Assessment of the baseline metal levels in the aquatic environment of Crater Lake, Deception, Puvirnituq and Vachon rivers, Nunavik

Environmental monitoring of the Raglan project

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Submitted to:

Northern villages of Kangirsuk,
Kangiqsujuaq, Salluit and Puvirnituq

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ᓇᐃᓪᓕᑎᑦᓯᒪᔪᑦ

ᑭᐅᑦᔪᑎᒋᔭᐅᑦᓱᓂ ᓄᓇᓖᑦ ᐃᓱᒫᓗᒋᔭᖏᓐᓄᑦ ᑐᑦᓯᕋᐅᑎᖏᓐᓄᓗ, ᐅᔭᕋᓐᓂᐊᓂᖃᓚᐅᕐᑎᓇᒍ ᐊᕙᑎᒥᒃ ᓇᐅᑦᓯᑐᑦᑕᐅᔪᖅᑎᓗᒍ ᖃᐅᔨᓴᑦᑕᐅᔪᖃᓚᐅᔪᕗᖅ ᓯᑉᑎᒻᐱᕆ 1997 ᐱᒋᐊᖅᑲᒥᐅᑎᓪᓗᒍ ᓇᓗᓇᐃᑦᑕᐅᔪᖃᕆᒪᑎᓪᓗᒍ ᓱᓇᒐᓚᒋᔭᐅᔪᓂᒃ ᐃᒪᐅᑉ ᖃᖓᓃᓯᕐᓂᒃ, ᐃᖅᑲᖓᑕᓗ ᓄᓇᖓᓂᒃ ᐊᒻᒪᓗ ᐃᒪᐅᑉ ᐊᕙᑎᖓᓂ ᐱᕈᕐᐸᓯᐊᒍᓐᓇᑐᓂᒃ ᑕᒫᓂ ᑲᑎᓐᓂᐅᓗ ᐱᖑᐊᓗᐃᓪᓗ ᓄᓇᖏᓐᓃᑐᓂᒃ, ᓄᓇᕚᒻᒥ (ᑯᐸᒃ ᑕᕿᖓᓂ). ᐱᐅᔩᒋᐊᖃᕐᓂᖏᓐᓄᑦ ᐊᐅᓚᑦᓯᒍᑎᓕᐊᖑᓯᒪᔪᑦ ᒪᓕᑦᑕᐅᑎᓪᓗᒋᑦ ᐊᕙᑎᒦᑦᑐᓂᓪᓗ ᐱᕈᕐᐸᓯᐊᔩᑦᓴᔭᓂᓪᓗ ᖃᐅᔨᓴᕋᑦᓴᓂᒃ ᓄᐊᑕᐅᔪᖃᓚᐅᔪᖅ ᕿᒥᕐᕈᔭᐅᔪᖃᑦᓯᓂᓗ ᓱᓇᑕᖃᕐᒪᖔᑕ ᒥᑭᔪᖕᖑᐊᕈᓃᒃᑯᑦ ᖃᐅᔨᓴᕐᓯᒋᑦ.

ᑰᑉ ᑕᐅᓇᓐᓇᖓᓃᑦᑐᖏᓐᓂᓗ ᐸᓃᑦᑐᖏᓐᓂᓗ ᖃᐅᔨᓴᕈᓯᖃᕐᓯᑎᒃ, ᑲᑎᓐᓂᐅᑉ ᐅᔭᕋᓐᓂᐊᕚᖓᓂ ᑰᑉ ᑕᐅᓇᓐᓇᖓᓂᒋᐊᕐᑐᑦ ᓱᒃᑯᓇᕈᓐᓇᑐᓂᒃ ᐱᑖᕐᓯᒪᓂᕐᓴᐅᓕᕐᑎᓪᓗᒍ ᑕᑯᔭᐅᔪᖃᓚᐅᔪᖅ ᑖᑦᓱᒪ Deception River ᐃᒪᖕᒋᑦᑕ ᖃᖓᓃᑦᑐᓂ. ᖁᓕᓪᓗ ᐱᖓᓱᓪᓗᓂᒃ ᐊᑦᔨᒌᖕᒋᑐᓂᒃ ᓱᓇᒐᓚᑦᑕᓚᐅᔪᑦ ᐊᖕᒋᓂᕐᓴᐅᓂᖃᕐᑎᓪᓗᒋᑦ 10-ᒥᑦ 100-ᒧᑦ ᑎᑭᑦᑐᓂᒃ ᑖᑦᓱᒪᖕᖓᑦ ᖃᐅᔨᓴᕐᕕᐅᓚᐅᕐᑐᒥᒃ ᑰᑉ ᐊᔨᐊᓃᑦᑐᒥᒃ, ᑕᒪᒃᑯᐊ cobalt 172-ᕕᓪᓗᐊᑐᒥᒃ ᐊᒻᒪᓗ manganese 261-ᕕᓪᓗᐊᑐᒥᒃ ᐱᑕᖃᕐᓂᓴᐅᑎᓪᓗᒋᑦ ᑖᑦᓱᒪᖕᖓᑦ ᖃᐅᔨᒪᒍᑎᒥᒃ ᑰᒻᒥᒃ. ᐅᓄᕐᓂᓴᐃᑦ ᓱᓇᒐᓚᐃᑦ ᖃᐅᔨᓴᑦᑕᓚᐅᕐᑐᑦ Deception River ᑰᖓᑕ ᐃᒪᖕᒋᓐᓃᑦᑐᑦ ᓈᒪᓈᕐᓯᒪᓂᖃᓚᐅᕐᑑᒐᓗᐊᑦ ᑖᒃᑯᓄᖓ ᑯᐸᒃᑯᑦ ᓱᒃᑯᓇᕈᓐᓇᑐᓄᑦ ᐸᕐᑐᓂᕋᔭᐅᒍᓐᓇᑐᓄᑦ ᑐᑭᒧᐊᒍᑎᓕᐊᖑᓯᒪᔪᓂᒃ ᑭᓯᐊᓂ ᑖᒃᑯᐊ nickel-ᖃᕐᓂᕆᓚᐅᕐᑕᖏᑦ 2.5-ᕕᓪᓗᐊᑐᒥᒃ ᐊᒻᒪᓗ zinc-ᖃᕐᓂᖏᑦ 1.2-ᕕᓪᓗᐊᑐᒥᒃ ᖃᖏᐅᑎᓯᒪᓂᖃᓚᐅᔪᑦ ᑐᑭᒧᐊᒍᑎᓕᐊᖑᓯᒪᔪᕐᓂᑦ. ᓯᒥᑦᑕᐅᒪᔫᑉ ᑕᓯᖓᓂ ᓱᓇᒐᓚᐃᑦ ᐱᑕᖃᕐᓂᐸᐅᕆᐊᖕᒋᑦ ᓇᓂᔭᐅᔪᖃᓚᐅᕐᑐᖅ 16-ᖑᔪᕐᓂᒃ ᐊᖕᒋᓂᕐᓴᐅᓂᖃᕐᑐᓂᒃ 10-ᒥᑦ 1000-ᒧᑦ ᑎᑭᑦᑐᓂᒃ ᐱᑕᖃᕐᓂᓴᐅᓚᐅᕐᑐᓂᒃ ᑖᑦᓱᒪᖕᖓᑦ ᖃᐅᔨᒪᒍᑎᒥᑦ ᑰᒻᒥᑦ. ᑖᒃᑯᐊ nickel 48-ᕕᓪᓗᐊᑐᒥᒃ ᐊᒻᒪᓗ manganese 67-ᕕᓪᓗᐊᑐᒥᒃ ᖃᖏᐅᑎᓂᖃᓚᐅᔪᒻᒥᔪᑦ ᑯᐸᒃᑯᑦ ᑐᑭᒧᐊᒍᑎᓕᐊᓇᓯᒪᔭᖕᖏᓂᑦ ᐃᒥᑦᑕᐅᒍᓐᓇᑑᑦᑐᓄᑦ.

ᐸᕕᕐᓂᑑᑉ ᐃᒪᖕᒋᑦ ᐅᔭᕋᑦᓴᔭᓂᒃ ᐱᑕᖃᖕᖏᓐᓂᕐᓴᐅᓚᐅᔪᑦ ᑖᑦᓱᒪᖕᖓᑦ Deception River ᑰᖓᓂᑦ. ᑰᑉ ᑕᐅᓇᓐᓇᕆᐊᖓᓂ ᖃᐅᔨᔭᐅᔪᖃᓚᐅᔪᖕᖏᑐᖅ ᐱᑕᖃᕐᒪᖔᑕ ᒪᑯᓂᖓ nickel, manganese, zinc, cobalt ᐅᕝᕙᓘᓐᓃᑦ ᐊᔨᖕᖏᓐᓂᒃ ᓱᓇᒐᓚᓐᓂᒃ ᑕᒡᒐᓂ ᑰᒻᒥ. ᐱᖑᐊᓗᐃᑦ ᑕᓯᖓᓂ ᓱᓇᒐᓚᐃᑦ ᐸᕐᑐᓂᖕᖏᑦ ᖃᐅᔨᔭᐅᒍᓐᓇᑐᐃᑦ ᓴᓂᐊᓃᓐᓂᖃᓚᐅᔪᑦ ᐸᒃᑭᓂᕐᓴᐅᓯᑎᓪᓘᓃᑦ ᐅᕙᓂᓗ Laflamme Lake ᑕᓯᖓᓃᑦᑐᐃᓗ, ᐋᑯᓗᑦᔫᑉ ᑰᖓᑕ ᐱᒋᐊᕐᕕᖓᓃᑦᑐᒥᒃ.

ᐃᒪᐅᑉ ᐃᖅᑲᖕᖏᓃᑐᓂᒃ ᓱᓇᒐᓚᓐᓂᒃ ᓄᐊᑕᐅᓚᐅᔪᕐᓂᒃ ᐅᑯᓇᖕᖓᑦ Laflamme Lake ᑕᓯᖓᓂᑦ, Deception River ᐊᒻᒪᓗ ᐸᕕᕐᓂᑑᑉ ᑰᖓᓂᑦ ᐊᑦᔨᒌᖕᖏᑑᖃᑦᑕᓚᐅᔪᑦ ᐊᑐᓂᑦ ᑭᓯᐊᓂ ᖃᐅᔨᓴᑦᑕᐅᔪᐃᑦ ᐃᓗᐊᓃᑦᑐᑦ ᐱᑕᖃᖕᖏᓐᓂᕐᓴᐅᑎᓪᓗᒋᑦ. ᐃᖅᑲᒦᑦᑐᐃᑦ ᐊᑦᔨᒌᖕᖏᑑᔪᓇᔭᐅᓚᕿᓚᐅᔪᔪᑦ ᐊᑦᔨᒌᖕᖏᑐᓂᒃ ᓄᓇᖕ ᐅᔭᕋᑦᑕᖃᕐᓂᖕᖓᓄᑦ ᐊᑐᓂᑦ ᓄᓇᒥᔭᖕᖏᓐᓂᓂᖃᕐᑐᓄᑦ. ᒪᑯᐊ aluminium, cobalt, chromium, iron, manganese, nickel, zinc ᐱᑕᖃᕐᓂᖕᖏᑦ ᐸᒃᑭᑑᓂᖃᓚᐅᕐᑐᑦ ᑕᒫᓂ Deception River ᑰᖓᑕ ᐃᖅᑲᖓᓂ, ᐱᑕᖃᕐᓂᖕᖏᑦ ᐸᕐᑐᓂᖃᕐᓯᑎᒃ 4-ᒥᑦ 20% ᐸᓴᓐᑎᓄᑦ ᑎᑭᑦᑐᓂᒃ. ᑕᒪᒃᑯᐊ ᓱᓇᒐᓚᐃᑦ ᑲᑎᒪᐅᑎᓂᕋᔭᖕᖏᑦ ᖃᐅᔨᒪᒍᑎᐅᒍᓐᓇᓂᐊᕐᑐᑦ ᐅᔭᕋᑦᓴᔭᒥᒃ ᐱᑖᕈᒥᓯᒪᒻᒪᖔᑕ ᓯᕗᓂᑦᓴᒥ ᖃᐅᔨᓴᕈᕐᒥᒍᑎᒃ. ᑕᒪᒃᑯᐊ chromium, copper, nickel, zinc ᐱᑕᖃᕐᓂᖕᖏᑦ ᐸᕐᑐᓂᕐᓴᐅᓚᐅᔪᑦ ᑖᒥᓂ Deception River ᑰᖓᑕ ᐃᖅᑲᖓᓂ ᐊᒻᒪᓗ ᐸᕐᑐᓂᕐᓴᐅᓯᑎᒃ ᑲᕙᒪᑐᖃᒃᑯᑦ ᐸᕐᑐᓂᓖᑦ 3-ᓂᒃ ᑐᑭᒧᐊᒍᑎᓕᐊᓇᓯᒪᔭᖕᖏᓂᑦ (ᓱᒃᑯᓇᕈᓐᓇᑐᒦᑦᑐᓂᒃ) ᑕᒪᓐᓇ ᐊᔪᓕᐃᑦᑑᔭᓕᓂᓗ ᐅᔭᕋᑦᓴᔭᑦᑕᖅᓚᕆᑐᐊᕐᒪᑦ ᓄᓇᒥ.

ᓄᓇᒥ ᑎᒃᑯᐅᔭᕐᑕᖃᑦᑐᐊᓚᐅᕙᓐᓂᖅᑐᖅ ᑲᑎᓐᓂᐅᑉ ᓄᓇᒃᑯᓂ ᖃᐅᔨᕋᑦᓴᓯᐊᒍᒋᑐᐊᓚᐅᕙᓂᒃ ᐱᑕᖃᕐᓂᓴᐅᓚᐅᕙᓚᒍᐊᕐᑎᓗᒍ ᐋᑯᓗᑦᔮᑉ ᑰᒃᑕ. Nickel-ᒥᒃ ᑭᓯᐊᓂ ᑭᑭᐊᖑᑎᓪᓗᒍ ᖃᐅᔨᓴᐅᕙᖃᓚᐅᕗᖅ ᑎᒃᑯᐅᔮᑦᑐᓂᒃ ᑲᑎᓐᓂᒥ ᐅᔭᕋᓐᓂᐊᑉ ᓴᓂᐊᓃᑦᑐᒥᒃ ᑎᒃᑯᐅᔮᑦᑐᖃᓚᐅᕙᑎᓐᓇᒍ ᐱᖑᐊᓗᐃᑦ ᓄᓇᒃᑰᑦᑐᓂᒃ. ᑕᒪᓐᓇ nickel ᑕᐃᒪᐃᒻᒪᑦ ᐊᑐᕐᑕᐅᒍᓐᓇᖓᕐᑐᖅ ᖃᐅᔨᒪᒍᑎᐅᓗᓂ ᐊᓗᓇᒎᑦ ᑎᑭᑎᑕᐅᕙᐃᑦ ᑕᒪᐅᔾᔭᑎᑕᐅᕙᖃᕗᖑᒻᒪᒃᑳᑦ ᓯᕗᓂᑦᓴᒥ.

ᑭᑭᐊᑦᓴᔭᐃᑦ ᐳᕐᑐᓂᖏᑦ ᓇᓗᓇᐃᕐᑕᐅᓚᐅᕗᑦ ᐃᖃᓗᐃᑦ ᑎᖑᖏᓐᓃᑎᓪᓗᒋᑦ, ᑕᕐᑐᖏᓐᓂᓗ ᓄᑭᖏᓐᓂᓗ ᑕᑳᓂ Deception River ᑰᒃᑯᓃᑦᑐᓂᒃ ᐊᒻᒪᓗ ᐱᖑᐊᓗᐃᓪᓗ Laflamme Lake ᑕᓯᖏᓐᓃᑦᑐᓂᒃ. ᑭᑭᐊᑦᓴᔭᐃᑦ ᐱᑕᖃᕐᓂᖏᑦ ᐊᑦᔨᒌᖏᑦᑑᓂᖃᓚᐅᕗᑦ ᒪᓕᑦᓯᒋᑦ ᓂᕿᖏᑦ, ᐅᑭᐅᖏᓪᓗ ᐊᒻᒪᓗ ᐃᖃᓗᐸᑐᐃᓐᓇᐅᒪᒌᑦ ᐅᑉᐸᓘᓐᓃᑦ ᓄᑎᓕᐅᒪᒌᑦ. ᑰᒻᒦᑦ ᐃᖃᓗᐃᑦ ᒥᑭᓂᕐᓴᐃᓗ ᕿᑎᒃᑲᓃᑦᑐᐃᓗ ᑕᕐᑐᖏᑦ ᓄᐊᑦᓯᓱᖑᓂᕐᓴᐅᓚᐅᕗᑦ ᒪᑯᓂᒃ arsenic, cadmium, cobalt, mercury, nickel, vanadium ᑕᒪᒃᑯᓇᙵᑦ ᑎᖑᖏᓐᓂᓗ ᓄᑭᖏᓐᓂᓗ. ᑎᖑᖏᑦ ᓄᐊᑉᐸᐅᓂᕐᓴᐅᓱᖑᓚᐅᕐᑐᑦ ᒪᑯᓂᒃ aluminium, copper, iron, zinc. ᐃᖃᓗᐱᓃᑦᑐᐃᑦ ᐊᖏᔾᔫᑦ ᓄᑭᖏᑦᑕ arsenic-ᖃᕐᓂᖏᑦ ᐊᑦᔨᒋᔭᐅᓂᖃᓚᐅᖏᑦᑐᑦ ᐊᓯᖏᓐᓄᑦ ᐊᖏᓂᕐᔭᐅᒥᔪᓄᑦ; ᓇᓗᓇᐃᒃᑯᓯᕐᑕᐅᒪᒍᑎᖃᕐᓯᑎᒃ 56-78-ᓂᒃ ᐱᑕᖃᕐᓂᓴᐅᕆᐊᖏᑦ ᑕᒪᒃᑯᓇᙵᑦ ᐃᖃᓗᓐᓂᒃ ᒥᑭᓂᕐᓴᓂᒃ ᕿᑎᒃᑳᓐᓂᓴᕐᓂᓗ. ᑕᒪᒃᑯᐊ ᐊᑦᔨᒌᖏᑦᑑᓂᖏᑦ ᐃᓕᓐᑐᐃᓐᓇᓇᐊᖃᕐᑐᑦ ᖃᐅᔨᓴᕐᑕᐅᓯᒪᔪᓄᑦ ᑕᒪᐃᓐᓄᑦ ᐃᖃᓗᐱᑐᐃᓐᓇᓄᓪᓗ ᓄᑎᓕᓄᓪᓗ.

