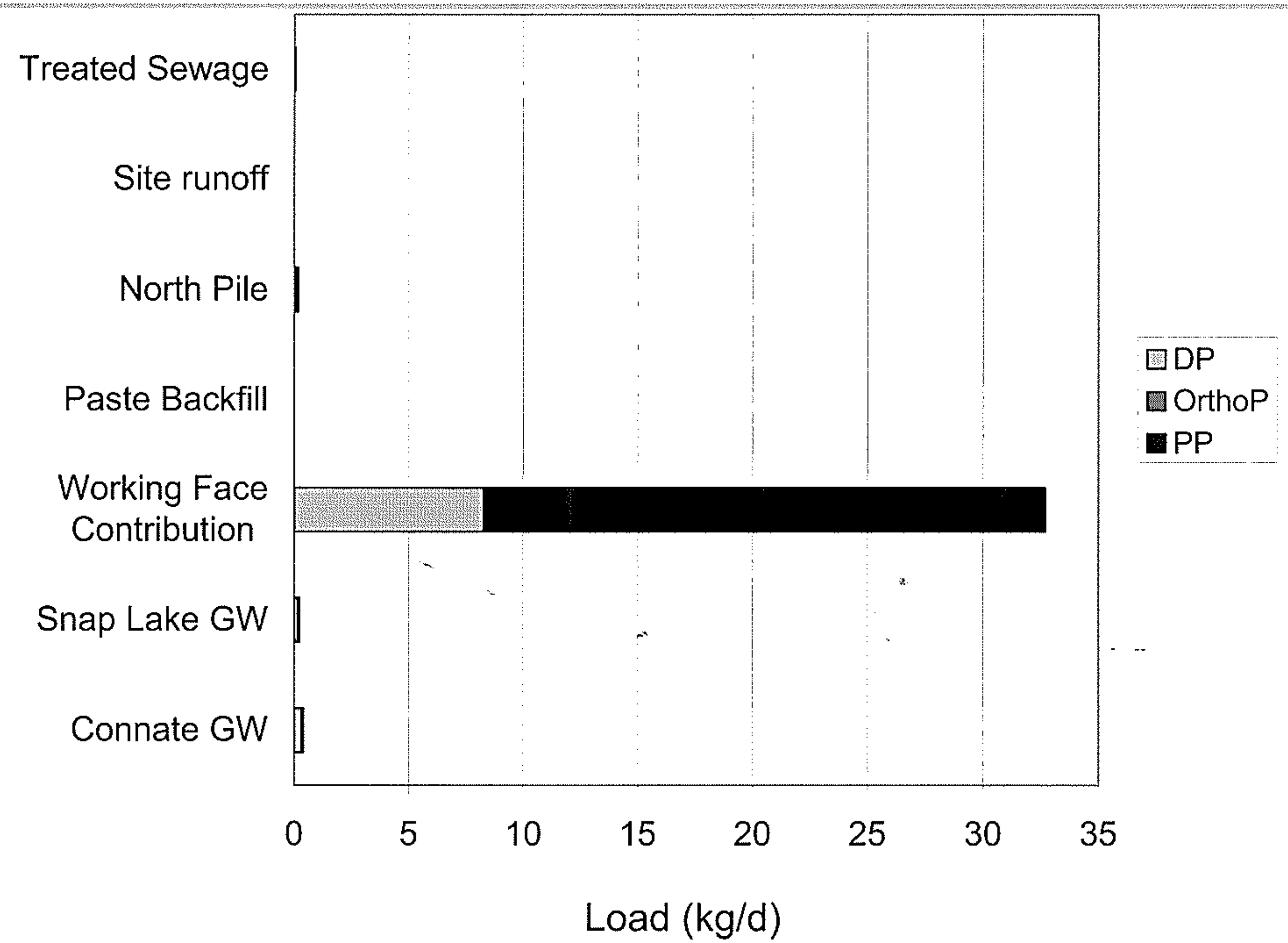
Average for years 15 - 22



DE BEERS

Phosphorus - Loading (pre-treatment)

