

**SEDIMENT IMPACT ON
FISHERIES**

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I WOULD LIKE TO BEGIN BY THANKING JIM LANT, MURRAY GALBRAITH AND THE OTHER ORGANIZERS OF THIS SYMPOSIUM FOR THE OPPORTUNITY TO ATTEND AND PARTICIPATE. THE CONTROL AND REDUCTION OF SEDIMENT IS AN IMPORTANT PART OF MINE WATER MANAGEMENT, AND IS CRITICAL TO THE MAINTENANCE OF PRODUCTIVE FISHERIES IN THE LAKES AND RIVERS THAT MINE WATERS ARE DISCHARGED INTO.

WORLD-WIDE, A SIGNIFICANT AMOUNT OF WORK HAS BEEN DONE ON THE IMPACTS OF SEDIMENT ON FISHERIES. MUCH OF IT HAS BEEN DONE IN EUROPE AND THE U.S. WEST COAST, HOWEVER, THERE IS NO REASON TO BELIEVE THAT THE AVAILABLE DATA IS NOT ALSO APPLICABLE TO B.C. AND TO WESTERN CANADA IN GENERAL.

IN THEORY SUSPENDED SOLIDS ARE ALL NON-DISSOLVED MATERIALS IN A WATER SAMPLE, IN PRACTICE THE CUT-OFF BETWEEN DISSOLVED AND SUSPENDED MATERIALS IS BASED ON THE ABILITY OF THE MATERIALS TO PASS THROUGH A 0.4 MICRON FILTER. TOTAL SUSPENDED SOLIDS CAN BE FURTHER SUBDIVIDED INTO SETTLEABLE AND NON-SETTLEABLE SOLIDS, WITH SETTLEABLE SOLIDS DEFINED AS A VOLUME OF PARTICLES THAT WILL SETTLE WITHIN AN ARBITRARY TIME PERIOD. THE SETTLEABLE SOLIDS TEST GENERALLY PROVIDES A MEASURE OF THE CONCENTRATION OF SOLIDS GREATER THAN APPROXIMATELY 10 MICRONS IN DIAMETER. COLLOIDAL SOLIDS SO SMALL THAT THEY REMAIN IN SUSPENSION DUE TO BROWNIAN MOTION ARE THUS NOT INCLUDED. THE SETTLEABLE/NON-SETTLEABLE DISTINCTION IS SIGNIFICANT AS THE TWO FRACTIONS HAVE DIFFERENT IMPACTS ON AQUATIC ECOSYSTEMS.

THIS DISTINCTION IS PARTICULARLY IMPORTANT IN B.C. WHERE RIVERS REGULARLY RECEIVE HEAVY LOADS OF SEDIMENT DURING SNOW MELT. THE SEDIMENTS ARE USUALLY TRANSPORTED WITH LARGE VOLUMES OF FAST FLOWING WATER AND THEREFORE REMAIN IN SUSPENSION UNTIL REACHING A LAKE OR OTHER SLOWER MOVING WATER BODY. THE GREATEST RISK FOR RIVERS THEN, IS IF ANTHROPROGENICALLY CREATED SEDIMENTS OCCUR DURING LOW FLOW PERIODS, OR ARE DISCHARGED IN LARGE AMOUNTS CONTINUOUSLY OVER AN EXTENDED TIME PERIOD.

THE DIRECT IMPACTS OF SUSPENDED SEDIMENTS ON FISH OVN INCLUDE DEATH, USUALLY DUE TO GILL DAMAGE AND SUBSEQUENT SUFFOCATION. LETHAL SEDIMENT LEVELS RARELY OCCUR, BUT LEVELS WHICH HAVE BEEN SHOWN TO PRODUCE SERIOUS SUB-LETHAL EFFECTS ARE KNOWN TO OCCUR ON A REGULAR BASIS IN MANY RIVERS. REDUCED GROWTH RATES, DECREASED RESISTANCE TO DISEASE AND DOWNSTREAM DISPLACEMENT ARE THREE OF THE MORE SIGNIFICANT SUB-LETHAL EFFECTS. REDUCED VISIBILITY DUE TO SUSPENDED SEDIMENT HAS BEEN SHOWN TO MAKE FOOD LOCATION SIGNIFICANTLY MORE DIFFICULT FOR FISH (ALABASTER AND LLOYD, 1980; McLEARY ET AL, 1984). THIS IN TURN INCREASES ENERGY EXPENDITURES AND RESULTS IN A REDUCED GROWTH RATE IN AFFECTED FISH. THE INCREASE IN ENERGY EXPENDITURES AND CHANGES IN BLOOD COMPONENT LEVELS DUE TO INCREASED SUSPENDED SEDIMENT ARE ALSO BOTH CONNECTED WITH DECREASED RESISTANCE OF FISH TO OTHER STRESSORS. McLEARY ET AL (1984) REPORTED ALL OF THE ABOVE SUB-LETHAL EFFECTS IN ARCTIC GRAYLING EXPOSED TO SUSPENDED SEDIMENT LEVELS GREATER THAN 100 MG/L BUT NOT IN THOSE FISH EXPOSED TO LESS OR NO SUSPENDED SEDIMENT.