ᐅᕝᕙᓗᕐᓂᒃ ᐊᑦᔨᒌᑲᓪᓚᑦᑐᓂᒃ ᑕᑭᓂᓕᓐᓂᒃ ᓄᐊᑕᐅᔭᐅᕙᐅᔾᔪᒥᔪᖅ ᐱᒃᑯᓯᓂᑦ ᐊᑦᔨᒌᖏᑦᑐᓂᒃ ᓄᐊᑕᐅᔭᓂᒃ ᑕᑳᓂ ᓴᓪᓗᐃᑦ ᐊᐃᑉᐸᒃᑕ ᓯᑦᔭᒃᑲᓂᑦ, ᑖᒃᑯᐊ ᐃᓚᒃᑲᑦ ᓄᐊᑦᓯᕝᕙᐅᓚᐅᕙᑦᓯᓂ 2-3 ᑕᑳᓂ ᐅᑭᐅᖅᑐᓂᒃ. ᐅᓄᕐᓂᓴᐃᑦ ᑭᑭᐊᑦᓴᔭᐃᑦ ᐱᑕᖃᕐᓂᖏᑦᑕ ᕿᑎᒃᑳᑦᑐᕐᑯᑎᖏᑦ ᑖᒃᑯᓇᓂ ᐃᓅᓯᖓᓂᓴᕐᓂ ᐅᕝᕙᓗᕐᓃᑐᓂᒃ ᐳᕐᑐᓂᓴᐅᓚᐅᕗᑦ ᐅᑉᐸᓘᓐᓃᑦ ᕿᑎᒃᑳᓐᓂᖃᕐᓯᑎᒃ ᑕᒪᒃᑯᓄᒃ ᐅᕝᕙᓗᑐᖃᐅᓂᓴᓄᑦ ᒪᕐᕈᐃᖑᓚᐅᕐᑐᓄᑦ lead–ᖃᖕᖏᓂᓴᐅᑲᓗᐊᕐᓯᑎᒃ. ᑎᒥᖏᑦᑕ ᐅᕐᑯᒪᐃᓐᓂᖏᑦ ᓱᕋᑦᑕᐅᒪᓂᖃᓚᐅᕐᑐᖅ ᑕᒪᒃᑯᓄᒃ copper, cobalt, nickel ᐱᑕᖃᕐᓂᖏᓐᓄᑦ. Cobalt ᐊᒻᒪᓗ nickel ᐱᑕᖃᕐᓂᖏᑦ ᖃᐅᔨᓴᕝᕙᒃᑲᓂ 1-ᒥ 0.001-ᒥᒃ ᐳᕐᑐᓂᖃᓚᐅᕗᑦ ᑕᒪᖏᒃ ᐊᒻᒪᓗ 0.05-ᒥᒃ ᐳᕐᑐᓂᖃᕐᑐᓂᒃ ᖃᐅᔨᓴᐅᕙᖃᓚᐅᕗᑦᓯᓂ ᖃᐅᔨᓴᕝᕙᒃᑲᓂ 2 ᐊᒻᒪᓗ 3 ᐊᑯᓐᓂᖏᓐᓃᑦᑐᓂᒃ. ᑭᑭᐊᑦᓴᔭᐃᑦ ᐱᑕᖃᕐᓂᖏᑦᑕ ᐳᒃᑮᑦᑐᓂᖏᑦ ᐃᖃᓗᓐᓃᑦᑐᓂᒃ ᐅᕝᕙᓗᕐᓃᑦᑐᓂᑦᓗ ᖃᐅᔨᒪᒍᑎᐅᒍᓐᓇᖓᕐᑐᑦ ᓯᕗᓂᑦᓴᒥ ᑭᑭᐊᑦᓴᔪᑦ ᓴᓗᒪᐃᓪᓕᔭᐅᕙᒃᓯᑦᓴᐸᑦ, ᐱᓗᐊᕐᑐᒥᒃ ᑭᑭᐊᑦᓴᔭᓂᒃ ᐳᒃᑭᑐᑐᖃᐅᓯᓂᒃ ᐳᒃᑭᓂᕐᓴᐅᓯᓂᓪᓘᓂᓂᑦ ᓂᕿᖏᓐᓂᑐᓂᒃ ᖃᐅᔨᓴᐅᒍᓇᑐᓂᒃ.

Summary

In response to community concerns and requests, an environmental pre-mine assessment study was conducted in early September 1997 to determine the baseline levels of elements in surface water, sediment core and biota of aquatic environments located in the Katinniq and Crater Lake regions, Nunavik (northern Quebec). Under rigorous quality control protocols, environmental and biological samples were collected and analysed for a series of ultra-trace and trace elements.

Based on an upstream-downstream sampling design, an increased contaminant concentration downstream of the Katinniq mines was observed in surface waters of the Deception River. Thirteen elements were within a concentration of 10 to 100 times the concentration of the control river station, of which cobalt and manganese were 172 and 261 times that of the reference river, respectively. Most elements tested in the Deception River waters met the provincial chronic toxicity guidelines with the exception of nickel and zinc which were 2.5 and 1.2 times the recommended guidelines, respectively. The highest concentrations of elements were found in the water reservoir located behind the dam of which 16 elements were 10 to 1000 times the concentration of the reference river. Nickel and manganese exceeded the provincial guidelines for drinking water with respectively, 48 $\mu g \cdot L^{-1}$ and 67 $\mu g \cdot L^{-1}$.

The Puvirnituq waters were lower in mineral content than waters from the Deception River. There was no evidence of downstream contamination with nickel, manganese, zinc, cobalt nor with other elements in this river. The levels of elements in Crater Lake were mostly near or below the detection limits as well as for Laflamme Lake, headwater of the Vachon River.

The concentrations of elements in fine sediments collected from the Laflamme Lake, Deception and Puvirnituq rivers varied from core to core but less within core. The variation among cores was associated with the different bedrock compositions that distinguish each area. The coefficients of variation of aluminium, cobalt, chromium, iron, manganese, nickel and zinc were relatively low in the Deception river core, ranging from 4 to 20%. The relative uniformity of these elements should allow the detection of increased metal depositions in future impact assessment studies. The average concentration of chromium, copper, nickel and zinc were higher in the Deception River core and above the federal level 3 guideline (harmful effect) which is not unusual in areas of high mineralisation.

The density of terrestrial mosses surrounding the Katinniq area was low and not suitable for monitoring whereas they were relatively more abundant on the banks of the Vachon River. Nickel was the only metal detected in terrestrial moss located near Katinniq mines and not in moss collected in the Crater Lake area. Nickel concentration could therefore be used as a bioindicator of windborne contamination if any occurs in the future.

Metal levels were characterised in liver, kidneys and muscle tissues of fish from the Deception River, Crater and Laflamme lakes. The concentrations of metals varied according to the type of tissue, age and if whether fish is landlocked or anadromous. Kidneys of small and medium-sized charr (*Salvelinus alpinus*) from the river

accumulate more arsenic, cadmium, cobalt, mercury, nickel and vanadium than livers and muscles. Livers predominately accumulate aluminium, copper, iron and zinc. The arsenic content in muscles of large charr contrasts with the other size classes; the median value being 56-78 times those of small and medium-sized fish. This difference likely indicates that the sample is composed of both, anadromous and landlocked charr.

Blue mussels (*Mytilus edulis*)of similar length were collected from three beds in the Deception Bay, one being composed of mussels of two to three years of age only (Decbay-3). Median values of most metals in the younger mussel group from were either higher or near the median values of the two older groups with the exception of lead. Body weight had a strong negative relationship with copper, cobalt and nickel concentrations. Cobalt and nickel concentrations in Decbay-1 station had the strongest correlation coefficients with r=-70.9 (p<0.001) and r=–71.8 (p<0.001), respectively. A significant difference (p<0.05) in cobalt, lead, mercury and nickel concentrations was observed between Decbay-1 and Decbay-2 stations. The low levels of metals found in fish and mussels should allow detection of future metal contamination, particularly of metals that are naturally low or below detection limit in tissues.

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1.0 Introduction

In December 1997, Falconbridge Limited started the operation phase of the nickel-copper deposits at Katinniq, upstream of the Deception River in Nunavik. Falconbridge estimated that a production of 20 000 ton per year maintained during a 20 year-period could be financially viable and competitive in the world market (Roche, 1993). Metal mines can be in operation for many years and generate high volumes of wastewater during mining and ore processing. Up to four ton of water per ton of ore milled can be used during grinding and concentrating operations (Aquamin, 1996). Wastewater must be treated and comply with the current regulations for metal liquid mining effluent prior to discharge into the receiving environment. In Quebec, Falconbridge, or its subsidiary company the Société minière Raglan du Québec Ltée (SMRQ), is required to monitor the level of metals in mining effluents to ensure that the water quality criteria of the Ministère de l'Environnement du Québec for the protection of the aquatic environment are met.

Several baseline studies were carried out by the mining company to determine the background level of metals in the receiving environment before the commencement of mining operations (Roche, 1991-1996). Such databases are currently used to evaluate the spatio-temporal trends of metals discharge into the receiving environment after mines have started production. In spite of this environmental management, the communities of Kangirsuk and Puvirnituq requested in January 1997, that the Nunavik Research Centre (NRC) conduct an independent assessment of the baseline levels of metals in the aquatic environment of the Payne and Puvirnituq rivers before mining commenced. The potential environmental impact of the Raglan Mine on water quality and its potential effects on fish populations concerned the communities. The proximity of the Crater Lake to the mining site and the increased traffic in the region also worried the community of Kangiqsujuaq since the access to the area is uncontrolled. The risk of polluting this pristine area will increase as the Crater becomes more accessible. The baseline levels of metals should be assessed in water and biota of this unique area before it becomes either contaminated locally by human activities or by airborne particles generated by present or future mining activities.

In response to these concerns and requests, a research team was formed in March 1997 to design an environmental study that will estimate the baseline levels of metals in the aquatic environments of the above lake and river systems. Specifically, the objective of the study was to build a database that could be used to evaluate the temporal trends of metals and detect significant increases of metal levels in the environment for future impact assessment. Another objective of the study was to complement or improve the SMRQ monitoring program by assessing new relevant sampling sites of the Deception River. Signs of metal contamination should be first observed in this river since it will receive discharges from two mining effluents of the Katinniq mines.

The environmental study took place on September 4-9, 1997 at Katinniq, Northern Quebec and in a southern area distant from any mining activities. Dr Eion Cameron, geochemist formerly with the Geological Survey Canada, Dr. Guy Chamberland regulatory toxicologist from CATO Research Canada, and Dr. Daniel Leclair and Chesley Mesher, respectively wildlife veterinarian and technician from the NRC of the Makivik Corporation, composed the field-team. Extensive sampling of water, sediment, moss, fish and mussel has been carried out in the receiving environments of the mines and in a pristine area located in the surroundings of Crater Lake. This report describes the water chemistry, sediment chemistry and metal levels in the biota of the Crater Lake, Deception, Vachon and Puvirnituq rivers before the beginning of mining production. It integrates and summarises major findings of the data analysis carried out by Drs. Cameron (1997, 1998) and Chamberland (1998).

2.0 Past contamination of Deception Bay

Asbestos Corporation Ltd. exploited an asbestos deposit between 1972-1984 at Purtiniq, 68 km southeast of Deception Bay. Close to 11.2 million ton of ore was produced from open-pit mining during a period of eight years. The concentrate was transported 65 km by trucks and stored in a large building at Deception Bay where port infrastructures were built. The port was equipped with loading facilities permitting the shipment of concentrate and reception of goods. As Falconbridge planned to use these port facilities for the Raglan Project, an environmental study was conducted in 1991 by Roche Limited to evaluate the past contamination by Asbestos Corporation in Deception Bay area (Roche, 1992a). Apart from the inventory of surface rubbish around the area, extensive sampling of soils, sediments and surface waters was carried out around the port, Bombardier Beach, and airport, where contamination was suspected. Across the bay, reference stations for soil and water were included for comparison. Sediment samples were also collected in several locations of the bay, from the mouth of Deception River to Neptune Island, to assess the distribution of metals and asbestos fibre contamination.

Several chemicals including metals, asbestos fibres, oil and grease were analyzed. Roche (1992a-93) reported that the sampling stations surrounding the port infrastructure were the most affected by the activities of the previous mine. High concentrations of asbestos fibres, grease and oil, nickel, cadmium, chromium, copper and lead were found in sediments of stations where no visual effects on the benthos could be detected. However, concentrations of nickel, copper and chromium were above level 3 criteria of Environment Canada (1993) and lead and cadmium above level 2. In both cases effects on the aquatic environment may occur. Concentrations of grease and oil were detected in most sediment stations of the bay but asbestos fibres were limited to the area around the wharf. In contrast, concentrations of arsenic were found to be lower in stations around the wharf than in stations of Careenage Arm, False Cove and the mouth of Deception River. These high levels of arsenic were associated with silt-sediment located downstream of the main tributaries which adsorbed the element issued from the fluvial environment (Roche, 1992a). For most soil samples, chemicals were below the level B criteria of the Ministère de l'environnement du Québec (MENVIQ, 1988) which means that no environmental problems can be suspected. High levels of grease and oil were found in soil samples near the garage and the oil tank. Soil samples collected around the wharf, storage building and under the conveyor showed high percentages of asbestos fibres.

High concentrations of cadmium (up to 12.4 ppm wet weight) have been reported in viscera of scallops (*Chlamys islandica*) of Deception Bay (Boivin, 1994). Although these results were based on a small sample size, Health and Welfare Canada has recommended that the viscera from this stock should not be consumed alone nor should the scallop be sold as a single food. In comparison with other areas of the Hudson Strait, cadmium concentrations in scallop viscera from Diana Bay and Salluit were found within the acceptable range for consumption. No relation could be made between past contamination of the bay and the level of cadmium in scallops. However, the authors suggested verifying the relationship between cadmium variations in shellfish, water and sediments in future mining exploitations.

3.0 Meterials and Methods

3.1 Study area

The study area included the two receiving environments, the Deception and Puvirnituq rivers, that will likely be exposed to discharge from metal mining liquid effluent during mining operation, and two pristine environments, the Vachon River and Crater Lake located far from any mining activities. The active mining area is located at Katinniq, near the confluence of three tributaries of the Deception River in the northern part of the Ungava peninsula of arctic Quebec (Map 1). Located on a plateau at 550-640 m above the sea, the Katinniq mining site has three surface and underground extraction zones with a concentrator, tailings site, treatment plant, waste-rock pile and other mining facilities (Roche, 1993). Katinniq has access to Deception Bay by a 101 km road which crosses the Deception River 1 km downstream of the Deception East River confluence. The concentrate is transported to Deception Bay by truck where the port infrastructures of the previous mining company, Asbestos Corporation Ltd., are used for the storage and transshipment of the concentrate.

The Deception River flows northwest into the Deception Bay. The river will drain the discharge from two mining effluents (Map 2). The Weiser Creek (eastern mining effluent) will drain used industrial waters and runoff waters from the tailings site and concentrator. A separate watercourse (western mining effluent) will receive waters from the holding ponds of the waste-rock pile, pit no. 2 and pit no. 3. Another mining site located at Donaldson, 20 km east of Katinniq, near the Raglan Lake, has three potential surface and underground extraction zones, a private airport with a landing strip, a processing plant for mineral exploration and other facilities. Raglan Lake is the headwater of the Puvirnituq River that flows southwest into Hudson Bay, near the community of Puvirnituq. The river might be used as the receiving basin of the Donaldson site in future mining development.

Two pristine areas located south of the mining sites were included in response to community concerns. Pingualuit or Cratère du Nouveau-Québec, is approximately 45 km south of Katinniq or 88 km southwest of Kangiqsujuaq. Like seven other craters in Quebec, Pingualuit is the result of a meteorite impact (Bouchard, 1989). The crater contains a circular lake of 2.8-km in diameter and a maximum depth of 267 meters. Four kilometers north of the crater, Laflamme Lake constitutes the headwater of the Vachon River. The stream is an important tributary of the Payne River that flows southeast into the Ungava Bay, near the community of Kangirsuk. This system is inhabited by an important anadromous charr (*Salvelinus alpinus*) population harvested for subsistence by the Inuit of Kangirsuk. Map 3 shows the drainage basins of different river systems in Nunavik and their relationship with Raglan property.

3.2 Sampling design

The study has been designed to evaluate the temporal trends of metals that will be released in the environment by mining activities. Several monitoring tools have been selected to assess short and long-term contamination of the aquatic environments with metal liquid mining effluents and airborne metal particles. Surface water is commonly used to assess punctual or short-term contamination of the aquatic environments as it provides a good indication of recent exposure to a mine's discharge. Surface waters were collected downstream and upstream of both the Katinniq and Donaldson mining sites. A downstream-upstream study compares stations exposed to mine discharge (downstream of mines) with a reference station (upstream of mines) at a particular time. The effect of seasonal variation is limited as water samples were collected on the same day. Map 4 shows the locations of the sampling stations for surface water in the receiving and pristine environments.

Upstream stations of Katinniq mines included the west (Dec-west), east (Dec-east) and south (Dec-south) branches of the Deception River. Downstream stations included two mining effluents (Dec-28 and Dec-26) and three stations selected below the rapids just downstream of Dec-28. Dec-27 was the first station downstream of Weiser Creek (Dec-28) followed by Dec-22, downstream of the western mining effluent (Dec-26), and finally Dec-6 below Deception East River, approximately seven kilometers from the mining effluents. In addition, the Deception East River, main tributary of the Deception River, has been sampled and used as a control river station (Dec-30) for the Deception River waters.

A limited number of sampling stations were sampled on the Puvirnituq River system since the Donaldson mines were not yet in operation. Two downstream stations (DS) and one upstream station (US) were assessed for the Donaldson site. Puv-4 (DS) and Puv-5 (UP) were respectively located on the west and north tributaries of the Raglan Lake which is the headwater of Puvirnituq River. Puv-1 was located at the origin of the river at the south end of the Raglan Lake.

No upstream-downstream study was required for the pristine environments as they were located too far from the mines for a measurable effect to be anticipated. Surface waters collected from the Vachon River system included one station on Laflamme Lake (Vac-1), one on the river (Vac-2) and one on a main tributary (Vac-3). At Crater Lake only, ten random sites were sampled in the eastern part of the lake to assess the variability of metal levels.

