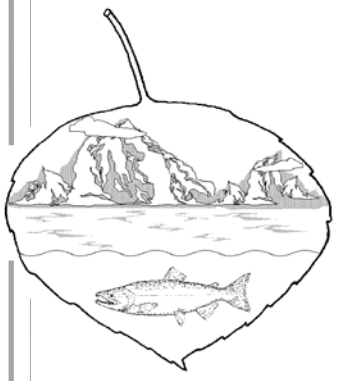

Aspen Applied Sciences Ltd.

Environmental Scientists and Consultants

August 9, 2002

Bob Westcott
BC Hydro and Power Authority
601 - 18th Street
Castlegar, B.C. V1N 4G7

Dear Bob:

With regard to the development of TGP performance measures for the Columbia River WUP process, I have completed the review of the relevant literature and submitted the final report as per the contract stipulations. The report recommends interim TGP thresholds of 115% and 120% for the Columbia River WUP performance measures. In addition, supporting experimental studies are recommended and described. The next step in developing the performance measures is to decide on the period over which alternate yearly hydrographs are to be included in the analyses and the time increments to be used. It appears that there is some question as to whether daily average flow data can be generated for the 45 years of record that have been used in past WUP analyses. There is also some question as to the relevance of the past 45 years of flow data to present and future operations of the Hugh Keenleyside Dam. As I already have indicated, I do not believe that monthly average flows, combined with monthly average total heads, can yield sufficiently accurate exceedence analyses for comparing alternate yearly hydrographs. All of these issues must be resolved within B.C. Hydro before the next steps in developing performance measures can be taken.

As we have discussed, Alan Woo has suggested using monthly average flow data, but with dam total heads calculated on a daily basis using linearly interpolation based on end of month values. This can be done to yield quasi-daily average data. However, I believe the flow and total head calculations will have to be performed by B.C. Hydro. Once this is completed, the HLK/TGP/GBT computer model can be used to predict Columbia River TGPs on a daily basis and the exceedence analyses can then be performed. However, if many years of data are to be analyzed, we cannot use the HLK/TGP/GBT model as we have in past exceedence analyses (i.e., on a one day at a time basis). An alternate approach would be to recode the program to read large flat file data. I estimate this could take up to 20 days to complete. However, I would like to suggest a still different approach. I recommend that we first use the HLK/TGP/GBT computer model to run a range of operating conditions to define a corresponding range of river TGPs. The two key parameters would be total discharge and total head.

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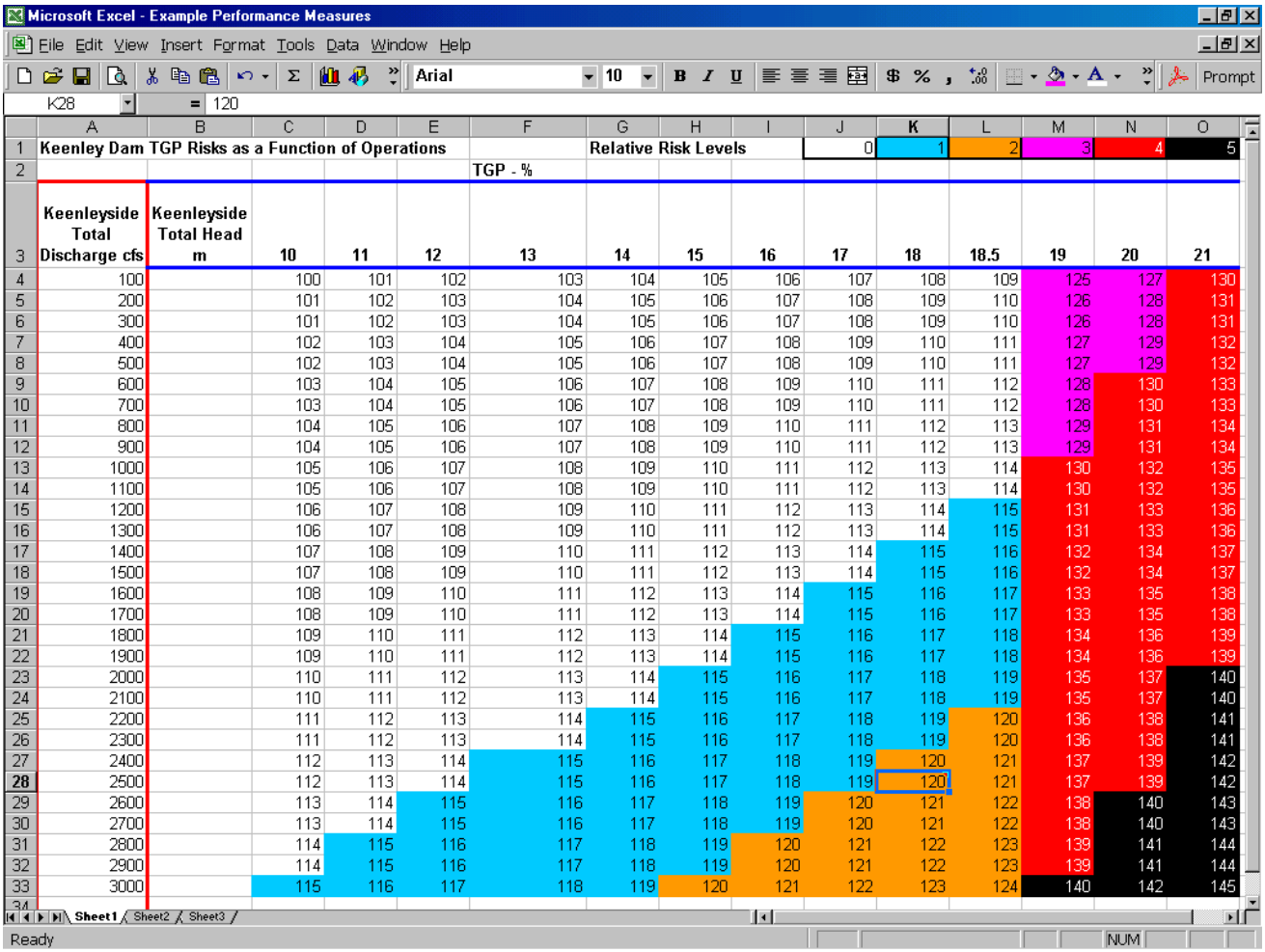
Because the HLK/TGP/GBT program has the local operating order constraints and the gate sequencing requirements built in, the automatic mode of the program assures configuring the discharge facilities to minimize TGP. The results of the HLK/TGP/GBT model analysis would allow the construction of an Excel spreadsheet table of river TGP as a function of total discharge and total head. An example of the spreadsheet is shown in Figure 1 below.