INDIRECTLY, FISH POPULATIONS WILL ALSO BE AFFECTED IF SUSPENDED SEDIMENTS INTERFERE WITH THE VIABILITY OF THEIR FOOD SOURCE. DEPENDING ON THE TYPE OF SEDIMENT, DAMAGE TO INVERTEBRATE POPULATIONS HAS BEEN RECORDED FOR SUSPENDED SEDIMENT LOADS OF 82 MG/L (COAL SEDIMENT) TO 1500 MG/L (POND SEDIMENT) (ALABASTER AND LLOYD, 1980). AQUATIC PLANT COMMUNITIES ARE ALSO AFFECTED BY SUSPENDED SEDIMENT LEVELS, WITH LIGHT SENSITIVE SPECIES BEING ELIMINATED OR REPLACED BY MORE "SHADE" TOLERANT SPECIES.

THE MORE SIGNIFICANT RISKS OF IMPACTS OF SEDIMENTS ON FISHERIES RESULT WHEN HYDRAULIC CONDITIONS ARE SUCH THAT THE SEDIMENT CAN SETTLE TO THE BOTTOM. IN B.C., MOST OF THE RIVER SPAWNING SPECIES OF FISH LAY THEIR EGGS ON OR BELOW THE RIVER GRAVELS. THESE EGGS DEPEND ON WATER CIRCULATION TO BRING OXYGEN AND TO REMOVE METABOLIC WASTES. IF SOLIDS SETTLE ON THE BOTTOM, WATER FLOW IS REDUCED, LEADING TO SUFFOCATION OF THE EGGS AND EVEN OF NEWLY HATCHED EMBRYOS IN THE GRAVELS. A RECENT STUDY IN NEW ZEALAND FOUND THAT AN ENTIRE SMELT FISHERY HAD BEEN ELIMINATED FROM A LAKE DUE TO POOR OR LOW REPRODUCTION FOLLOWING INCREASED SEDIMENT LOADING FROM UPSTREAM MINES (WARD ET AL, 1987). SALMONID EGGS ARE PARTICULARLY SENSITIVE TO SEULED SEDIMENT LEVELS. ALABASTER AND LLOYD (1980) REPORT THAT THE GREATEST MORTALITY OF TROUT EGGS OCCURRED IN REDDS WITH A GREATER PROPORTION OF SOLIDS LESS THAN 8MM IN DIAMETER. SEVERAL STUDIES HAVE SHOWN THAT SALMONID FISH WILL NOT DIG REDDS IN CHOKED GRAVELS AND WILL ABANDON A REDD IF THEY ENCOUNTER SILT WHILE DIGGING. THIS IS LESS LIKELY TO BE A PROBLEM IN B.C. RIVERS WHERE SPAWNING IS LIKELY TO OCCUR IN RIVERS WHERE SILTS WILL HAVE BEEN FLUSHED OUT OF THE GRAVEL BY HIGH, FAST FLOWS.