Fine sediments, terrestrial moss, fish and mussels are being used to assess long-term contamination of the aquatic environments since they integrate the variable contaminant loading over time. Stations were selected downstream to the mines at various distances where repeated sampling can be conducted effectively for monitoring purposes. Locations of the sampling stations are shown on Map 5-8. A single core from suitable fine sediment beds was collected near each of the two mining sites (Deception River: Dec-2 and Purvurnituq River: Puv-6) and far from the mines in the southern area (Laflamme Lake: Vac-1). Arctic charr (*Salvelinus alpinus*) were also sampled from Dec-2. These constitute the highest trophic level of the biota that will be exposed to mine's discharges. Three blue mussel (*Mytilus edulis*) beds of Deception Bay (Decbay1, Decbay2, Decbay-3) used for subsistence

(Doidge, 1992) were selected to assess future long-distance (100 km from the Katinniq mines) contamination of the marine ecosystem by metal liquid mining effluents.

Two fish populations from the pristine area, respectively lake trout (*Salvelinus namaycush*) and landlocked charr (*Salvelinus alpinus*) from Laflamme and Crater lakes were sampled for future assessment of contamination with airborne metal particles. In addition, terrestrial moss was sampled near the Deception (Dec-26) and Vachon (Vac-1, VaC-2, Vac-3) river systems on an experimental basis for this purpose.

3.3 Field procedures and QA/QC

The use of a quality assurance and quality control (QA/QC) program is a common practice in pharmaceutical laboratories to ensure data accuracy, minimise error and provide authenticity of records. A QA/QC program can also be applied in field situations to minimise pre-analytical variation of environmental analyses. Prior to fieldwork, all procedures including sample identification, collection, handling and processing of all sample types were outlined in ten Standard Operating Procedures (SOPs) (Chamberland, 1997). Each procedure had to be followed in the field, any deviations from these SOPs were documented. A chain-of-custody procedure was developed to ensure the maintenance of an unbroken record of possession from the time samples were collected in the field to the time they were received by the outside laboratory (Chamberland, 1998).

With a sample-handling documentation system, Dr. Chamberland was responsible for identifying each sample and ensuring their custody during fieldwork. For all samples, monitoring site, sample number, GPS locator, date and time of sampling were recorded on a data form. Data entry was dated and signed by Dr. Chamberland or performed by Dr. Leclair when needed. Other data specific to each sample type (see sample collection) were also entered on the same data form.

Several precautions were taken to protect samples against tampering. Fine tamper resistant tape was used to seal caps of water bottles and sediment-collecting cylinder, and sample bags for sediment, moss and small fish. Writing over the two edges of the tape placed on the bags provided additional protection. Expired Ministère du losir, de la chasse et de la pêche (MLCP) coded salmon tags were attached to the tail of medium and large fish while a blue plastic coded resistant seals were placed in bags containing the mussels for identification purposes. All samples were stored in large plastic boxes sealed with blue tamper resistant seals.

Dr. Cameron used several means in the field to assess any external contamination of the water samples that could have occurred during collection, handling, storage or transport, and to evaluate the quality of metal analyses performed by Activation Laboratories Ltd. (Actlab). Water samples were collected in duplicate and Actlab analysed each sample in duplicate generating four analyses per station. A certified reference water material from the National Research Council of Canada (NRCC) (SLRS-3) and a volume of ultra-pure water (blank) were brought in the field and subjected to different site-specific conditions. Water bottles were filled with SLRS-3 at Dec-26 near Katinniq mines and at Vac-2 station in the Crater Lake area, while the ultra-pure water was subjected to the Donaldson Base Camp condition where water samples were stored during fieldwork.

Northern waters are not usually required to be filtered and acidified prior to metal analysis (Cameron, 1978). However, additional samples from Vac-1, Dec-27, Dec-east and Dec-6 stations were collected, filtered and acidified to confirm the previous findings. Due to the air transport constraint associated with ultra-pure nitric acid, these water samples along with a blank sample were filtered and acidified in a biological safety cabinet (Class II, type A) at the NRC by Dr. Kwan.

All samples and their respective containers were protected against tampering at all times and examined for signs of tampering during the fieldwork and storage and following transport to Makivik. Similarly, packages shipped to analytical laboratories were wrapped in brown packaging paper and techniques such as writing over tape edges were used to detect tampering. These packaging papers were cut open by the receiver and returned to Makivik for examination. All forensic examinations conducted did not reveal or indicate any signs of tampering.

3.4 Sample collection

The field-team was based and accommodated by the SMRQ at the Donaldson Camp (61° 42' .165' N, 73° 17' .125'W). An Astar 350 BA helicopter was chartered by Makivik Corporation to travel to the sampling stations. GPS locations were recorded in latitude-longitude for each station using an Ensign GPS™ (Trimble Navigation Limited). Appendix 1 contains the list of sampling stations along with the coordinates.

3.4.1 Surface water

All water samples were collected directly from the shore of each sampling station except for Crater Lake. Ten samples from the eastern part of the lake were randomly collected using a nine-foot Zodiac boat without motor to prevent any contamination of the basin with hydrocarbons. High-density polyethylene bottles (Nalgene 125 mL) were rinsed twice and filled with surface water. To avoid contamination with hands, Dr. Cameron used a sweeping motion against the current, approximately 10 cm under the water surface (Cameron, 1997). Water conductivity and pH were measured using a field meter and a standard mercury thermometer. Samples were kept at room temperature until they were shipped to the NRC where they were stored temporarily in a refrigerator pending shipment to Actlab.

As indicated in section 3.3 of this report, all samples were protected against possible tampering during storage and transport.

3.4.2 Sediment cores

Fine sediments were first spotted by helicopter, as they appeared brighter than rocks when the sunshine reflected from the bottom of the basin. The Zodiac boat was immobilised over the area with two or three anchors depending on current and wind directions. To reach the sediments, a long pole made of a series of aluminium rods was connected and secured to a 6.4-cm internal diameter Glassifex tube. The tube was equipped with a rubber plunger connected to an external wire.

Perpendicular to water surface, the sediment-sampler was manually driven into the bed. The plunger was then gently pulled to create a partial vacuum until the sampler was pulled out and brought above the boat. A plastic cap was immediately put on the tube's opening to prevent loss of sediments. The tube was then transported vertically to the camp to keep the sediment column intact. Sections 2 cm thick were cut with a knife, transferred into individual sample bags and stored in the same conditions as the water samples.

As indicated in section 3.3 of this report, all samples were protected against possible tampering during storage and transport.

3.4.3 Terrestrial moss

A search for terrestrial mosses was performed near the shore of water sampling stations only. Each type of moss was described and sampled separately. Using standard stainless steel scissors, several clumps from one or two main beds were cut at the base and kept in a small paper bag at room temperature until they were sent to the NRC. As for water and sediment samples, moss samples were stored in a refrigerator until shipment to Actlab for metal analysis.

As indicated in section 3.3 of this report, all samples were protected against possible tampering during storage and transport.

3.4.4 Fish

A scientific permit (N° séq. 105) was obtained from the Ministère de l'environnement et de la faune (MEF) to capture 30 fish per station. Two experimental meshed nets of 6 X 150 ft. divided in six panels of different mesh size (min: 2.5 cm, max: 10.8 cm) and equipped with a floating rope, were set apart (over 150 ft.) transversally to the shore of each station. Nets were installed in the afternoon and checked the following morning. A camp was temporarily set up on the east side (61° 16' .806' N, 73° 38' .512 W) of Pingualuit to verify the nets in early morning. Fish weights and fork lengths were recorded in the field or at the base camp if time was limiting. Whole fish were put in large sample bags and stored at –18°C in the walk-in freezer of the base camp until they were shipped to the NRC.

Fish were dissected in the biological safety cabinet (Class II, type A) of the NRC to reduce contamination from both, air and handler. Sterile scalpels were used to open small fish while medium and large fish were dissected with a butchering knife. To reduce cross-contamination between samples, dissecting tools were immersed in deionized water between each sample. Water was changed between groups (30 specimen per group) and within group if needed. A large muscle sample was collected from each side of the fish, just behind the dorsal fin and above the lateral line. After collection of gills, a ventral midline incision was performed to identify the sex, assess gonad maturity and collect the whole liver and kidneys. Tissue samples were put in 15 or 50-mL polyethylene tubes depending on size and stored at –18°C until shipment to Actlab. The otoliths were taken and put in a small envelope. Age were determined using the methodology described by Nordeng (1961).

As indicated in section 3.3 of this report, all samples were protected against possible tampering during storage and transport.

3.4.5 Mussels

At each station, 30 to 60 mussels of similar lengths were handpicked at low tide, put into a large sample bag and preserved on ice until the return to Donaldson Camp. Ten gallons of seawater were also transported to the camp and filtered through a 0.8-μm filter to remove any suspended matter. Each group of mussels was then put in separate meshed bags and suspended in filtered water for a 24-hour starving period to allow the invertebrates to eliminate most of their intestinal contents. Water was intermittently oxygenated with the pump over night. Each mussel group was then transferred to a large sample bag and stored at –18°C.

Similar to the fish, mussels were manipulated in the biological safety cabinet of the NRC. The whole mussel was weighed and measured for length prior to dissection. A sterile scalpel and a pair of tweezers were used to open the mussel. To reduce cross-contamination between samples, dissecting tools were immersed in deionized water between each sample and water changed between groups. After removing the byssus, the entire soft tissue was collected, weighed and put in a 15-mL polyethylene tube for storage at –18°C. Shells were kept at –18°C until they were aged according to the method of Thompson (1993).

As indicated in section 3.3 of this report, all samples were protected against possible tampering during storage and transport.

3.5 Metal analysis and QA/QC

Assessing the levels of ultra-trace metals in aquatic environments requires the use of sensitive analytical methods that can measure in μg/L to ηg/L concentration range. Depending on the sample type and the element of interest, the concentration of the element may be detected below 10 μg/L or above 100 μg/g depending of the matrix. The selection of an analytical method is based on its capacity to detect the element at the expected environmental levels. Moreover, the appropriate methods should be reproducible (low analytical variation) in the matrix of interest enabling detection of small increases of metals in future environmental impact assessment studies.

Activation Laboratories Ltd. (Actlab) of Ancaster, Ontario, was contracted to measure a series of metals in water, sediment, moss, mussel and fish tissues. In addition to their internal QA/QC program, Actlab used a documentation system to ensure the custody of samples during all manipulations, including reception, storage, preparation, analysis, and archiving.

The analysed elements were based on the list of metals recommended by the MEF and the Kativik Environmental Quality Commission (KEQC, 1995) for the environmental monitoring of mining effluents. Other elements commonly used in geological surveys were also tested in water, sediments and moss. Sixty-six metals were analyzed in water samples by an inductively coupled plasma mass spectrometer (ICP-MS) which is the most sensitive analytical instrument for detecting ultra-trace metals simultaneously in water. Table 2 shows the list of elements and their detection limits. As part of the internal quality control program, Actlab analyzed samples of two water certified reference materials (SLRS-3 and NIST1643d) and of one reagent blank (ultra-pure water) several times between batches of samples to verify the analytical precision and accuracy throughout the analyses.

Each layer of sediment samples were analyzed for 48 metals using a combination of neutron activation (NA) and ICP methods (Table 3). For NA analysis, samples were first dried to avoid formation of gases inside the capsule during irradiation. A subsample was encapsulated and irradiated with neutron yields in a nuclear reactor. The specific radiation from each element was then quantitatively measured in a radiation counter. Another subsample was acid-digested and analyzed by ICP for a different set of metals. Two sediment standards (GXR-1, GXR-2) with known concentrations were analyzed once by each method for quality control. As the matrix of the standards differ from the true samples, one replicate of RS-004F, RS-104A and RS-004I were analyzed between batch of NA analysis whereas one replicate of RS-104A and RS-004I and three reagent blanks were analyzed at the end of the run of ICP analysis.

Moss samples were analyzed for 35 metals by NA only. One replicate sample from RM-013 and one standard (NBS-1632b) were analyzed once to check the accuracy and precision of the procedure. Table 4 shows the list of detection limits and metals analysed in moss.

Mussels and fish tissues (liver, kidney, and muscle) were acid-digested and analyzed for 12 metals by ICP-MS and for mercury by Flow Injection Mercury Analyzer (FIMS). The list of metals and detection limits in tissues are presented in Tables 6-9. The entire sample or approximately 5 grams was digested in a Teflon tube with nitric acid under intermittent heating cycles (4 cycles, room temperature to 90°C). Hydrogen peroxide was then added to the digested sample and heated once to remove any oxides of nitrogen and then brought up to a 10 mL final volume with ultra-pure water. A small volume from the tube was transferred in a polystyrene tube for ICP-MS analysis and another into a glass tube for a second hot digestion (90°C for 2 hrs) using potassium permanganate [1 mL of 5% (w/v)], potassium persulphate [0.32 mL of 5% (w/v) and nitric acid (1.1 mL) to ensure complete oxidation of mercury. Sodium chloride/hydroxylamine hydrochloride [0.4 mL of 12%/12% (w/v) was then added to stabilize the solution by reducing the manganese oxide precipitate into manganese ion ($Mn2^{+}$). The solution was brought up to 10 mL with ultra-pure water and analyzed for total mercury by FIMS. Three NRCC tissue certified reference materials (DORM-2, DOLT-2, TORT-2) were analyzed several times (n=10) between batches of samples for quality control. In spite of the close relatedness with the sample matrix, one muscle replicate (RF-021M2) and four liver replicates (RF-009L, RF-011L, RF-003L and RF-413L) were analysed once during the run to verify the stability of the method.

3.6 Analytical performance

The precision and accuracy were calculated to assess the analytical performance of the methods used by Actlab to measure metals in water, sediment and biological materials. The accuracy is the measurement of the nearness of a result or the mean of a set of results to a true value. This was assessed by testing replicates of certified reference materials analogs to the matrix of each sample type several times between batches of samples and comparing the mean of results to the known value using percent recovery (%R). The precision is a measurement of the reproducibility of a method or the conformity between a set of replicate samples and can be assessed by calculating the relative standard deviation (%RSD). The accuracy and precision were ranked good when results were inferior to 10%, acceptable between 10 to 15% and poor above 15%.

The quality control data for SLRS-3 and NIST1643 water reference materials and blanks were analysed and presented in a separate report (Cameron, 1997). Results from the SLRS-3 and blanks (unfiltered) brought in the field (external) were in agreement with the laboratory (internal) SLRS-3 and blank results for most metals. Manganese has been detected in both external unfiltered and filtered blanks while the internal blank values remained under the limit of detection (LOD). However, the difference was only of 0.17 $\mu g \cdot L^{-1}$ and therefore does not constitute a significant contamination.

By comparing results of filtered acidified water samples (one blank and four river samples) with their untreated pair samples, Cameron showed that a greater number of metals had higher values when the samples were treated. Pre-analytical contamination could have occurred during filtration or when samples were acidified with nitric acid. This corroborates the results a previous study (Cameron, 1978) in which the author concluded that filtration and acidification is not required for northern surface waters as these procedures may contaminate the samples. The accuracy and precision were basically good for most of the elements analysed in SLRS-3 (n=16) and NIST1643 (n=2). Accuracy and/or precision were either acceptable or unacceptable for Br, Co, Ni, Se, Sb, Sn, Sr, Y, Zn and Zr in the SLRS-3 standard but most of them had values close to their LODs where the analytical variation is usually high. The agreement between some sets of values was unacceptable for Ce, Nb, Y and Zr in NIST1643. Note that the accuracy of several metal analyses could not be assessed because the reference materials had no certified values for these elements.

Tables 1 shows the precision and accuracy of each metal tested in biological certified reference materials with their expected or certified values. The precision and accuracy were found good or acceptable for many of the elements tested in the fish kidney of RF-022K, RF-320K and RF-112K from Crater Lake, Deception River and Laflamme Lake, respectively. This essential element was not detected because of the small amount of tissues (sample weights<0,03 g) tested.

3.8 Descriptive statistics

Median and range were used to describe the average and variation of metal levels in fish and mussel tissues. The median was preferred over the mean due to the presence of extreme values. The box-and-whisker plot was used to illustrate the variation in age between mussel groups and fish classes. Correlation coefficients were calculated to evaluate the relationship between age, length and weight with metal concentrations in mussels. The Mann-Whitney U test was used to compare metal levels between fish classes of the Deception River and Crater Lake and between Decbay-1 and Decbay-2 mussel groups. The level of statistical significance was set at $p<0.05$.

4.0 Results

4.1 Surface water

All measurements conducted in surface waters of rivers and lakes are presented in Table 2. Many of the sixty-six elements tested in sampling stations of the Deception River were below or close to the detection limits. However, an increased contaminant concentration downstream of the Katinniq mines was noted when results were compared with the reference station (Dec-30). By plotting data from Dec-27 (closest river station to Katinniq mines) versus Dec-30, Cameron (1997) demonstrated that 13 elements were 10 to 100 times the concentration of Dec-30. Levels of cobalt and manganese in Dec-27 waters were 172 and 261 times that of the reference river, respectively. The highest concentrations of metals were found in the water supply located behind the dam of which 16 elements were 10 to 1000 times the concentration of the reference river.

Most elements tested in the Deception River waters met the provincial water quality guidelines for the protection of aquatic life (MENVIQ, 1990a) with the exception of nickel and zinc. The levels of nickel and zinc in water at Dec-27 sampling station were respectively 64 $\mu g \cdot L^{-1}$ and 21.6 $\mu g \cdot L^{-1}$ averages which were 2.5 and 1.2 times the recommended guidelines, respectively. The concentration in cobalt was also relatively high in Dec-27 with 2.9 $\mu g \cdot L^{-1}$ and close to its guideline of 5 $\mu g \cdot L^{-1}$. There are no chronic toxicity guidelines for manganese, but the level of this metal in Dec-27 was high with 29 $\mu g \cdot L^{-1}$ which was 2.9 times the guideline for full use.

Nickel concentration decreased slowly in the receiving watercourse compared to other elevated metals. Figure 1 shows the trends of four metals released in the Deception River. Nickel remained relatively high 7 km downstream (Dec-6) of the mining sites with 19 $\mu g \cdot L^{-1}$ whereas manganese and cobalt decreased rapidly by Dec-22 station from 28.7 and 2.9 $\mu g \cdot L^{-1}$ to 0.8 and 0.07 $\mu g \cdot L^{-1}$, respectively. Zinc concentration also decreased rapidly but less than cobalt and manganese. The bioavailability of nickel is therefore higher in the water column than any other metals, which consequently increases the risk of exposure of the landlocked charr population to this metal.