Average for years 15 - 22

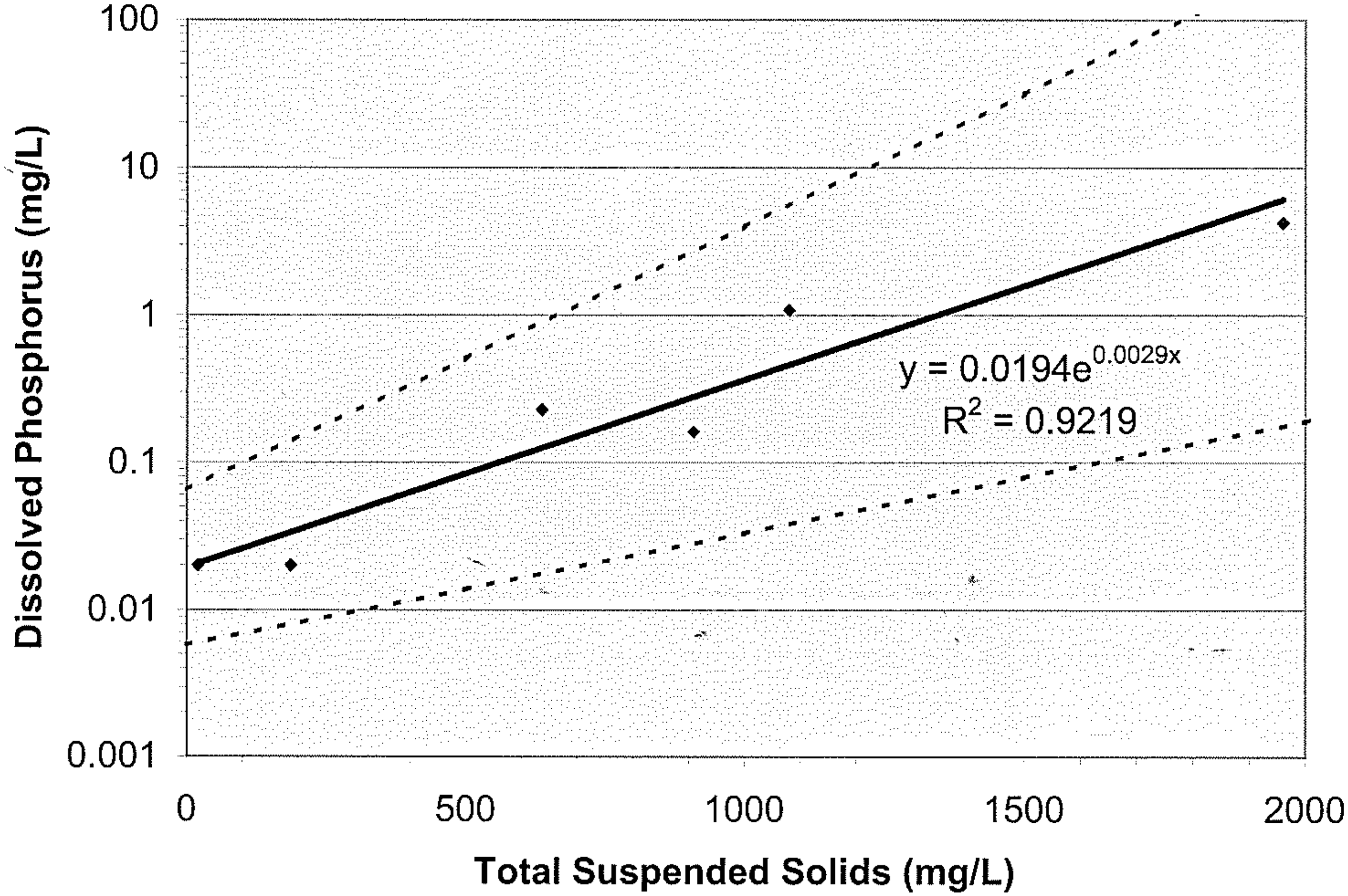


Phosphorus - Water Treatment

- Particulate (PP)
  - Will remove PP proportionately to TSS removal
- Orthophosphate (OrthoP)
  - No removal assumed in modelling
- Dissolved (DP)
  - Removal of colloidal component
  - No removal of dissolved component