A LESS DIRECT, BUT PERHAPS EVEN MORE SIGNIFICANT IMPACT OF SETTLED SOLIDS IS THE DESTRUCTION OF FOOD ORGANISMS FOR THE FISH. BENTHIC INVERTEBRATES ARE OFTEN A MAJOR FOOD SOURCE. HOWEVER, MANY INVERTEBRATE SPECIES ARE EXTREMELY SENSITIVE TO SUBSTRATE CONDITIONS AND ARE EITHER KILLED OR FORCED TO DRIFT DOWNSTREAM BY THE DEPOSITION OF FINE MATERIALS. ALABASTER AND LLOYD (1980) REPORTED ON EARLIER WORK WHICH INDICATED THAT REDUCTIONS IN BENTHIC ORGANISM NUMBERS DUE TO INCREASED SEDIMENT CAN RANGE FROM 40 TO 60%. CHANGES IN THE TYPE AND DIVERSITY OF BENTHIC SPECIES ALSO OCCUR IN AREAS SUBJECT TO SEDIMENT DEPOSITION. THESE SORTS OF CHANGES IN INVERTEBRATE POPULATIONS HAVE BEEN DOCUMENTED UNDER BOTH FIELD AND LABORATORY CONDITIONS (MCLEARY ET AL, 1989; McCART ET AL, 1980). WHILE NEW SUBSTRATES MAY EVENTUALLY BE RECOLONIZED, THE NEW ASSEMBLAGES OF SPECIES OF INVERTEBRATES ARE OFTEN NOT AS VALUABLE TO THE FISH, AND THE FINER SUBSTRATES WILL BE MUCH LESS STABLE, PERIODICALLY FURTHER REDUCING THEIR VALUE IN PRODUCING FISH FOOD.

AS WITH SUSPENDED SEDIMENT, PLANT COMMUNITIES ARE ALSO AFFECTED BY INCREASED SEDIMENT DEPOSITION. INITIALLY, SOME SPECIES WILL BE CHOKED OUT AND A REDUCTION IN PLANT NUMBERS MAY OCCUR. GIVEN SUFFICIENT TIME AND SEDIMENT DEPOSITION, AN ENTIRELY NEW VEGETATIVE COMMUNITY MAY DEVELOP WHERE LITTLE OR NONE PREVIOUSLY EXISTED. THIS IN TURN AFFECTS FISH, FAVOURING THOSE SPECIES WHICH THRIVE IN AREAS OF HEAVY PLANT COVER.

FIGURE 1 SUMMARIZES THE RESULTS OF A NUMBER OF STUDIES EXAMINING THE IMPACTS OF SEDIMENT ON FISHERIES. FROM THIS FIGURE IT CAN BE SEEN THAT SOME INCREASE IN SEDIMENT LEVELS ABOVE NATURALLY OCCURRING LEVELS CAN BE TOLERATED BY FISH. THE MAXIMUM TOLERABLE LEVEL OCCURS SOMEWHERE BETWEEN 100 AND 500 MG/L