Contamination of downstream waters was also observed in the mining effluent (Dec-28) that drains the mills. The contaminated water samples had the highest conductivity with 130 µs and a neutral pH of 6.9. Copper concentration was 9 times more concentrated than the non-industrial tributary, sodium 6 times, magnesium 4.5 times, calcium 3.3 times and potassium 2.7 times as concentrated. The conductivity decreased from 70 µs in Dec-27 to 30 µs by Dec-6 station and the pH remained close to neutral, in the range of 6.9 to 7.7. In contrast, the mineral contents of the other mining effluent (Dec-26) was low and comparable to Dec-30 (Table 2), which indicates that Dec-26 did not contribute significantly to the increased concentrations of metals in Dec-22 station.

The concentrations of elements in the Puvirnituq River waters were low and comparable within stations. No evidence of punctual contamination of the system was demonstrated. Concentrations of elements were slightly higher in Puv-4, the closest station to Donaldson, but were consistently under the water quality guidelines. Surface waters from the Vachon River and Crater Lake showed very low concentrations of all elements, particularly in Crater Lake. Most elements from the latter were close to or under the LODs. Vac-3 station had a slightly higher mineral content than Vac-1 and Vac-2 stations, but as with Crater Lake, they were all considered pristine areas. The conductivity and pH of these aquatic environment were also within the acceptable range. However, pH values from the 10 randomized sites of Crater Lake varied significantly from 6.1 to 7.2.

4.2 Sediment cores

Fine sediments were hard to find in the rocky substrate of the Deception and Puvirnituq rivers whereas they were more abundant and easily spotted along the shoreline of Laflamme Lake. The cores were respectively 10, 12 and 22 cm long for Puv-6, Dec-2 and Vac-1 stations. As expected, the river cores, Dec-2 and Puv-6 were half the length of the Vac-1 core that originated from a lake. The velocity of the current prevailing in river decreases the sedimentation rate and increases the erosion rate. Forty-eight elements were determined in 2-cm layers from surface to bottom of the cores. Table 3 shows the averages and the relative standard deviation (%RSD) of elements. Although the composition of elements varied greatly between cores, several elements were consistently found near or below the LODs in each layer of the cores such as cadmium, mercury, molybdenum and others. Figure 2 compares the concentrations of five metals to illustrate this variation in background levels among cores.

The metal profile varies from core to core but less among layers of each core, particularly in Dec-2 core. The %RSD of aluminium, cobalt, chromium, iron, manganese, nickel and zinc ranged from 4 to 20% in Dec-2 core. Figure 3 shows variations of four metals in Dec-2 core which were detected in high concentrations in Dec-27 waters. These low variations are characterised by a profile of vertical lines from top to bottom of the core. Cesium, cobalt, copper, manganese, nickel and vanadium had similar profiles in Vac-1 core (Figure 4) but different from Figure 3. The latter profiles were characterised by a high concentration of the elements in the first centimeter which steadied down to six centimetres, followed by an increase trend down to 14 centimetres and finally steadied or decreased in concentration towards the bottom. The concentrations of copper, nickel and manganese in the top layer were respectively 5.2, 2.1 and 2.4 times the minimum concentrations detected in Vac-1 core. Manganese and relatively less for iron were also found in high concentrations in the first two centimetres of Dec-2 and Puv-6 cores.

The average concentration of arsenic in Dec-2 core was detected above the level 2 guideline of Environment Canada (1993) and above level 3 for chromium, copper, nickel and zinc. Level 2 refers to a range of concentrations tolerable by the majority of benthic organisms (minor effects) whereas above level 3 is harmful. The core had an average concentration of 736 $\mu g \cdot g^{-1}$ of chromium and 317 $\mu g \cdot g^{-1}$ of nickel which were respectively, 14 and 9 times the level 1 guidelines where no acute or chronic adverse effects can be observed on benthic organisms. A high concentration of 18 $\mu g \cdot g^{-1}$ of arsenic was also measured 2 cm below the surface of Dec-2 core while the average concentration was 7 $\mu g \cdot g^{-1}$. Along with the concentrations (%RSD: 79.4), the level of toxicity for arsenic largely varied through the core, from below level 1 to above level 3. However, most elements found at the toxic level were generally found in each layer of cores. As shown in Table 3, the background levels of metals in Puv-6 core were also above level 3 for chromium, copper and nickel but in lower concentrations than Dec-2 core. In contrast, the baseline values of metals were all under level 1 in Vac-1 core.

4.3 Terrestrial moss

4.3.1 Abundance of vegetation

The surface of the Katinniq area is sparsely vegetated. The landscape appears like a rock desert from the helicopter. The collection of moss down-wind of the mine in a gradient fashion was not possible. The vegetation is poor and scarce on the banks of the Puvirnituq and Deception rivers study area. Only one sample of thick yellow-brownish branched moss could be collected on the plateau near Dec-26 water sampling station, northeast of the open pits no.2 and no.3.

The density and abundance of vegetation improved on the banks of the Vachon River despite the Crater Lake area being poor in vascular flora. Similar types of mosses were collected near the edge of Vac-1 and Vac-2 water sampling stations. Two samples instead of one were collected at Vac-1 to verify the variability of metal concentrations within the site. As opposed to other samples, a different stringy-type of moss could be collected at Vac-3. Identification of moss samples was not completed.

4.3.2 Metals in terrestrial moss

Most of the 35 elements analyzed were found to be in the low $\mu g \cdot g^{-1}$ range, sodium being the highest with 4910 $\mu g \cdot g^{-1}$ in the moss sample from Vac-3 station (Table 4). The concentrations of elements were generally higher in the stringy moss from Vac-3 than any other moss samples with the exception of antimony, chromium, gold, nickel and zinc. Some of the elements in Vac-3 moss, such as sodium, thorium, scandium and samarium, were higher than the minimum values observed in the other stations by factors of 9, 18, 19 and 27, respectively. This difference is likely to be species-related since the variability of metal concentrations appeared smaller among moss samples of similar types.

Some elements were in the same range of concentrations whereas others varied largely among thick-moss samples. The mean coefficient of variation of the Vac-1 data set was 45% (<LOD values not included) which means that metals naturally have a high variation in mosses. A larger sample size would be required to determine the extent of this variation. Nickel was detected in Dec-26 station with a level of 18.5 $\mu g \cdot g^{-1}$ but not in any of the other samples including the stringy sample. The level of nickel in mosses is therefore a good indicator of potential wind-borne metal contamination for the Crater Lake area. As opposed to nickel, rubidium was not detected in Dec-26 but in all the other stations indicating two different geological settings. Potassium was low in Vac-1 and Vac-2 and singularly not detected in Dec-

26 indicating that the soil of these areas is poor in this essential element which can compromise vegetation growth.

4.4 Fish

4.4.1 Catch-per-unit-effort

The total catch of Deception River fish exceeded 100 fish in 17.25 hours of net fishing. Based on an approximate number of 120 fish, the catch-per-unit-effort (CPUE) was estimated at 82 fish/net/day. The majority of the fish were caught in one net (n>80) located in a larger and deeper pool (Dec-2 station). Because of an elevated mortality rate, an additional 45 medium-size fish were kept and stored at the NRC for metal analysis.

Nets were kept for longer periods in lakes to obtain the allocated number of 30 fish per lake. The CPUE was 18 and 12 fish/net/day in 41.75 and 36.5 hours of net fishing at the Laflamme and Crater lakes, respectively. A group of 20 fish was captured 13 hours after setting the nets in Crater Lake and another of 15 on the next morning of which, 5 small-size fish were released. In Laflamme Lake, 23 lake trout were captured 22.5 hours after setting the nets and a group of 38 including one charr on the next day. Seven trout and one charr were kept from the last group and the excess was released.

4.4.2 Age variation

To reduce the variation of metal concentrations associated with size, fish were grouped in three length-size classes as follows: 10-20 cm (class 1), 20-40 cm (class 2) and 40-60 cm (class 3). The variation in age within and among classes of the Deception River and Crater Lake charr is shown in Figure 5. The age ranges overlapped between all classes of the river charr but less so between classes of Crater Lake. However, the number of class 2 fish captured from Crater Lake was too small (n=3) for appropriate comparison (Table 5). Plotting length versus age of the river charr showed a clear bimodal pattern with length, which indicates the presence of two separate populations (Figure 6). The oldest charr from Crater Lake was 31 years of age while the youngest was 5 years-old. In comparison, the youngest charr from Deception River were 5 years-old, but the oldest was 16 and belonged to class 2 instead of class 3. Despite the small sample size from each charr population, Crater Lake charr appeared older in each class but the great difference observed between the two size modes support the hypothesis that some of the charr from the Deception River could be anadromous. Most lake trout caught from the Laflamme Lake were within the size of class 2 and were aged between 8 to 19 years.

4.4.3 Metals in fish tissues

Tables 6-8 show the medians and concentration ranges of metals in liver, kidneys and muscle tissues of charr and lake trout. The range in arsenic, cadmium, lead, mercury, nickel and vanadium concentrations was generally in the low $\eta g \cdot g^{-1}$

zinc (*r*=-64.0, $p<0.001$) in muscles, copper (*r*=-67.4, $p<0.001$) in kidneys, and cobalt (*r*=-53.2, $p=0.002$) and zinc (*r*=-75.2, $p<0.001$) in livers.

4.5 Mussel

4.5.1 Size and density

The intertidal mussels from Decbay-3 station near the Hudson Strait were small and scattered on a large bed made of rocks and sand. Large mussels of 50-60 mm length were difficult to find and required a search of 35 minutes. The selected mussels weighed (total weight) 6.4 g in average and measured 42.9 mm (Table 9).

In contrast, mussels from Decbay-2 station (eastern bank of Deception Bay) were large and spread in clusters on a small sandy bed located at the mouth of a watercourse, reducing the search period to 10 minutes. The collected mussels weighed 17.1 g and measured 57.7 mm in average. Similar to Decbay-2 mussels, mussels from Decbay-1 weighed 17.2 g and measured 62.1 mm on average but were gathered in 20 minutes from a large muddy bed located in the southern part of the bay, near the road.

4.5.2 Age variation

Average age of Decbay-3 mussel group was 2.7 years and much younger than Decbay-1 and Decbay-2 which were respectively, 11.2 and 8.9 years. The age frequency distributions of Decbay-1 and Decbay-2 groups were similar and thus statistically comparable (Figure 10) for metal levels if both groups have identical growth rates. Mussels were pooled to test the strength of association between age and size and describe their relationship. A strong positive correlation (*r*=0.85, $p<0.001$) was observed between the two variables that increase according to a logarithmic regression pattern (Figure 11). Mussels from Decbay-2 and Decbay-1 stations appear to have similar growth rate although a higher number of mussels from different age class is needed to confirm the observation.

4.5.3 Metals in mussels

Table 10 shows the medians and concentration ranges of metals in whole body tissues of blue mussels of Deception Bay. Similar to Deception River charr, beryllium and chromium levels in mussels were mostly below the LODs. The profile of metal concentrations were generally comparable among groups with aluminium, arsenic, iron and zinc median values superior to 1000 $\eta g \cdot g^{-1}$, cobalt, mercury, lead and vanadium below 100 $\eta g \cdot g^{-1}$ and cadmium, copper and nickel intermediates. The individual variation of metal concentrations were large for aluminium and iron in all groups while lead and mercury variations were mainly large in Decbay-1 and Decbay-2 as demonstrated by the higher ranges. Median values of most metals in Decbay-3 group were generally superior to or near Decbay-1 and Decbay-2 medians excepted for lead.

Correlation coefficients were calculated to evaluate the relationship between age, length and wet weight with metal concentrations before comparing groups for metal levels. The correlation coefficients of weight and metal concentrations were higher than the corresponding age and length coefficients. A negative correlation was observed between weight and cobalt, copper and nickel levels in each mussel group (Figures 12-14). Cobalt and nickel in Decbay-1 had the strongest correlation coefficients with r=-70.9 (p<0.001) and r=–71.8 (p<0.001), respectively. Comparison of metal levels were then performed between Decbay-1 and Decbay-2 only since Decbay-3 mussels were much smaller in size and different in age distribution frequency. Concentrations of cobalt, lead, mercury and nickel in Decbay-1 group were significantly higher than in Decbay-2 group at $p<0.05$.

5.0 Discussion

5.1 Surface water

The mineral content of surface waters of two lakes and three river systems located in the surroundings of the Katinniq and Crater Lake areas was characterised before the commencement of mining production. The baseline data reflect the background levels of elements detected under the natural conditions that prevailed in early September 1997 in the studied areas. The natural occurrence of many elements measured in surface water was very low or unknown because they were below the LODs. The presence of one of these undetected elements in elevated concentrations in either downstream or upstream waters of the mine sites will likely indicate a contamination of the aquatic environment. However, contamination of the environment usually occurs when untreated wastewater from mining and ore processing is discharged in the final mining effluents. The wastewater will contain metals that mostly reflects the mineral composition of the ore (base metal) and host rocks like aluminium, arsenic, cadmium, copper, iron, lead, manganese, molybdenum, nickel and zinc (AQUAMIN, 1996a).

Contamination of the receiving environment was demonstrated by comparing data from the Deception East River station (Dec-30) with three stations of the Deception river located downstream of Katinniq mines. Many elements were detected 10 to 100 times the concentration of the Deception East River ever though the mines had not officially started production. Cobalt, manganese, nickel and zinc were more elevated in Dec-27 waters than in any of the two mining effluents. Consequently, the increased concentrations in the receiving waters were not only the result of effluent discharge. Cameron (1997) has shown that contamination with aluminium, zinc, nickel, copper, cadmium and other metals also occurred around the mines in a collecting pond and in the water supply used for domestic and industrial purposes. Nickel and manganese were particularly elevated in the latter with respectively 48 $\mu g \cdot L^{-1}$ and 67 $\mu g \cdot L^{-1}$, exceeding the provincial guidelines for drinking water of 13.4 $\mu g \cdot L^{-1}$ and 50 $\mu g \cdot L^{-1}$. For health reasons, water from the reservoir should be monitored on a regular basis and treated prior to consumption.

The sources of high levels of cobalt, manganese and nickel in the water reservoir was likely due to the oxidation of sulphide minerals in the environment (Cameron, personal communication). Sulphides are found in host rocks and ore deposits of the

Ungava region and can oxidise naturally in the presence of water and oxygen or when they are exposed at the earth's surface. This phenomenon called acid rock drainage (ARD) generates sulphuric acid and decreases water pH. At low pH, most metals are relatively soluble and increase in concentration in acid mine drainage environments (Aquamin, 1996a).

The levels of metals in the Weiser Creek was also elevated but differed in elements and sources. The high levels of magnesium, calcium and sodium observed in Dec-28 station were the results of leakage from the tailings and collecting ponds that contained high levels of these elements. The industrial water discharged into the ponds may contain chemical agents rich in salt used in ore processing, and metals reflecting the geological setting. Roche (1997a) found that these elements and others such as nickel, zinc, manganese and cobalt were elevated in Weiser Creek in early September 1995. The authors associated the increases with the low water flow that prevailed during that period which enhanced the evaporation rate and increased metal concentrations. The water flow of both mining effluents, Dec-28 and Dec-26 was low in this study. The metal contents of the latter were comparable to the reference station. Thus, the downstream contamination observed at Dec-27 resulted from the reservoir, tailings and collecting ponds minus the natural sources of metals from precipitation and erosion.

Nickel and zinc concentrations exceeded the recommended concentrations for the protection of aquatic life in Dec-27 station. These guidelines were based on acute and chronic toxicity studies conducted on several animal aquatic species. The acute toxicity bioassays for nickel caused a higher mortality rate in the first stages of life of fish. Using fertilised eggs in soft water (inferior to 50 $mg{\cdot}L^{-1}$ of $CaCO_3$), Nebeker (1985) demonstrated that the highest concentration of which no effect could be detected in the rainbow trout is 35 $\mu g{\cdot}L^{-1}$. The concentration of nickel in Dec-27 was 1.8 times this level and occurred during the spawning period. In comparison, a concentration 1000 times greater (35.5 $mg{\cdot}L^{-1}$) was required to affect mature salmonids in water of unknown hardness (Hale, 1977).

The maximum concentration for zinc in softwater at which no effects were observed on rainbow trout is 36 $\mu g{\cdot}L^{-1}$ (Goettl et al., 1976). Based on the average water hardness of 12 $mg{\cdot}L^{-1}$ of $CaCO_3$ (Roche, 1992b), the calculated guideline for Deception River would be 17.6 $\mu g{\cdot}L^{-1}$. The concentration of zinc was found just above this level with 21 $\mu g{\cdot}L^{-1}$ at Dec-27 station. The toxicity of a metal in water generally varies as a function of the physico-chemical characteristics of the system such water hardness, pH, dissolved oxygen, levels of organic matter and other metals. The presence of zinc with other metals may either have an additive (Marking, 1977) or synergistic toxic effect (Anderson and Weber 1976) on fish depending on factors such as water hardness. The addition of copper has been reported to increase the toxicity of nickel in fish (Taylor et al., 1983). The water quality guidelines for nickel, zinc and other metals have not been determined as a function of their interactions with other metals that could be released simultaneously in the aquatic environment. The evaluation of toxicity should therefore take into account the physico-chemical characteristics of the aquatic environment and of the metal composition of the mining effluents.

The reproductive success of the Deception River's landlocked charr may be affected if they are chronically exposed to these levels of zinc and nickel. In a temporal study, from 1990 to 1995, Roche (1997a) showed that the levels of cobalt, copper, iron, nickel and zinc occasionally exceeded the guidelines for chronic toxicity at Dec-27 (Dec-7 station for Roche Ltd.). The highest levels recorded were 180 and 40 $\mu g \cdot L^{-1}$ for nickel and zinc, respectively, during high-water periods. In another study, Roche (1992b) has demonstrated that metal concentrations generally increased during flooding compared to low-water periods in Puvirnituq and Deception rivers. The levels of zinc and aluminium in water samples collected in early September (low-water period) of 1991 and 1995, respectively also exceeded the guidelines at Dec-7. The increased concentration of aluminium in the river was associated to the increased construction activities at Katinniq (Roche 1997a) whereas the elevated concentrations of zinc at Dec-27 and of copper, nickel and zinc at Dec-9 (upstream of Weiser Creek) in 1991 appeared to be attributed to the natural variation of the elements in waters.