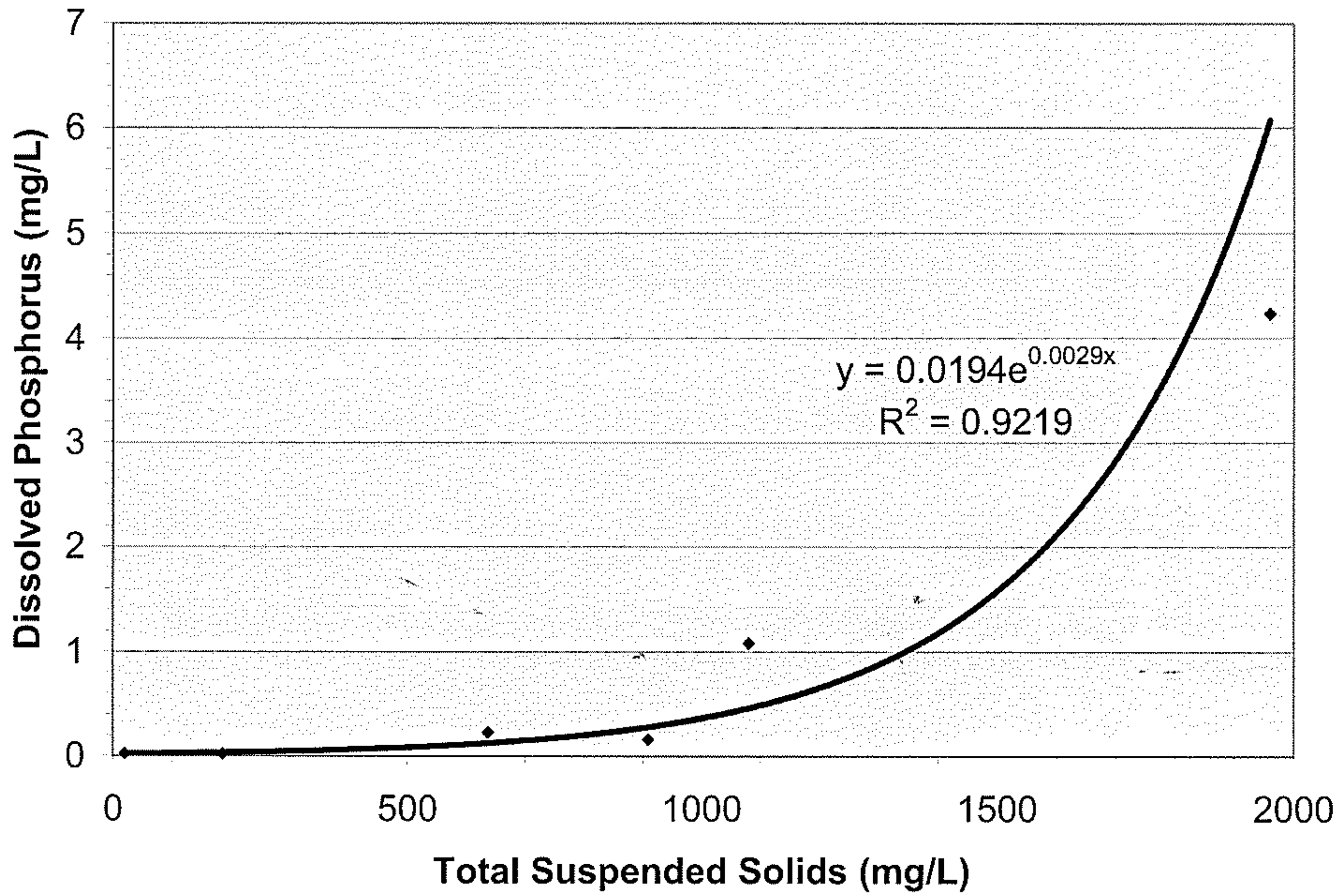
DE BEERS

Dissolved Phosphorus in Underground Minewater - From AEP



De Beers

Dissolved Phosphorus in Underground Minewater - From AEP

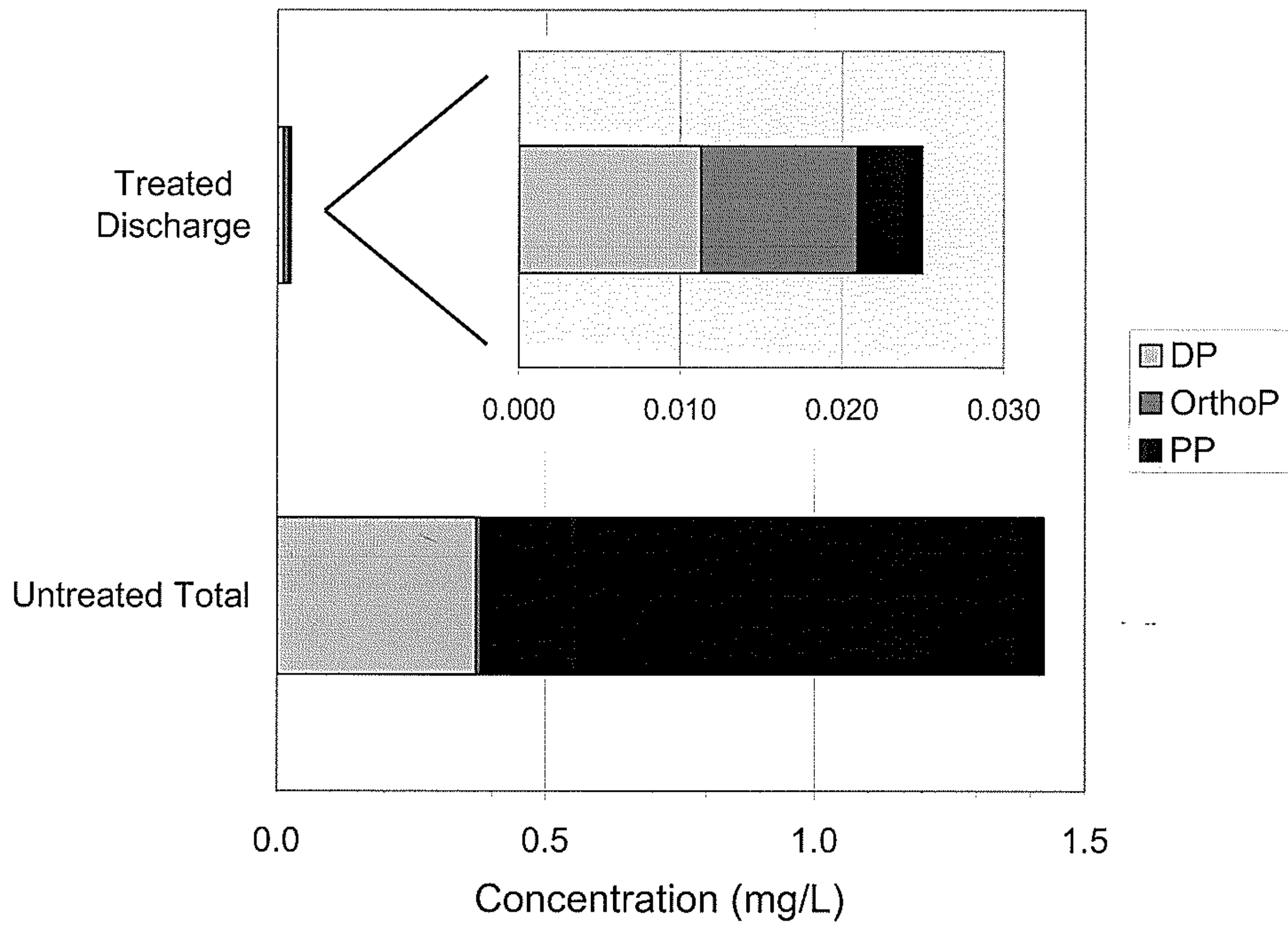


Same as previous graph without log scale

De Beers

Phosphorus - Concentrations
Pre- and Post-treatment

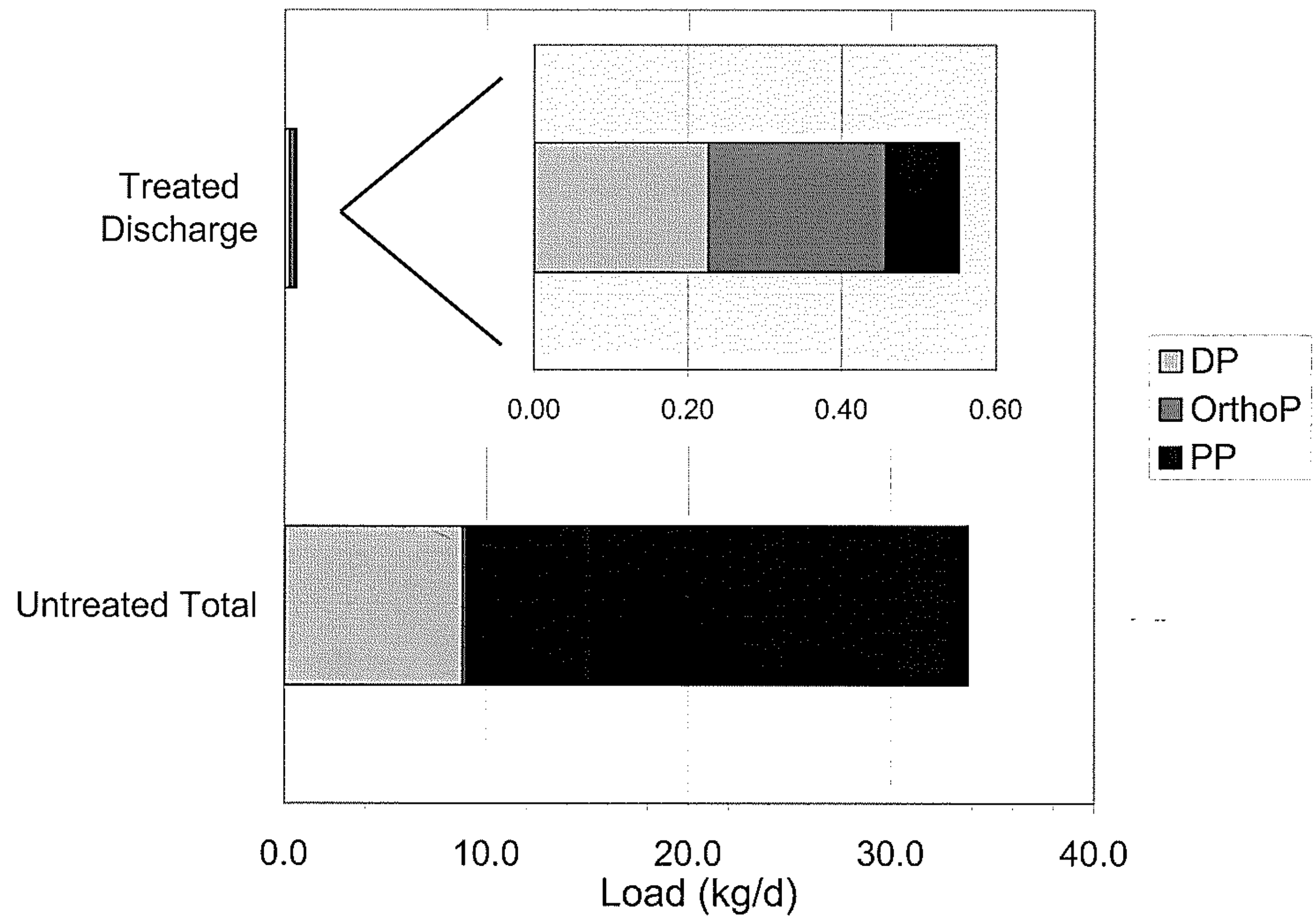
Average for years 15 - 22



DE BEERS

Phosphorus - Loading
Pre- and Post-treatment

Average for years 15 - 22



DE BEERS

Phosphorus - Availability

- Immediately Available
  - Can be utilized directly by Algae
  - Orthophosphate
- Labile
  - Relatively stable but reactive forms that can be converted to orthophosphate by bacteria
- Refractory
  - Stable and not reactive, except with very long contact times

DE BEERS

Phosphorus - Available Forms