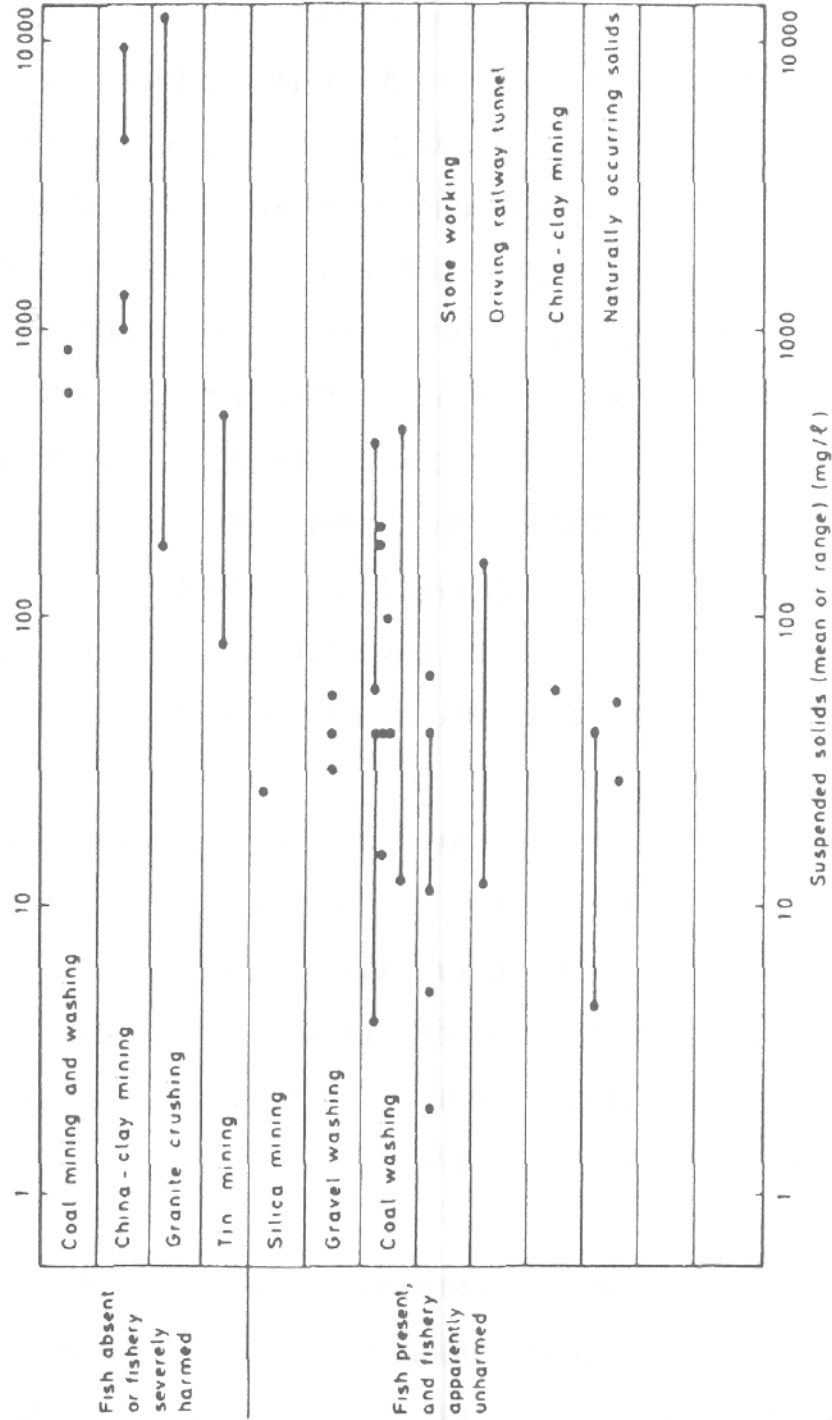


Figure 1: Effects of Various Levels of Suspended Solids on Fish

SUSPENDED SOLIDS_x AND IS DEPENDENT ON THE FISH SPECIES, TYPE OF SEDIMENT AND THE DEPOSITIONS ENVIRONMENT. THIS MAXIMUM IS IN KEEPING WITH THE RECOMMENDATIONS OF A SUBCOMMITTEE OF THE U.N. FOOD AND AGRICULTURE ORGANIZATION (FIRST MADE IN 1964 AND REVISED IN 1980 AND 1984). THEIR RECOMMENDATIONS ARE:

1. SUSPENDED SEDIMENT LEVELS BELOW 25 MG/L: NO HARMFUL EFFECTS.
2. SUSPENDED SEDIMENT LEVELS FROM 25 - 80 MG/L: FISHERY WILL BE MAINTAINED WITH SOME SMALL DECREASES IN NUMBERS AND GROWTH RATES.
3. SUSPENDED SEDIMENT LEVELS FROM 80 - 400 MG/L: A GOOD FISHERY CANNOT BE SUPPORTED ALTHOUGH FISH MAY BE FOUND.
4. SUSPENDED SEDIMENT LEVELS OVER 400 MG/L: FEW OR NO FISH.

THE FAO GUIDELINES ARE JUST THAT, GUIDELINES, THAT INDICATE THE PROBABLE EFFECTS ON FISHERIES OF VARIOUS SUSPENDED SEDIMENT LEVELS.

IN WESTERN CANADA, THESE SORTS OF RECOMMENDATIONS HAVE BEEN TRANSLATED INTO SURFACE WATER QUALITY CRITERIA FOR VARIOUS INDUSTRIAL USERS. IN ALBERTA_x THE SURFACE MINE WATER QUALITY CRITERIA HAS GENERALLY BEEN SET AT 50 MG/L TOTAL SUSPENDED SOLIDS, WHILE IN B.C. THE OBJECTIVE LEVEL IS 25 TO 75 MG/L DEPENDING ON THE SENSITIVITY OF THE AQUATIC SYSTEM AND THE SPECIFIC MINE INVOLVED. IN BOTH PROVINCES PERMITS TO DISCHARGE ARE USUALLY GRANTED ON AN INDIVIDUAL BASIS_x AND DESIGN CRITERIA FOR SETTLING PONDS ARE USUALLY PART OF THE PERMIT. IN THE YUKON TERRITORY, PILACER MINING OPERATIONS ARE RESTRICTED TO SETTLABLE SEDIMENT DISCHARGES OF 0.2ML/L OR A CEILING OF 200MG/L TOTAL SUSPENDED SOLIDS, WHICHEVER IS LESS, IN WATERBODIES OF MODERATE BIOLOGICAL IMPORATNCE