Nickel is more bio-available than manganese and cobalt in surface waters of the Deception River since its concentration remained relatively high by Dec-22, whereas cobalt and manganese decreased rapidly in concentration by Dec-6 as a result of precipitation. According to Cameron (1997), Mn^{2+} would oxidise to Mn^{4+} and precipitate as manganese oxide. The latter can co-precipitate with cobalt reducing their bio-availability in the water column. However, the portion of the metals bio-available in sediments to living organism is currently unknown. A sequential extraction procedure would be required to evaluate how easily a metal can be released from the solid phase (AQUAMIN, 1996b). An alternative would be to evaluate the community structure (abundance and diversity) of benthic invertebrates as a bioindicator of the local ecosystem health. Macroinvertebrates have limited migration patterns and therefore are appropriate to assess local impacts (AQUAMIN, 1996c). Roche (1992b) has evaluated the composition and abundance of benthic organisms of the Deception River and its tributaries in 1991. The macroinvertebrates were composed of two phyla: arthropods and annelids. The arthropods were subdivided in three orders: diptera, ephemeroptera and plecoptera. In general, species from the ephemeroptera and plecoptera orders are metal-sensitive whereas those from diptera are metal-resistant (AQUAMIN, 1996d).

By comparing station to station of the Puvirnituq River, this study showed that the levels of metals were usually higher in Puv-4, located closer to the Donaldson site. The Puvirnituq waters were, however, lower in metals than waters from Dec-27 station. There was no evidence of downstream contamination with nickel, manganese, zinc, cobalt nor with other metals in the Puvirnituq River. In addition, if compared to the Vachon River, the Puvirnituq River waters were lower in manganese, potassium and zinc. Based on the conductivity and metal levels, the order of aquatic systems as a function of their mineral contents appeared to be Deception River > Puvirnituq River > Vachon River > Crater Lake.

The levels of metals in Crater Lake were mostly near or below the LODs. The mineral content of the ultraoligotrophic milieu was reported to be 50 times less than the world average and 10 times less than the average of northern lakes (Ouellet et al., 1989). The levels of elements were also very low in Vac-1 (Laflamme Lake), near the values of the Crater Lake waters. Ouellet and co-authors (1989) proposed that Crater Lake regulates its hydrostatic pressure through a north-south fault connected to Laflamme Lake. Using isotope analysis in water, Ouellet showed that the Laflamme Lake was enriched in $\delta^{18}O$ isotope that could originated from the Crater Lake waters.

Comparison of metal levels between baseline studies is difficult since they have used different sampling seasons and analytical procedures. Some of the metals were found at the part-per-trillion level in surface water so field and analytical procedures must be similar in order to reduce variation. In addition, the background levels were unknown for several metals in the other studies as they have used too high detection limits. Nevertheless, these aquatic systems were low in minerals, particularly the Crater Lake and Vachon River system, which make them naturally sensitive to acid precipitation or discharge from mining liquid effluent (for Deception River).

5.2 Sediment cores

The application of this technique was limited in the upper portions of the Deception and Puvirnituq rivers as rocks mostly covered their bottoms. Only one station per stream could be discovered and one fine sediment core extracted. The collection of duplicate samples was not possible since we could not sufficiently stabilize the zodiac boat. An alternative proposed by Dr. Cameron would be to collect the duplicate samples in winter through the ice. The ice cover acting as a stable platform during coring would allow the collection of two separate samples located in a defined zone. Nevertheless, the cores were at least collected downstream of the mines and their composition in elements was characterised before the commencement of mining operations.

As opposed to the grab sediment technique, the core sediment allows the measurement of inorganic chemicals from surface to various depths of the bed in small increments. The top layer of the core provides information on the recent deposition of elements although some elements may migrate from lower layers depending of their geochemical behaviours and the local geochemical setting (AQUAMIN, 1996a). The increase in manganese and iron concentrations observed in the top layers of cores was associated with the dissolution of the elements in deeper layers which then migrated in the sediment column through the interstitial waters toward the top and re-precipitated near the surface (Cameron, 1998). According to the author, the insoluble iron precipitate (Fe^{3+}) buried in the sediment would eventually be reduced into a soluble ion (Fe^{2+}), as the deep sediment becomes a reducing environment. The soluble form would then diffuse through the interstitial waters up to surface, oxidise to Fe^{3+} and re-precipitate. This dynamic process tangles the estimation of the true deposition of these elements in sediment.

The three cores were collected from three aquatic environments of different geological settings. Cameron (1998) associated this variation with the different bedrock compositions that distinguish each area. Most of the bedrocks in Dec-2 (Deception River) area are mafic igneous, granitic in Vac-1 (Laflamme Lake) and a combination of both in Puv-6 (Puvirnituq River) area. The elements that are more abundant in mafic versus granitic rocks were described by Cameron (1998). The mafic rocks are rich in nickel-copper deposits, which was reflected in Dec-2 core composition with its high base metal content. Chromium, cobalt, copper, nickel and zinc were constantly in high concentration throughout the core and not limited to the superficial layer. These findings are not unusual in areas of high mineralisation. Roche (1997a) has observed a high background in metal contents in grab sediments collected from the river in 1991, 1995 and 1996. Results from the three head tributaries collected in 1996, however, contrasted with the sediments collected from the receiver (Deception River). The baseline values of the three branches were significantly lower than the sediments collected from the river. The authors associated this variation with the presence of different bedrock among sampling sites.

The relative uniformity of nickel, manganese, cobalt and zinc distributions in Dec-2 core should allow the detection of increased metal depositions (right shifts) in future assessment studies. Although the %RSD of these metals were higher in Vac-1 core, airborne contamination should be detected as well, if any occurs, as the erosion rate in Laflamme lake is lower. However, apart from Vac-1, Dec-2 and especially Puv-6 stations do not allow frequent sampling.

5.3 Terrestrial moss

Mosses and other terrestrial vegetation are not abundant at Katinniq and Crater Lake areas. The growth of vegetation in the arctic environment is limited by several factors including temperature, humidity, luminosity, nebulosity and wind conditions (Roche, 1992b). The scarcity and low density of terrestrial mosses limit their use for assessing local contamination with airborne pollutants at Katinniq. The highest levels of airborne pollutants are usually found in the immediate surroundings of industrial sites and the elongation pattern of contamination follows the main winds and topographical features of the area (Ayräs et al., 1997). Moss station Dec-26 is located northeast of two open pits in a region where the main winds are westerly and southwesterly throughout the year (Coulombe, 1990). The location of the station is thus appropriate to assess the temporal trend of local metal contamination.

However, neither the gradient nor the extent of airborne contamination can be assessed due to the lack of terrestrial mosses in the surroundings of the mines and further south towards the Crater Lake area. The southern area appeared like a rock desert poor in vegetation and relief where the average speed wind is 50 km/hr in July (Roche, 1992b). Wind-borne metal particles could travel for a long distance in these conditions when the winds are northerly and northeasterly.

Nickel was the only metal detected in Dec-26 moss and not in any moss samples from the Crater Lake area. Due to the lack of a control station, we cannot estimate how close or far 18.5 $\mu g \cdot g^{-1}$ is from the background level. Using the terrestrial moss (*Hylocomium splendus*), Ayräs and co-workers (1997) demonstrated that nickel, copper and cobalt were the three main metals emitted from Russia's nickel industry (includes smelting activities). Although not comparable with this study, the minimum and maximum values were 0.97 and 396 $\mu g \cdot g^{-1}$ respectively, and the median of 5.4 $\mu g \cdot g^{-1}$. Nevertheless, a higher number of samples should be tested to confirm the low level of nickel in Vachon River stations as well as the variability of other metals.

Such a study could be conducted at Vac-1 station, which has the advantage of being closer to the Crater and Laflamme Lake ecosystems as well as to the mining sites.

5.4 Fish

The baseline levels of 13 metals were not uniformly determined in three length-size classes of each fish population. The fishing effort was not sufficient to capture 10 fish per class from each basin despite the use of two experimental meshed nets of six mesh sizes for fishing periods varying from 17 to 42 hours. Based on the catch composition and the high CPUE (82 fish/net/day) obtained at the Deception River, two single-meshed size nets would have been sufficient to catch 30 specimens of either the small or medium class. This population has been previously reported to be sparse and unsuitable for monitoring since the average CPUE obtained was 12 fish/net/day in 1994 (Roche, 1995a). The difference in CPUE between studies is likely attributed to the different sampling stations and fishing periods selected. Fish collected in this study were likely spawning since the majority of fish (n>80) were collected in one deeper pool of which 15 (nine females and six males) out of 30 charr (50%) collected reached stage IV in gonad development (Bagenal 1978) which indicates that they will spawn before the winter.

However, a minimum of 48 and 72 hours would be needed to capture 30 fish of medium size from Vac-1 and 30 fish of small or large size from the Crater Lake. According to an average CPUE of 6.7 fish/net/day from Roche (1997b) in 1995, a fishing period of three to seven days should be planned in order to catch 30 specimen. Twelve (two males and ten females) out of 26 trout (46%) examined, were either at stage IV or V of sexual maturity. Furthermore, several of the released female were spilling of roe under slight pressure. Therefore, a close monitoring of the nets should be performed to prevent overfishing and mortalities in early September in both, the Deception River and Laflamme Lake.

The analysis of 13 metals was conducted in tissues of all fish but several individuals of small size had missing values for aluminium, arsenic, lead, nickel and vanadium. There was not enough biological material digested to allow the detection of these metals, particularly in the kidney. The analytical performance of a method varies as a function of the analytical LOD, the element concentration and the type and amount of tissue tested. The kidneys of a 10-cm fish can weigh as little as 0.02 g and may contain trace amounts of arsenic, lead, nickel and vanadium that could not be detected in the low $\eta g \cdot g^{-1}$ range by ICP-MS despite their low LODs.

In spite of this limitation, the kidneys appear to be the appropriate tissue for use in biomonitoring of a smaller range of metals. By comparing the concentrations of metals between tissues, the kidneys of the small and medium charr from the Deception River concentrate more arsenic, cadmium, cobalt, mercury, nickel and vanadium than the liver and muscles. However, the liver predominately concentrate aluminium, copper, iron and zinc. Liver, kidney and gills are generally the target organs used in environmental toxicology as they can accumulate metals at a higher level except for mercury in the flesh. Median values of mercury in the kidneys of fish from the three studied population were higher than in the flesh, which contrasts with previous findings.

Comparison of metal levels between baseline studies is difficult due to the different metals, tissues, size class and analytical procedure used by the research groups. Roche (1995a) has determined the baseline levels of four metals in the liver and five others in the muscle of one length-size class (20-40 cm) landlocked charr from the Deception River. The analytical procedure selected did not allow the detection of arsenic in muscle and lead in liver which will make future temporal trend assessment of these elements difficult. The average concentrations of cadmium, copper and nickel in liver and cobalt, iron and mercury in muscle were 3 to 20 times higher than the median values of class 2 charr from this study. The lack of agreement between studies is hardly associated to the biological variation of metals in the species despite the samples not being collected during the same month (July versus September). The digestion procedure and the instrumentation used by the two groups differed for most metals.

Similar to the landlocked charr, metals were analyzed in muscle and liver of lake trout from the Vachon River system in 1995 by Roche to establish the baseline levels in the population before the start-up of the mining operation (Roche, 1997b). A small number (n=7) of trout of various sizes were collected from Vac-1. As for the landlocked charr, the levels of metals were generally higher in the Roche study with the exception of iron that overlaps with these results. However, the mercury content in lake trout from our study ranged from 1 to 184 $\eta g \cdot g^{-1}$ only, with a median value of 36 $\eta g \cdot g^{-1}$. In comparison, the mercury levels of four specimens of class 2 from Roche's study ranged from 280 to 1400 $\eta g \cdot g^{-1}$. Mercury levels should be reassessed in the NRC's stored duplicate samples to confirm this unusually low level of mercury for a predatory species, inasmuch Actlab did not analyse sufficient check samples for this element.

Twenty out of 23 landlocked charr captured in August 1983 by Delisle (1986) were tested for heavy metals. Mercury and manganese were analysed in muscles of all fish while arsenic and zinc were analysed in two fish only. The range in mercury and manganese concentrations varied from 116 to 282 $\eta g \cdot g^{-1}$ and 31 to 121 $\eta g \cdot g^{-1}$, respectively in fish of 40-60 cm length (n=10). The median value for mercury (167 $\eta g \cdot g^{-1}$ is almost seven times the median (24.5 $\eta g \cdot g^{-1}$) of class 3 charr from this study. As for the river charr, mercury should be tested in stored muscle samples as it appears that the analytical procedure of Actlab did not allow a total recovery of mercury in fish tissues. According to Dr. Kwan from the Nunavik Research Centre (personal communication), the concentration in reducing agent used in cold vapour atomic absorption (CVAA) is critical in fish muscle to allow total recovery of mercury which is 99% in organic form (methylmercury), as opposed to other tissues that could be around 50%. Manganese was not analysed in any of the fish collected in this study but all duplicate muscle samples and tissues from the extra 45 Deception River charr should be tested for manganese since it was found in high concentrations in water downstream of the Raglan Mine.

Arsenic was the only metal found higher in muscle but only from large charr (class 3) of the Deception River which appear to belong to the anadromous stock, located further downstream. As opposed to the anadromous population, the landlocked charr does not migrate to sea and spend their life span in freshwater. The median value of these five mature females was 78 times that of class 2. Similar findings has been reported by Roche (1995a) in 1994 but the private firm also reported that the average concentration of arsenic was comparable between both populations in 1991 which could be explained like in this study by some of their landlocked fish being anadromous (Roche, 1992b). Median values of arsenic concentrations in class 3 were also 25 and 10 times the median values of class 2 in liver and kidney, respectively.

Another metal that possibly discriminates anadromous charr from landlocked charr is cobalt. The median values of cobalt in muscle, liver and kidney tissues of larger charr were approximately 7-10 times lower than the median values of class 2. Furthermore, lengths and weights of these five fish fall within the range of lengths and weights of the Deception River anadromous charr of similar age, whereas class 1 and class 2 fish do not fit into the growth rate curve of anadromous charr (Roche, 1992b). Stable isotope analysis is presently underway in muscle tissues of 74 charr to confirm the composition of the catch.

In 1991, Roche (1992b) evaluated the rapids and obstacles that could hinder the upstream migration of the Deception River charr and concluded that the species cannot migrate above the natural barrier located 87 km from the mouth of the river. However, the water level was sufficiently low at the natural barrier in early September, 1997 that the migrants could have passed through the small waterfall. Because the water flow had significantly decreased after the construction of the barrage in 1995, both landlocked and anadromous charr may have extended their ranges. Therefore, the smaller length classes (class 1 and class2) should be monitored to determine the temporal trend of metal contamination in the biota since larger fish may travel over a long distance and may originate from a different stock. A biomarker enabling stock identification must be measured on each fish to ensure that this bias does not mislead the data interpretation.

The community structure of a fish population can be used as a monitoring tool to assess potential impacts of mining activities (AQUAMIN, 1996). A shift to the right in the age frequency distribution due to a lower recruitment rate may indicate a decrease in the reproductive success. The biological response to a chemical stress occurs more rapidly in an oligotrophic (low level of productivity) milieu such as the Deception River that is low in water hardness, buffering capacity and in organic matter content, and will be less able to counter the toxic effect of metals. The use of the experimental net with various mesh sizes has the advantage of capturing fish of various ages. Fork length and weight of each specimen from the overcatch should be recorded in the field before being released in order to detect any shift in weight or length frequency distribution of the population.

5.5 Mussels

The collection of similar, large length-size mussels was achieved in two stations out of three. Large mussels of approximately the same size were easily spotted from the first two beds downstream of the mouth of the Deception River. The density of beds was yet relatively low which could be related to previous harvesting activities. The northern bed located on the Hudson Strait coastline was however less abundant and composed of smaller size mussels only. Decbay-3 mussel group was much smaller and younger but more homogeneous as shown by the low standard deviations. Median values of most metals in the younger group were either higher or near the median values of older groups with the exception of lead. Phillips (1980) have reported that most metals either decrease or remain unchanged with age except for mercury while Ritz (1982) has found by comparing two different size groups that only copper concentration was lower, and cadmium and lead higher in larger mussels. Moreover, immature mussels have a higher rate of metal accumulation (Ritz 1982).

The whole body weight had a stronger negative relationship with levels of metals when compared to age and length of mussels from the three stations. The correlation coefficients were particularly high for cobalt and nickel in Decbay-1 group. Apart from age and size effects, other factors related to the habitat can contribute to the variability of metal concentrations between the mussel groups. The habitat of each station may differ in spite their relative proximity, Decbay-2 being 6.7 km apart from both Decbay-1 and Decbay-3 stations. Doidge and co-workers (1995) showed that the growth rate of Nunavik mussels varied extensively between communities's harvesting sites. The authors explained the variation by the difference in genetic and environmental factors. Decbay-1 and Decbay-2 mussels appear to be growing at the same rate, but both growth curves should be compared using similar and larger sample of mussels of different size classes.

Despite of their low concentration ranges, significant differences in cobalt, lead, mercury and nickel concentrations were observed between Decbay-1 and Decbay-2 stations. The location of Decbay-1 is near the mouth of a main stream, the Deception River, while Decbay-2 station is located at the mouth of a small watercourse. Ray (1984) has reviewed the effect of salinity on cadmium uptake by marine organisms and found that in most cases cadmium accumulation increases in diluted seawater. Median values of cadmium levels in Decbay-1 and Decbay-2 groups were identical. The habitat of each mussel bed also differed in type of substrate. Decbay-1 substrate was described as mud whereas Decbay-2 was mainly composed of sand. Roche (1992a) has found relatively high levels of arsenic in sediments of Careenage Arm, False Cove and the mouth of the Deception River. The authors attributed these levels to the silt content in the sediments that could adsorb elements from the watercourses. However, no statistical difference in arsenic content was observed between the two groups of mussels. Further study would be required to characterise the local environment in an attempt to explain the small difference in background levels that occurred in the $\eta g \cdot g^{-1}$ ranges. In the polluted estuarine harbour of the Isle of Man area, a significant relationship has been demonstrated between lead and zinc content in mussels and in sediments collected from the same sites (Southgate et al., 1983).