Microsoft Excel - Example Performance Measures

File Edit View Insert Format Tools Data Window Help

Arial 10 Prompt

K28 = 120

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Keenley Dam TGP Risks as a Function of Operations						Relative Risk Levels			0	1	2	3	4	5
2						TGP - %									
3	Keenleyside Total Discharge cfs	Keenleyside Total Head m	10	11	12	13	14	15	16	17	18	18.5	19	20	21
4	100		100	101	102	103	104	105	106	107	108	109	125	127	130
5	200		101	102	103	104	105	106	107	108	109	110	126	128	131
6	300		101	102	103	104	105	106	107	108	109	110	126	128	131
7	400		102	103	104	105	106	107	108	109	110	111	127	129	132
8	500		102	103	104	105	106	107	108	109	110	111	127	129	132
9	600		103	104	105	106	107	108	109	110	111	112	128	130	133
10	700		103	104	105	106	107	108	109	110	111	112	128	130	133
11	800		104	105	106	107	108	109	110	111	112	113	129	131	134
12	900		104	105	106	107	108	109	110	111	112	113	129	131	134
13	1000		105	106	107	108	109	110	111	112	113	114	130	132	135
14	1100		105	106	107	108	109	110	111	112	113	114	130	132	135
15	1200		106	107	108	109	110	111	112	113	114	115	131	133	136
16	1300		106	107	108	109	110	111	112	113	114	115	131	133	136
17	1400		107	108	109	110	111	112	113	114	115	116	132	134	137
18	1500		107	108	109	110	111	112	113	114	115	116	132	134	137
19	1600		108	109	110	111	112	113	114	115	116	117	133	135	138
20	1700		108	109	110	111	112	113	114	115	116	117	133	135	138
21	1800		109	110	111	112	113	114	115	116	117	118	134	136	139
22	1900		109	110	111	112	113	114	115	116	117	118	134	136	139
23	2000		110	111	112	113	114	115	116	117	118	119	135	137	140
24	2100		110	111	112	113	114	115	116	117	118	119	135	137	140
25	2200		111	112	113	114	115	116	117	118	119	120	136	138	141
26	2300		111	112	113	114	115	116	117	118	119	120	136	138	141
27	2400		112	113	114	115	116	117	118	119	120	121	137	139	142
28	2500		112	113	114	115	116	117	118	119	120	121	137	139	142
29	2600		113	114	115	116	117	118	119	120	121	122	138	140	143
30	2700		113	114	115	116	117	118	119	120	121	122	138	140	143
31	2800		114	115	116	117	118	119	120	121	122	123	139	141	144
32	2900		114	115	116	117	118	119	120	121	122	123	139	141	144
33	3000		115	116	117	118	119	120	121	122	123	124	140	142	145