- Total Phosphorus in Groundwater/Minewater
  - Particulate
    - Mineral
  - Dissolved
    - Orthophosphate
    - Dissolved mineral phosphates ?
      Colloidal phosphorus ?

} Not included in EIA

DE BEERS

Options for DP in treated discharge

- OrthoP only (EA case)
- OrthoP + 0 to 100% DP as OrthoP
- OrthoP + 0 to 100% DP as Labile P

Flows, phosphorus and TSS concentrations and mass loadings in site waters

	Flow/loading component	Flows (m³/d)	Concentration (mg/L)					Load (kg/d)			
			DP	OrthoP	PP	TP	TSS	DP	OrthoP	PP	TotalP
Inflows to Mine	Connate groundwater inflow	6894	0.047	0.012	0.000	0.059	31	0.32	0.08	0.00	0.41
Inflows to Mine	Recharge from Snap Lake	15934	0.009	0.006	0.000	0.015	0	0.15	0.09	0.00	0.24
Inflows to Mine	Paste backfill consolidation	182	0.000	0.013	0.000	0.013	0	0.000	0.002	0.000	0.002
Inflows to Mine	Incremental Chemistry at Working Face	13965	0.591	0.000	1.750	2.341	2120	8.25	0.00	24.44	32.69
Inflows to Water Treatment	from the Mine	23010	0.379	0.008	1.076	1.463	1299	8.72	0.18	24.77	33.67
Inflows to Water Treatment	North Pile runoff and seepage	533	0.142	0.030	0.172	0.344	2175	0.08	0.02	0.09	0.18
Inflows to Water Treatment	Site runoff	185	0.010	0.004	0.000	0.013	28	0.002	0.001	0.000	0.00
Inflows to Water Treatment	Treatment Feed [Total]	23728	0.371	0.008	1.045	1.424	1309	8.80	0.20	24.79	33.79
	Treated Sewage	200	0.000	0.200	0.000	0.200	25	0.000	0.04	0.00	0.04
	Treated Discharge to Snap Lake	23701	0.011	0.010	0.004	0.025	5	0.23	0.23	0.09	0.59

Notes: DP = total dissolved phosphorus - OrthoP, OrthoP = orthophosphate, PP = particulate phosphorus, TP = total phosphorus
TSS = total suspended solids

Average for years 15 - 22