6.0 Conclusion and recommendations

Surface water can be easily and repeatedly studied in the Deception River at various distances from the mines and does not require any specialised equipment for collection nor pre-analytical treatment prior to testing. The downstream-upstream sampling design and the use of multiple element analyses were effective in detecting downstream contamination in the receiving environment prior to commencement of mining production. For use in biomonitoring, a suitable landlocked charr population inhabiting the upstream portion of the Deception River has been sampled and characterised for metal levels. In addition, two mussel beds were sufficiently abundant to allow future monitoring of Deception Bay ecosystem although a difference in background levels of metals was observed between the two beds. Fine sediment core and terrestrial moss were not abundant in the surroundings of the mines. Frequent sampling of sediment core and moss is therefore not possible due to the limited number of monitoring stations. However, several moss sampling stations were discovered along the Vachon River system which could be used to assess wind-borne contamination, inasmuch nickel was the only element detected near the open mines and not from the Crater Lake area. Surface water, fine sediments and fish were also characterised in the pristine area. A series of recommendations are listed below for the completion of the current database and for future assessment studies.

Additional analysis

1- In addition to the pre-selected elements that were found above the LODs, manganese should be analysed in tissues (including gills) of the extra 45 charr from the Deception River.

2- Mercury should be re-assessed in duplicate muscle samples of fish from the Deception River, Laflamme and Crater lakes.

3- Stable-isotope analysis should be conducted in muscle of the Deception River charr to confirm their status (landlocked versus anadromous).

Future monitoring

1- Water chemistry of the Deception River waters should be assessed in all monitoring stations including the reservoir within three years after the beginning of mining production.

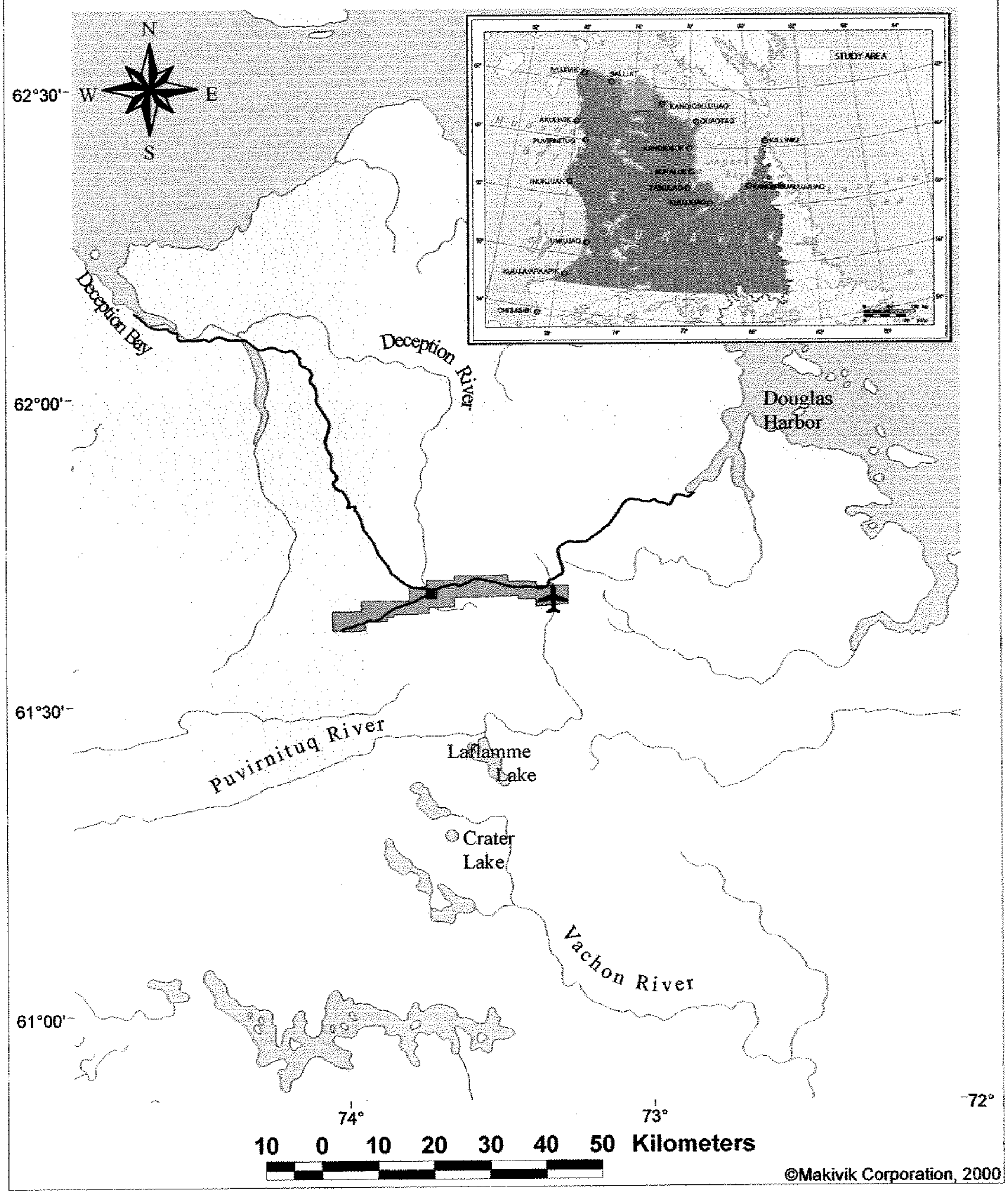
2- Kidney and liver tissues of medium-size landlocked charr from the Deception River should be analysed for metal contents within three years after the beginning of mining production.

3- A characterisation study on macroinvertebrates should be conducted downstream of Katinniq mines.

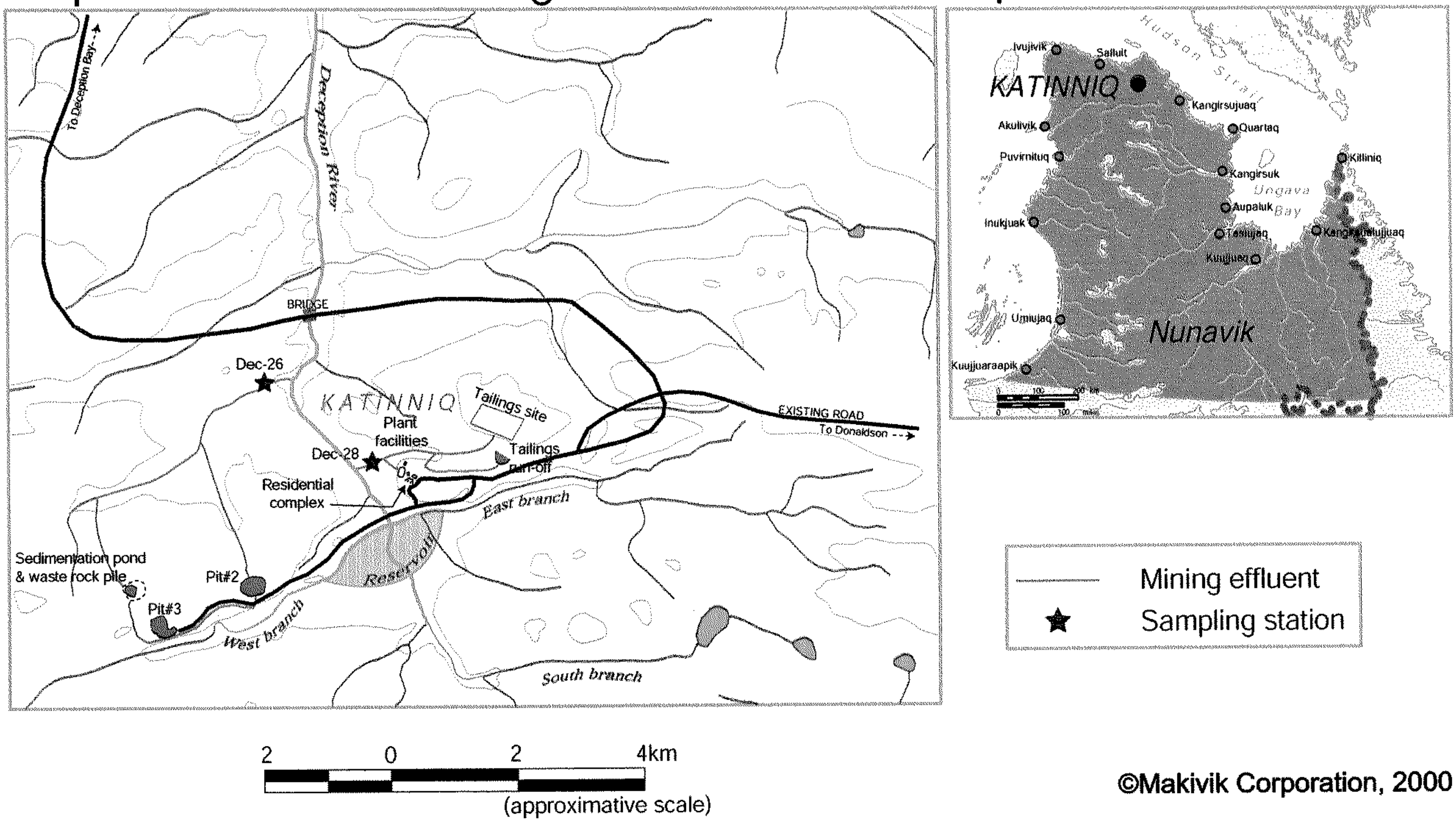
4- Fine sediment, terrestrial moss and mussels downstream of Katinniq mines should be analysed for metal contents within five years after the beginning of mining production. Additional monitoring stations should be investigated for terrestrial moss at lower elevation nearer the coast and for mussels at the mouth of the Deception River .

5- Surface water, fine sediment, terrestrial moss and fish from the Crater Lake region should be assessed for metal contents within five years after the beginning of mining production.

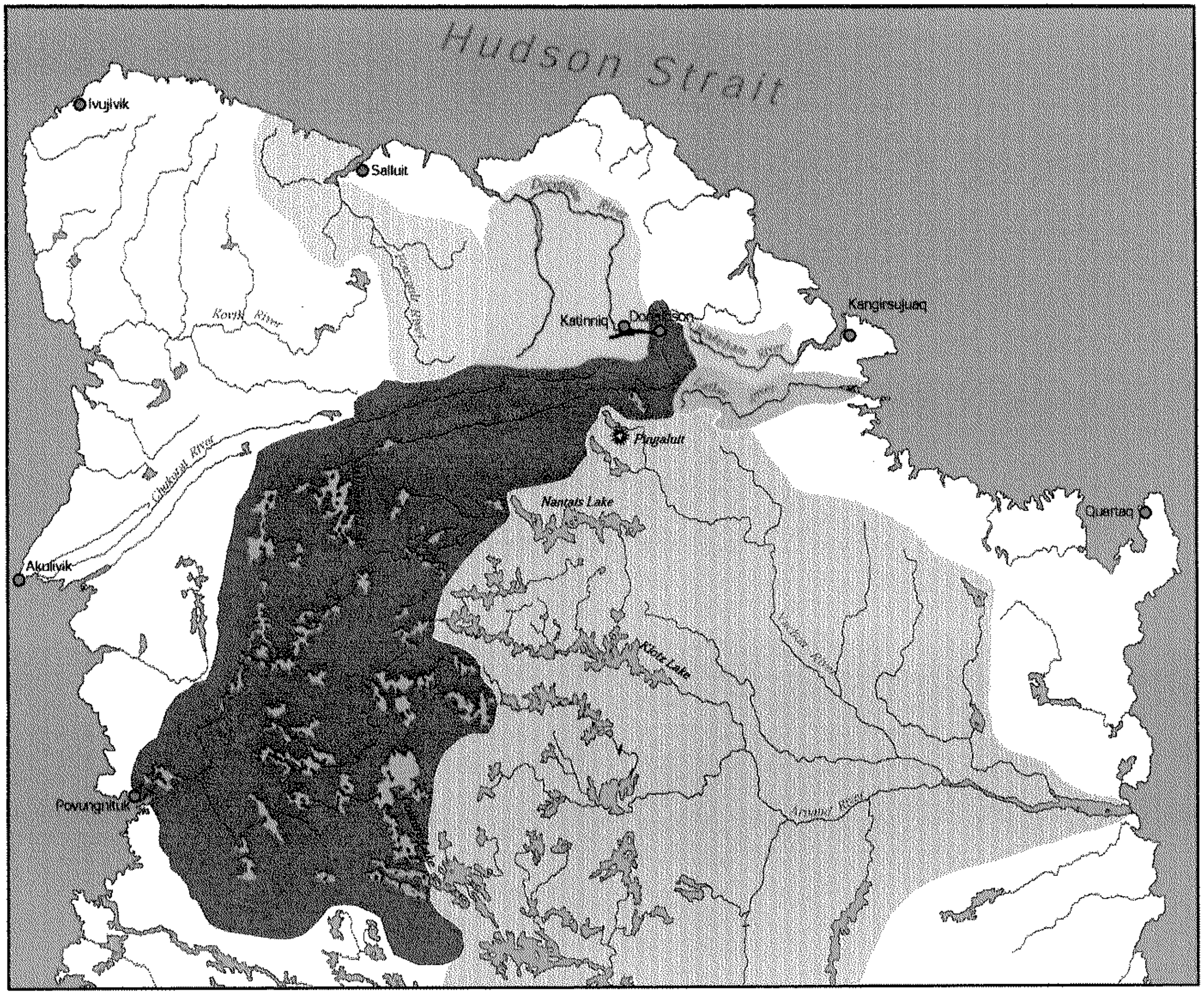
Map 1 Location of the study area

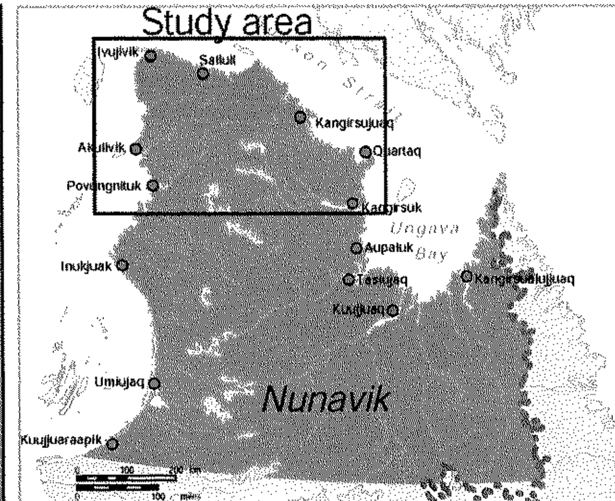


Map 2 Location of mining effluents at Katinniq



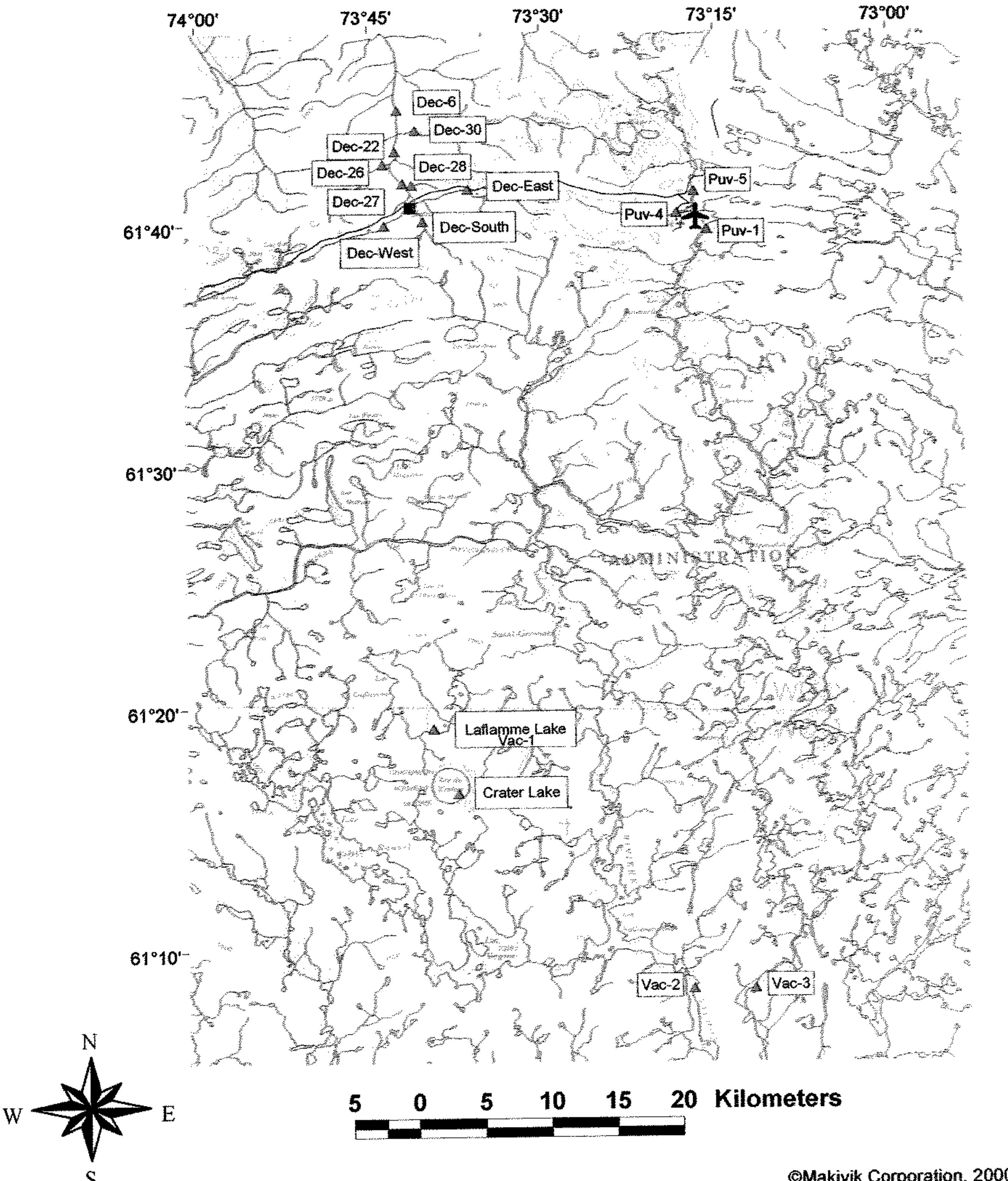
Map 3 Watershed limit of Nunavik rivers (partial view)