(TYPE II STREAMS). FOR WATERBODIES OF LOW BIOLOGICAL IMPORTANCE (TYPE IV STREAMS) SETTLEABLE SOLIDS DISCHARGES ARE RESTRICTED TO 5.0ML/L WHILE NO SEDIMENT DISCHARGES ABOVE NATURAL BACKGROUND ARE PERMITTED FOR WATERBODIES OF HIGH BIOLOGICAL IMPORTANCE (TYPE I STREAMS). TYPE I AND II STREAMS ARE SALMONID SPAWNING AND REARING STREAMS RESPECTIVELY AND TYPE IV STREAMS ARE THOSE WITH NO FISH OR FISH OF NO SIGNIFICANT VALUE TO SPORT, COMMERCIAL OR DOMESTIC FISHERIES (YUKON FISHERIES PROTECTION AUTHORIZATION, 1988).

WHILE I AM NOT EXTREMELY FAMILIAR WITH THE SITUATION IN B.C., OUR FIRM CONDUCTED AN EXTENSIVE REVIEW OF ALBERTA'S SURFACE MINE WATER QUALITY CRITERIA IN 1985. SEVERAL POINTS RAISED IN THAT REVIEW ARE APPLICABLE HERE. THE FIRST IS THAT NEITHER B.C. NOR ALBERTA LEGISLATION OR CRITERIA, DISTINGUISH BETWEEN SUSPENDED SOLIDS AND SETTLEABLE SOLIDS, A DISTINCTION THAT, AS I HAVE DISCUSSED, IS SIGNIFICANT WITH RESPECT TO SEDIMENT IMPACT ON FISHERIES. THE YUKON PLACER MINING GUIDELINES DO MAKE THE DISTINCTION, BUT UNFORTUNATELY THE SETTLEABLE SOLIDS CRITERIA WAS ADDED BECAUSE IT IS EASIER TO MEASURE, NOT BECAUSE IT PROVIDED BETTER ENVIRONMENTAL PROTECTION.

SECOND, THOSE MINE EFFLUENTS MEETING A GUIDELINE OF 50 MG/L TOTAL SUSPENDED SOLIDS, WERE LIKELY TO HAVE A SIGNIFICANTLY LOWER PROPORTION OF SETTLEABLE SOLIDS THAN OCCURRED NATURALLY IN THE RECEIVING STREAMS. THIS WAS BECAUSE THE SOLIDS WHICH PASSED THROUGH THE SETTLING POND WERE, OF COURSE, THE FINEST PARTICLES, THAT IS, THOSE PARTICLES TOO SMALL TO SETTLE OUT AND WHICH WILL REMAIN IN SUSPENSION. THIS SUGGESTED TO US THAT ALBERTA CRITERIA WERE PERHAPS OVERLY CONSERVATIVE, IN THAT A TOTAL SUSPENDED SOLIDS MEASUREMENT FROM A

MINE DISCHARGE POINT CANNOT NECESSARILY BE COMPARED WITH TSS MEASUREMENTS FROM NATURAL STREAMS. COMPARISONS ARE MEANINGLESS GIVEN THE DIFFERENT PROPORTIONS OF SETTLEABLE SOLIDS_x AND HENCE, THE DIFFERENT IMPACT OF THE SEDIMENT ON AQUATIC SYSTEMS.

THIRD, WE FOUND THAT CURRENT SETTLING POND TECHNOLOGY, EVEN WITH THE USE OF FLOCULANTS, WAS INSUFFICIENT TO ALLOW ALBERTA MINES TO CONSISTENTLY MEET THE GUIDELINES. WHILE EXEMPTION GUIDELINES EXIST FOR TSS WITHIN 48 HOURS OF A 10 YEAR - 24 HOUR STORM, MINES WERE UNABLE TO MEET U.S. EPA TSS CRITERIA FOLLOWING SIGNIFICANTLY SMALLER STORM EVENTS. RECENT RESEARCH HAS SHOWN THAT NOT ONLY ARE SETTLING PONDS DESIGNED TO CURRENT STANDARDS UNABLE TO MEET TSS CRITERIA DURING SOME STORM EVENTS, IT IS NOT EVEN THEORETICALLY POSSIBLE TO MEET THE CRITERIA, USING ANY REASONABLE SIZE OF SETTLING POND (ETTINGER AND LICHTY, 1979; POE ETAL, 1983). THE EPA EVENTUALLY SOLVED ITS NON-COMPLIANCE PROBLEM BY SETTING AN ALTERNATIVE SETTLEABLE SOLIDS CRITERION OF 0.5ML/L TO BE USED FOR RAINFALL ON SNOWMELT EVENTS SMALLER THAN THE 10 YEAR- 24 HOUR STORM. THIS ALTERNATIVE REQUIREMENT WAS BASED ON STUDIES SHOWING THAT SETTLEABLE SOLIDS CAN BE CONSISTENTLY CONTROLLED IN STORM CIRCUMSTANCES, EVEN WHEN TSS CANNOT (U.S. EPA, 1982).