Sheet1 Sheet2 Sheet3

Ready NUM

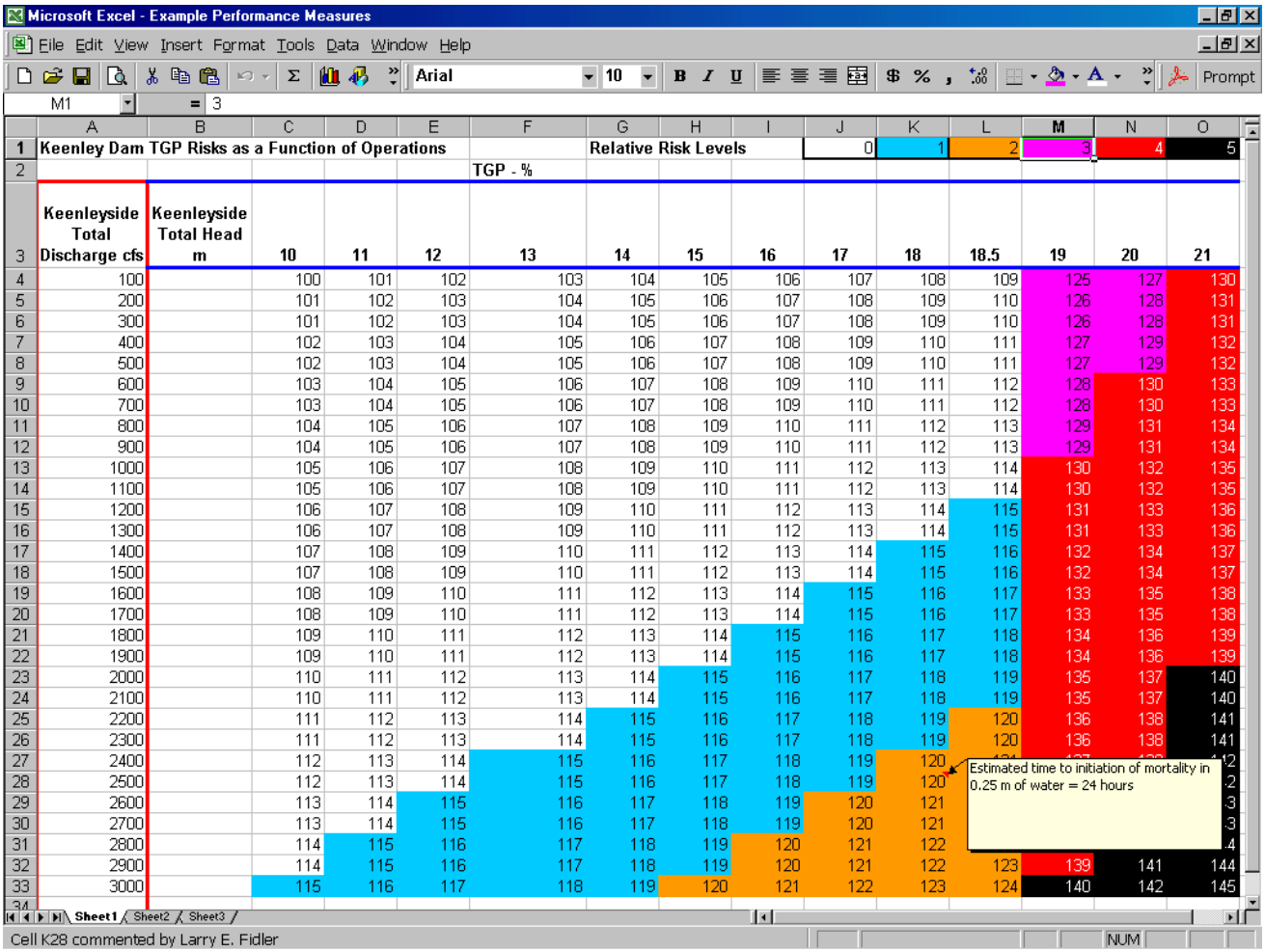
Figure 1: Example of Performance Measure Spreadsheet

In the spreadsheet, the divisions of discharge and total head are quit coarse in order to fit the spreadsheet on the page. In the proposed spreadsheet, the flows might be divided into 25 cms or 50 cms increments while the total head might be in 0.1 m increments. The TGP numbers shown are somewhat arbitrary and were generated with an edit, linear fill, feature of Excel. Notice, that when the total head exceeds 18.5 m, the TGPs rise sharply. Rather than TGP%, ΔP might also be used. Also, I have color coded (somewhat arbitrarily) the cells to reflect relative risk (0 to 5), using a TGP of 115% as the starting point for a risk level of 1. These color codes might be more finely divided in the actual spreadsheet.