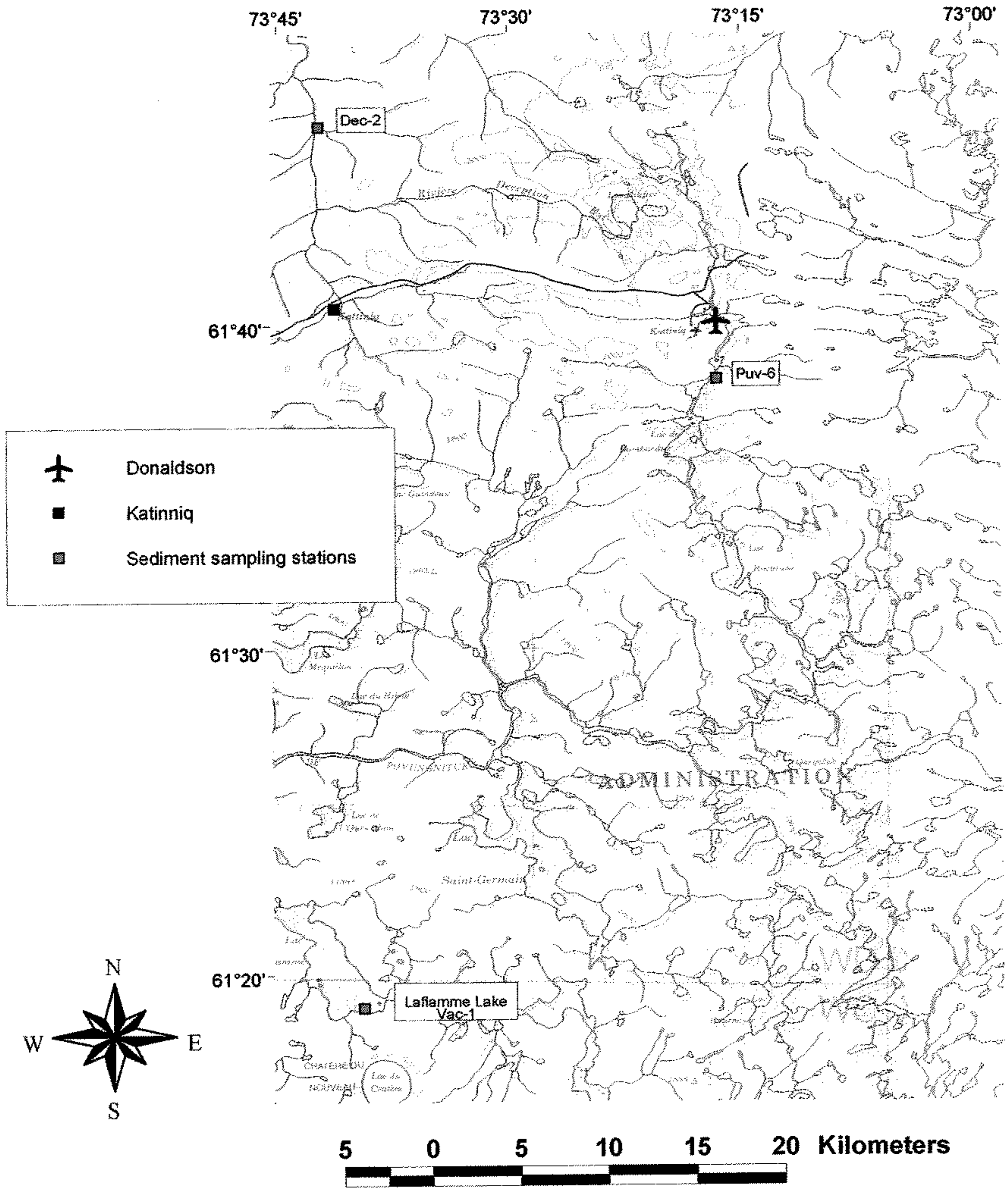


Watershed	Area (km^2)
Deception	3 900
Wakeham	840
Laflau	1 150
Arnaud	49 660
Povungnituk	28 600
Foucault	3 170
Raglan claims	156

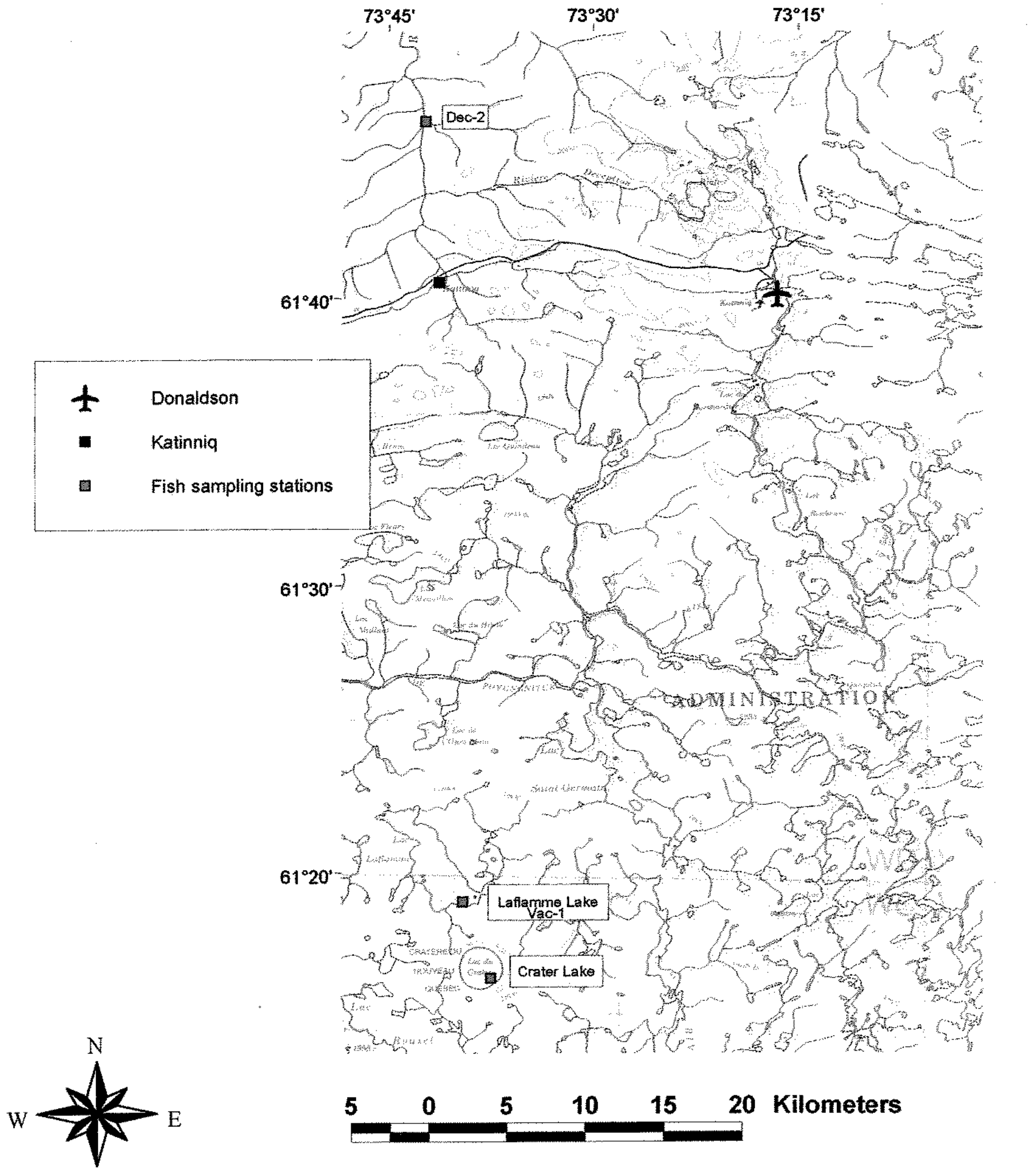
Map 4 Location of surface water sampling stations



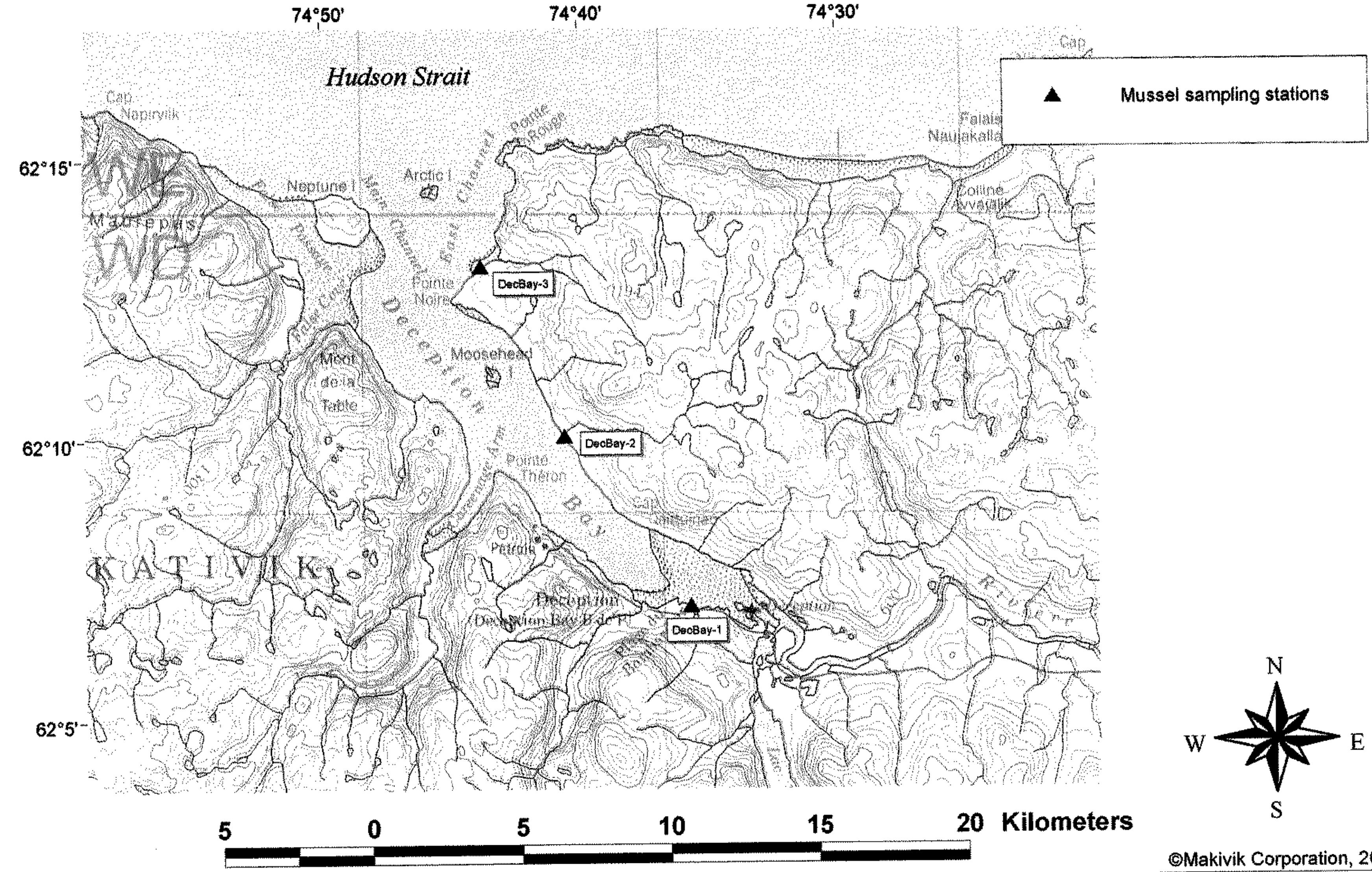
Map 5 Location of the core sediment sampling stations



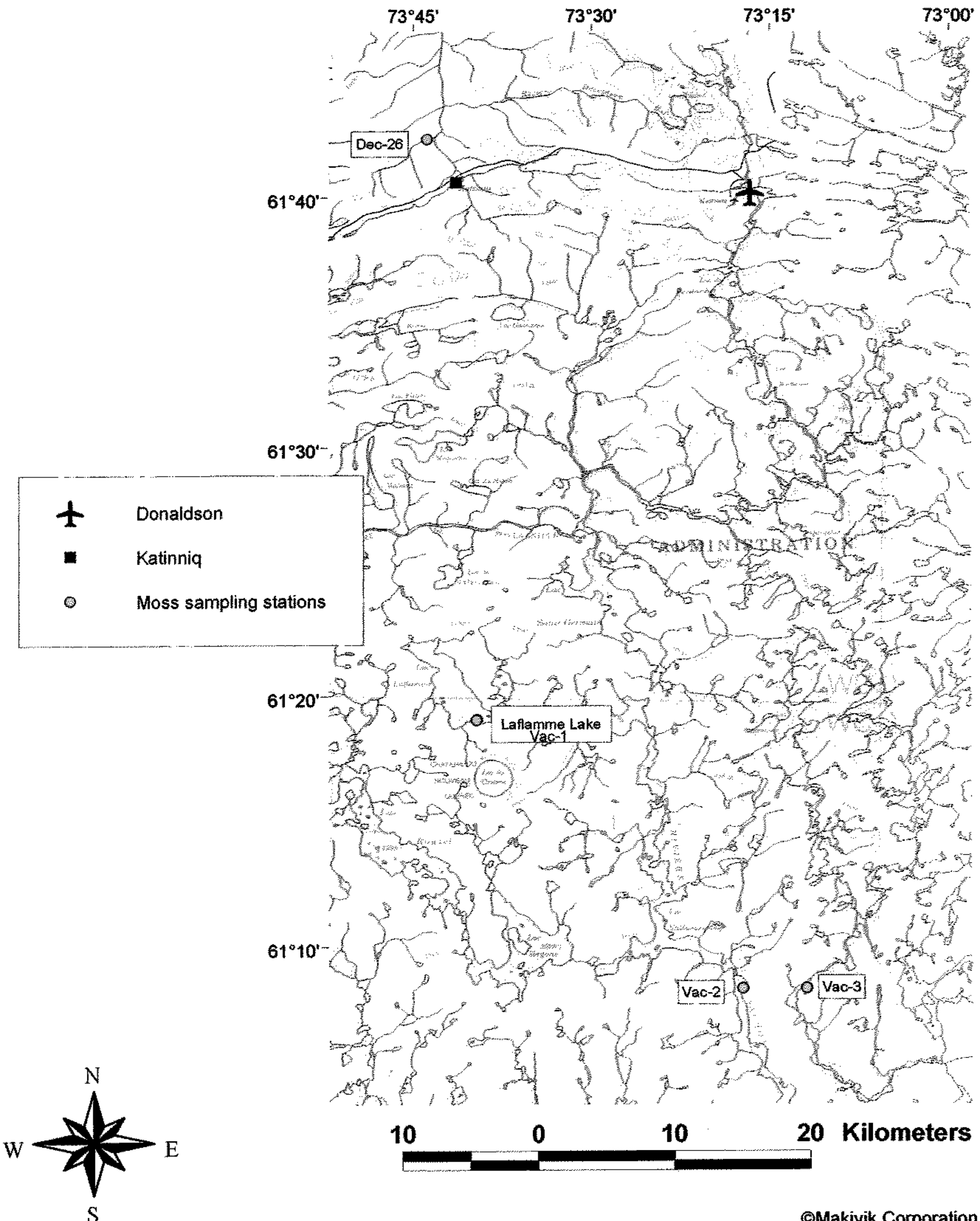
Map 6 Location of fish sampling stations



Map 7 Location of mussel sampling stations



Map 8 Location of moss sampling stations



Ta[illegible]. Precision and accuracy of trace metal analysis in biological sa[illegible]s based on NRCC certified reference materials and duplicate tissue sample analyses

Materials*	Be	Al	V	Cr	Fe	Co	Ni	Cu	Zn	As	Cd	Pb	Hg
DOLT-2	<LOD	21800	270	786	1280000	255	153	28600	97200	15300	19100	156	1990
DOLT-2	<LOD	19900	239	436	1220000	250	174	27300	90300	14800	19500	143	1950
DOLT-2	<LOD	19200	248	586	1230000	253	180	27400	90100	14900	18700	149	
DOLT-2	<LOD	20600	253	682	1280000	265	175	29000	96700	15200	18700	142	
DOLT-2	<LOD	25600	281	542	1300000	228	236	26100	92200	14500	20100	185	
DOLT-2	<LOD	25400	275	500	1180000	227	253	25600	90100	14500	19600	189	
DOLT-2	<LOD	25600	282	549	1170000	233	261	26800	91300	14700	19400	190	
DOLT-2	<LOD	24100	285	538	1140000	230	252	26400	92400	14700	19400	192	
DOLT-2	<LOD	22400	243	370	1170000	254	226	28200	104000	14500	18400	152	
DOLT-2	<LOD	28000	256	635	1310000	277	231	30000	104000	14900	17400	149	
Average		23260	263	562	1228000	247.16	214.1	27540	94830	14800	19030	164.6	1970
Certified values		25200		370	1103000	240	200	25800	85800	16600	20800	220	2140
Precision (%RSD)		12.5	6.6	21.0	5.0	6.9	18.5	5.1	5.8	1.9	4.0	12.9	1.4
Accuracy (%R)		-7.7		52.0	11.3	3.0	7.1	6.7	10.5	-10.8	-8.5	-25.2	-7.9
TORT-2	10	22000	1750	1100	128000	720	2850	97700	201000	24000	16200	280	300
TORT-2	8	22200	1600	661	119000	657	3230	101000	185000	23300	25500	266	
TORT-2	12	18900	1660	857	123000	667	3340	103000	189000	23500	25500	276	
TORT-2	9	22100	1550	504	112000	623	3233	102000	188000	23000	25900	313	
TORT-2	5	23500	1660	1130	114000	607	2800	112000	183000	23300	27500	346	
TORT-2	8	21800	1570	932	108000	600	2640	100000	181000	22800	26900	345	
TORT-2	8	23200	1670	1110	113000	618	2710	101000	184000	23100	27000	349	
TORT-2	8	20800	1660	1180	110000	624	2630	92300	182000	22900	26900	344	
TORT-2	6	18700	1590	796	122000	675	3170	81400	165000	22300	21800	209	
TORT-2	8	13300	1690	1250	132000	721	2970	105000	162000	22300	24200	297	
Average	8.2	20650	1640	952	118100	651.14	2957	99540	182000	23050	24740	302.4	
Certified values			1640	770	105000	510	2500	106000	180000	21600	26700	350	270
Precision (%RSD)	23.6	14.7	3.7	25.7	6.8	6.8	9.1	8.2	6.2	2.3	13.9	15.2	
Accuracy (%R)			0.0	23.6	12.5	27.7	18.3	-6.1	1.1	6.7	-7.3	-13.6	11.1
DORM-2	<LOD	12700	82	28400	119000	149	16800	2390	23000	18300	51	41	
DORM-2	<LOD	12700	62	25600	110000	140	17000	2200	21400	18300	50	42	
DORM-2	<LOD	14400	70	28100	117000	148	16100	2060	22500	18900	50	43	

*DORM-2 and DOLT-2 are dogfish muscle and liver certified materials, respectively while TORT-2 is a certified lobster hepatopancreas materials.