ALBERTA DOES NOT HAVE SUCH AN ALTERNATIVE CRITERIA, BASED ON CONTROLLING SETTLEABLE SOLIDS, WHICH IS THE MORE DAMAGING COMPONENT OF SEDIMENT. MLNES THEREFORE CONTINUE TO REGULARLY FAIL TO COMPLY WITH EXISTING ALBERTA WATER QUALITY GUIDELINES FOR SEDIMENT. THIS SITUATION, IN MY VIEW, IS NOT CONSISTENT WITH GOOD ENVIRONMENTAL PRACTICE, SINCE IT CREATES AN UNTENABLE SITUATION FOR THE MINING COMPANIES, AND ONLY ENCOURAGES ENVIRONMENTALLY MEANINGLESS

CONFRONTATIONS WITH THE GOVERNMENT. THIS IS PARTICULARLY TRUE SINCE THE SITUATION COULD LIKELY BE READILY RESOLVED. TWO POSSIBLE OPTIONS WOULD BE TO EITHER SET A NEW AVERAGE SUSPENDED SOLIDS CRITERIA, RATHER THAN MAXIMA, OR TO SET AN ALTERNATIVE SETTLABLE SOLIDS CRITERIA.

B.C. GOVERNMENT OFFICIALS HAVE INDICATED THAT THEY FEEL THAT FOR THE MOST PART, GUIDELINES OF 50 MG/L ARE BEING MET WITH CURRENTLY AVAILABLE TECHNOLOGY BY MINES IN B.C.. THIS DISCREPANCY BETWEEN THE TWO PROVINCES IN MINES MEETING THE WATER QUALITY CRITERIA CAN PERHAPS BE CREDITED TO DIFFERENCES IN SOILS, SLOPES AND OVERALL RIVERINE ECOSYSTEMS BETWEEN B.C. AND ALBERTA. FASTER, MORE REGULAR FLOW IN B.C. RIVERS, AND DIFFERENT SEASONAL FLOW PATTERNS WOULD ALSO CONTRIBUTE TO A MINE'S ABILITY TO MEET THE 50 MG/L GUIDELINE.

WHILE IT IS ENCOURAGING TO LEARN THAT THE 50 MG/L GUIDELINE IS BEING MET, THE ISSUE OF SUSPENDED AND SETTLABLE SOLIDS REMAINS. WITH THE FAST FLOW AND REGULAR NATURAL HEAVY LOADS OF SUSPENDED SEDIMENT OF MANY B.C. RIVERS AND STREAMS, NEITHER SUSPENDED NOR SETTLABLE SEDIMENTS ARE LIKELY TO BE A SERIOUS PROBLEM. WHERE BOTH, AND ESPECIALLY SETTLABLE SEDIMENTS, BECOME OF CONCERN IS IN LAKES AND THOSE RIVERS WHOSE FLOW IS NOW REGULATED, AND WHERE SEDIMENT LADEN EFFLUENTS ARE DISCHARGED DURING PERIODS OF LOW FLOW.

IN CONCLUSION, I HOPE IT IS CLEAR THAT WHILE INCREASES IN BOTH SUSPENDED AND SETTLED SEDIMENT CAN NEGATIVELY AFFECT RIVERS AND LAKES AND THEIR NATIVE FISHERIES, IT IS POSSIBLE FOR BOTH MINES AND FISHERIES TO OPERATE ON THE SAME WATERSHED, GIVEN THAT THE PROPER SEDIMENT CONTROL TECHNIQUES ARE EMPLOYED. HOWEVER, IT APPEARS THAT SOME GOVERNMENT REGULATIONS MAY, UNDER CERTAIN

CIRCUMSTANCES, BE UNREALISTIC AND NOT SCIENTIFICALLY JUSTIFIABLE. THIS SITUATION
NEEDS TO BE RECTIFIED IF UNNECESSARY CONFLICTS ARE TO BE AVOIDED.

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