Once the spreadsheet is completed, an adjacent spreadsheet could contain 10, 20, 30, or 45 years of quasi-daily average flow and total head data. Using the table lookup feature of Excel, the corresponding TGPs could then be calculated automatically. With the TGPs determined, the

exceedence calculations could be performed on the same spreadsheet. Essentially, the entire Columbia River WUP TGP performance measure analyses could be performed in an Excel workbook. This would avoid having to recode the HLK/TGP/GBT model and allow the overall tasks to be completed more quickly. I estimate it would take between 7 and 10 days of my time to generate the Excel spreadsheet table. Once we decide on how fine the flow and total head increments must be, I can give a more accurate estimate. Once B.C. Hydro has the tabulated flow and total head data, the exceedence analysis should take no more than a couple of days plus a few more days for a final report.

Figure 2: Example of Performance Measure Spreadsheet with Comment



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5	200		101	102	103	104	105	106	107	108	109	110	126	128	131
6	300		101	102	103	104	105	106	107	108	109	110	126	128	131
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8	500		102	103	104	105	106	107	108	109	110	111	127	129	132
9	600		103	104	105	106	107	108	109	110	111	112	128	130	133
10	700		103	104	105	106	107	108	109	110	111	112	128	130	133
11	800		104	105	106	107	108	109	110	111	112	113	129	131	134
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18	1500		107	108	109	110	111	112	113	114	115	116	132	134	137
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25	2200		111	112	113	114	115	116	117	118	119	120	136	138	141
26	2300		111	112	113	114	115	116	117	118	119	120	136	138	141
27	2400		112	113	114	115	116	117	118	119	120				12
28	2500		112	113	114	115	116	117	118	119	120				12
29	2600		113	114	115	116	117	118	119	120	121				13
30	2700		113	114	115	116	117	118	119	120	121				13
31	2800		114	115	116	117	118	119	120	121	122				14
32	2900		114	115	116	117	118	119	120	121	122	123	139	141	144
33	3000		115	116	117	118	119	120	121	122	123	124	140	142	145

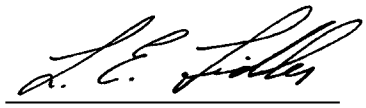
At some point in the future, further improvements can be made to the spreadsheet table. For example, a comment could be attached to each cell that describes the duration of exposure required to produce mortality in shallow water environments. The comments are normally hidden, but when the user moves the mouse pointer over the red triangle in the corner of the cell, the comment appears for that cell. This is shown in Figure 2. The comment cells could contain considerably more that just the time to initiation of mortality. If data were available, this might include species and age class specific information along with temperature dependency. The comment might also contain information on adjusted relative risk based on fish depth (see below).

The spreadsheet can also be cross-referenced with one of the tables from the R. L. & L. Environmental Services (2002) report (rebuilt into an adjacent spreadsheet – Sheet 2), which shows species versus life stage activity and season. The table would be revised to show fish presence/absence and depth for that particular activity rather than risk. Thus, once a total discharge and total head were determined for the Keenleyside Dam, a corresponding TGP, relative risk, and time to initiation of mortality in shallow water could be determined from the spreadsheet. Next, this information could be transferred to the R. L. & L. table for the correct season, a particular fish species, and life stage activity. Depending on the fish depth indicated, the risk could be adjusted accordingly. For example, if the TGP% from the spreadsheet was 125% and the fish were typically in shallow water, the relative risk might be considered a level three (purple) risk. However, if the fish were in 1 m of water, the TGP could be reduced by 10% to 115% and the risk reduced to a level 1 risk. Fish in deeper water would have a zero level risk. An advantage to the spreadsheet is that it can be easily revised as new TGP/GBT data become available.

The proposed spreadsheet approach to performing WUP TGP exceedence analyses should simplify and shorten the process. The spreadsheet table could be developed while we are waiting on the flow/total head data to be generated. The added features that I suggested do not need to be implemented now, but could provide useful tools for assessing GBT risks to fish on a day-by-day basis throughout the year.

I hope this recommendation will be helpful in facilitating the Columbia River WUP process. Please let me know if you have any questions.

Sincerely,



Larry E. Fidler, Ph.D.
President