**Duplicate samples: RF-413L/Dup, RF-003L/Dup, RF-009L/Dup and RF-011L/Dup are liver duplicates while RF-021M2/Dup is a muscle duplicate.

Ta[illegible]. Precision and accuracy of trace metal analysis in biological sa[illegible] based on NRCC certified reference ma[illegible]ls and duplicate tissue sample analyses

Materials*	Be	Al	V	Cr	Fe	Co	Ni	Cu	Zn	As	Cd	Pb	Hg
DORM-2	<LOD	14300	59	25500	107000	136	16088	2220	22100	18000	47	41	
DORM-2	<LOD	12300	87	26900	124000	158	15500	2450	23600	19000	45	73	
DORM-2	<LOD	14200	81	22200	123000	157	15000	2390	23700	19600	47	82	
DORM-2	<LOD	12400	86	28600	127000	167	15300	2610	23700	19400	43	79	
DORM-2	<LOD	12500	89	27200	126000	167	15100	2390	24200	19600	44	82	
DORM-2	<LOD	10200	89	27100	103000	126	18900	2250	23800	20000	41	61	
DORM-2	<LOD	12900	87	27800	117000	140	17600	2540	23800	19900	47	74	
Average		12860	79.1	26.74	117300	148.96	16339	2349.9	23180	19100	46.6	61.9	
Certified values		10900		34700	142000	182	19400	2340	25600	18000	43	65	
Precision (%RSD)		9.7	14.3	7.2	7.0	9.1	7.6	7.1	3.9	3.7	6.8	29.6	
Accuracy (%R)		18.0		-22.9	-17.4	-18.2	-15.8	0.4	-9.5	6.1	8.4	-4.8	
RF-011L	<LOD	1100	3	304	417000	93	87	5600	20700	10	474	37	93
RF-011L/Dup**	<LOD	1330	4	698	422000	91	101	7160	19400	8	452	36	103
Average		1215	3.5	501	419500	92	94	6380	20050	9	463	36.5	98
Precision (%RSD)		13.4	20.2	55.6	0.8	1.5	10.5	17.3	4.6	15.7	3.4	1.9	7.2
RF-009L	<LOD	1280	5	290	347000	141	101	5480	23700	12	600	30	78
RF-009L/Dup	<LOD	1090	4	200	342000	142	88	7020	23000	13	587	29	13
Average		1185	4.5	245	344500	141.5	94.5	6250	23350	12.5	593.5	29.5	45.5
Precision (%RSD)		11.3	15.7	26.0	1.0	0.5	9.7	17.4	2.1	5.7	1.5	2.4	101.0
RF-003L	<LOD	637	4	<LOD	351000	104	69	1420	21400	9	375	31	93
RF-003L/Dup	<LOD	885	4	<LOD	404000	104	74	1260	21400	13	374	37	85
Average		761	4		377500	104	71.5	1340	21400	11	374.5	34	89
Precision (%RSD)		23.0	0.0		9.9	0.0	4.9	8.4	0.0	25.7	0.2	12.5	6.4
RF-021M2	<LOD	670	<LOD	239	2420	27	21	183	3630	20	3.1	2	120
RF-021M2/Dup	<LOD	5570	<LOD	250	2190	22	22	195	3330	21	2.9	2	130
Average		3120		244.5	2305	24.5	21.5	189	3480	20.5	3	2	125
Precision (%RSD)		111.1		3.2	7.1	14.4	3.3	4.5	6.1	3.4	4.7	0.0	5.7
RF-413L	<LOD	1670	30	<LOD	156000	141	275	2850	22100	5	122	2	62
RF-413L/Dup	<LOD	1350	31	<LOD	150000	158	305	2940	27200	15	118	5	64
Average		1510	30.5		153000	149.5	290	2895	24650	10	120	3.5	63
Precision (%RSD)		15.0	2.3		2.8	8.0	7.3	2.2	14.6	70.7	2.4	60.6	2.2

*DORM-2 and DOLT-2 are dogfish muscle and liver certified materials, respectively while TORT-2 is a certified lobster hepatopancreas materials.

**Duplicate samples: RF-413L/Dup, RF-003L/Dup, RF-009L/Dup and RF-011L/Dup are liver duplicates while RF-021M2/Dup is a muscle duplicate.

Table 2. Concentrations of ultra-trace elements (μg/L) in Crater Lake, Deception, Puvirnituq and Vachon rivers

Element	Ag	Al	As	Au	Ba	Bi	Br	Ca	Cd	Ce	Co	Cr	Cs	Cu	Dy	Er
LOD[#]	0.1	1	0.03	0.002	0.05	0.005	3	50	0.01	0.005	0.005	0.5	0.002	0.1	0.001	0.001
Deception River																
Uptream																
Dec-east	<LOD	9	0.01	<LOD	0.82	<LOD	22	1179	<LOD	0.030	0.031	<LOD	<LOD	0.4	0.007	0.003
Dec-west	<LOD	24	0.05	<LOD	0.59	<LOD	19	1796	0.01	0.095	0.160	<LOD	<LOD	0.4	0.009	0.004
Dec-south	<LOD	11	0.05	<LOD	0.51	<LOD	23	2038	<LOD	0.035	0.017	<LOD	<LOD	0.6	0.008	0.004
Dec-30**	<LOD	4	0.07	<LOD	0.91	<LOD	22	3769	0.02	0.020	0.017	<LOD	<LOD	0.3	0.002	0.002
Downstream																
Dec-28***	<LOD	13	0.13	<LOD	3.61	0.042	86	12445	0.04	0.138	0,647*	<LOD	0.006	**2.7**	0.015	0.009
Dec-27	<LOD	9	0.07	<LOD	4.12	<LOD	26	6200	0.15	0.631	2.925	<LOD	0.004	0.9	0.040	0.021
Dec-26***	<LOD	7	0.09	<LOD	0.69	<LOD	29	3223	<LOD	0.022	0.016	<LOD	<LOD	0.3	0.002	<LOD
Dec-22	<LOD	8	0.08	<LOD	2.05	<LOD	25	5223	0.04	0.021	0.065	<LOD	<LOD	0.4	0.003	0.001
Dec-6	<LOD	4	0.09	<LOD	1.53	<LOD	26	4673	0.03	0.017	0.027	<LOD	<LOD	0.3	0.001	<LOD
Puvirnituq R.																
Upstream																
Puv-5	<LOD	6	0.07	<LOD	0.56	<LOD	11	1065	<LOD	0.021	0.011	<LOD	<LOD	0.7	0.003	<LOD
Downstream																
Puv-4	<LOD	22	0.09	<LOD	0.72	<LOD	18	2079	<LOD	0.094	0.033	<LOD	<LOD	1.0	0.010	0.006
Puv-1	<LOD	6	0.07	<LOD	0.60	<LOD	9	1349	<LOD	0.037	0.013	<LOD	<LOD	0.8	0.004	0.003
Vachon R.																
Vac-1	<LOD	2	0.02	<LOD	1.37	0.042	5	247	0.02	0.050	0.007	<LOD	<LOD	0.1	0.001	<LOD
Vac-2	<LOD	8	0.07	<LOD	2.01	<LOD	7	529	0.06	0.115	0.019	<LOD	<LOD	0.3	0.003	0.001
Vac-3	<LOD	28	0.05	<LOD	2.64	<LOD	8	614	0.03	0.402	0.028	<LOD	<LOD	0.4	0.008	0.004
Crater Lake																
Crater Lake[&]	<LOD	<LOD	0.02	<LOD	1.16	<LOD	3	222	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Water quality criteria																
MENVIQ[#]	0.1	87	50	N/C[&&]	50000	N/C	N/C	N/C	0.4	N/C	5	2	N/C	2.0	N/C	N/C

[#]LOD: Limit of detection in μg/L.

**Dec-30 is a monitoring station located on the Deception East River and was used a reference station for the Deception River.

***Dec-28 and Dec-26 are stations located on mining effluents.

[&]Average values from a set of ten randomly samples collected in different areas of the eastern part of the lake.

[#]MENVIQ:Critères de qualité de l'eau. Ministère de l'environnement du Québec, 1990. Calculations of Ca, Ni, Pb and Zn criteria were based on a water hardness of 12 mg of $CaC0_3$ (Roche, 1995). N/C: No criteria. Values in blue are either found high or above the chronic toxicity guidelines.

Table 2. Concentrations of ultra-trace elements (µg/L) in Crater Lake, Deception, Puvirnituq and Vachon rivers

Element	Eu	Fe	Ga	Gd	Ge	Hf	Hg	Ho	I	In	K	La	Li	Lu	Mg
LOD[¤]	0.001	3	0.01	0.001	0.01	0.002	0.2	0.001	0.2	0.002	10	0.005	1	0.001	0.5
Deception River															
Uptream															
Dec-east	0.002	13	<LOD	0.005	<LOD	<LOD	<LOD	0.001	0.7	<LOD	107	0.037	<LOD	<LOD	1129
Dec-west	0.003	31	<LOD	0.010	<LOD	<LOD	<LOD	0.002	0.9	<LOD	92	0.066	<LOD	<LOD	979
Dec-south	0.002	15	<LOD	0.010	<LOD	<LOD	<LOD	0.002	1.1	<LOD	92	0.032	<LOD	<LOD	632
Dec-30**	<LOD	<LOD	<LOD	0.003	<LOD	<LOD	<LOD	<LOD	0.5	<LOD	94	0.020	<LOD	<LOD	1172
Downstream															
Dec-28***	0.003	25	<LOD	0.012	<LOD	<LOD	<LOD	0.004	5.1	<LOD	256	0.072	<LOD	<LOD	**5269**
Dec-27	0.011	<LOD	<LOD	0.049	<LOD	<LOD	<LOD	0.008	1.3	<LOD	261	0.571	<LOD	<LOD	2573
Dec-26***	<LOD	6	<LOD	0.002	<LOD	<LOD	<LOD	<LOD	1.0	<LOD	85	0.015	<LOD	<LOD	1551
Dec-22	<LOD	10	<LOD	0.005	<LOD	<LOD	<LOD	<LOD	0.9	<LOD	178	0.022	<LOD	<LOD	2054
Dec-6	<LOD	<LOD	<LOD	0.003	<LOD	<LOD	<LOD	<LOD	0.9	<LOD	159	0.017	<LOD	<LOD	1855
Puvirnituq R.															
Upstream															
Puv-5	<LOD	9	<LOD	0.030	<LOD	<LOD	<LOD	<LOD	0.5	<LOD	98	0.021	<LOD	<LOD	933
Downstream															
Puv-4	0.004	36	<LOD	0.014	<LOD	<LOD	<LOD	0.003	0.7	<LOD	45	0.057	<LOD	<LOD	1124
Puv-1	0.001	7	<LOD	0.006	<LOD	<LOD	<LOD	0.001	0.5	<LOD	78	0.024	<LOD	<LOD	848
Vachon R.															
Vac-1	<LOD	3	<LOD	0.002	<LOD	<LOD	<LOD	<LOD	0.4	<LOD	190	0.031	<LOD	<LOD	117
Vac-2	0.002	42	<LOD	0.007	<LOD	<LOD	<LOD	<LOD	0.5	<LOD	257	0.076	<LOD	<LOD	184
Vac-3	0.003	39	<LOD	0.016	<LOD	<LOD	<LOD	0.002	0.4	<LOD	267	0.200	<LOD	<LOD	211
Crater Lake															
Crater Lake[&]	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.4	<LOD	148	0.006	<LOD	<LOD	76
Water quality criteria															
MENVIQ[#]	N/C	300	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C

[¤]LOD: Limit of detection in µg/L.

**Dec-30 is a monitoring station located on the Deception East River and was used a reference station for the Deception River.

***Dec-28 and Dec-26 are stations located on mining effluents.

[&]Average values from a set of ten randomly samples collected in different areas of the eastern part of the lake.

[#]MENVIQ:Critères de qualité de l'eau. Ministère de l'environnement du Québec, 1990. Calculations of Ca, Ni, Pb and Zn criteria were based on a water hardness of 12 mg of $CaC0_3$ (Roche, 1995). N/C: No criteria. Values in blue are either found high or above the chronic toxicity guidelines.

Table 2. Concentrations of ultra-trace elements (µg/L) in Crater Lake, Deception, Puvirnituq and Vachon rivers

Element	Mn	Mo	Na	Nb	Nd	Ni	Os	Pb	Pd	Pr	Pt	Rb	Re	Ru	Sb	Sc
LOD[a]	0.05	0.05	20	0.005	0.004	0.05	0.002	0.1	0.02	0.002	0.02	0.005	0.001	0.02	0.005	1
Deception River																
Uptream																
Dec-east	0.32	<LOD	608	<LOD	0.034	7.08	<LOD	<LOD	<LOD	0.011	<LOD	0.060	0.001	<LOD	0.018	<LOD
Dec-west	3.01	<LOD	542	<LOD	0.057	5.34	<LOD	<LOD	<LOD	0.016	<LOD	0.050	<LOD	<LOD	0.013	<LOD
Dec-south	0.47	<LOD	511	<LOD	0.043	0.43	<LOD	<LOD	<LOD	0.010	<LOD	0.068	<LOD	<LOD	0.022	<LOD
Dec-30**	0.11	<LOD	572	<LOD	0.020	1.08	<LOD	<LOD	<LOD	0.007	<LOD	0.058	<LOD	<LOD	0.026	<LOD
Downstream																
Dec-28***	7.65	<LOD	**3452**	<LOD	0.051	9.71	<LOD	<LOD	<LOD	0.014	<LOD	0.238	0.003	<LOD	0.071	<LOD
Dec-27	**28.7**	<LOD	1067	<LOD	0.280	**63.6**	<LOD	<LOD	<LOD	0.089	<LOD	0.445	0.002	<LOD	0.023	<LOD
Dec-26***	0.11	<LOD	623	<LOD	0.018	0.76	<LOD	<LOD	<LOD	0.005	<LOD	0.045	<LOD	<LOD	0.018	<LOD
Dec-22	0.77	<LOD	841	<LOD	0.026	27.83	<LOD	<LOD	<LOD	0.005	<LOD	0.147	0.002	<LOD	0.023	<LOD
Dec-6	0.11	<LOD	780	<LOD	0.020	19.43	<LOD	<LOD	<LOD	0.005	<LOD	0.126	0.001	<LOD	0.023	<LOD
Puvirnituq R.																
Upstream																
Puv-5	0.16	<LOD	506	<LOD	0.018	1.77	<LOD	<LOD	<LOD	0.005	<LOD	0.064	<LOD	<LOD	0.020	<LOD
Downstream																
Puv-4	0.56	<LOD	679	0.004	0.069	6.23	<LOD	<LOD	<LOD	0.018	<LOD	0.054	<LOD	<LOD	0.015	<LOD
Puv-1	0.34	<LOD	495	<LOD	0.028	4.92	<LOD	<LOD	<LOD	0.008	<LOD	0.054	<LOD	<LOD	0.019	<LOD
Vachon R.																
Vac-1	0.52	<LOD	343	<LOD	0.022	0.05	<LOD	<LOD	<LOD	0.007	<LOD	0.508	<LOD	<LOD	0.018	<LOD
Vac-2	1.81	<LOD	440	<LOD	0.059	0.09	<LOD	<LOD	<LOD	0.017	<LOD	0.779	<LOD	<LOD	0.034	<LOD
Vac-3	1.84	<LOD	511	<LOD	0.166	0.20	<LOD	<LOD	<LOD	0.051	<LOD	0.801	<LOD	<LOD	0.026	<LOD
Crater Lake																
Crater Lake[&]	0.56	<LOD	292	<LOD	0.002	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.285	<LOD	<LOD	0.021	<LOD
Water quality criteria																
MENVIQ[#]	N/C	<LOD	N/C	N/C	N/C	26	N/C	0.2	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C

[a]LOD: Limit of detection in µg/L.

**Dec-30 is a monitoring station located on the Deception East River and was used a reference station for the Deception River.

***Dec-28 and Dec-26 are stations located on mining effluents.

[&]Average values from a set of ten randomly samples collected in different areas of the eastern part of the lake.

[#]MENVIQ:Critères de qualité de l'eau. Ministère de l'environnement du Québec, 1990. Calculations of Ca, Ni, Pb and Zn criteria were based on a water hardness of 12 mg of $CaC0_3$ (Roche, 1995). N/C: No criteria. Values in blue are either found high or above the chronic toxicity guidelines.

Table 2. Concentrations of ultra-trace elements (µg/L) in Crater Lake, Deception, Puvirnituq and Vachon rivers

Element	Se	Si	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y
LOD[a]	0.2	20	0.001	0.05	0.02	0.01	0.001	0.2	0.002	0.1	0.005	0.001	0.001	0.05	0.01	0.003
Deception River																
Uptream																
Dec-east	0.2	1218	0.005	<LOD	<LOD	<LOD	0.002	<LOD	0.004	0.2	<LOD	<LOD	<LOD	0.06	<LOD	0.028
Dec-west	<LOD	1153	0.010	<LOD	<LOD	<LOD	0.003	<LOD	0.005	0.5	<LOD	<LOD	<LOD	0.14	<LOD	0.060
Dec-south	<LOD	944	0.009	<LOD	<LOD	<LOD	0.002	<LOD	0.004	0.3	<LOD	<LOD	<LOD	0.12	<LOD	0.055
Dec-30**	0.2	795	0.003	<LOD	<LOD	<LOD	0.001	<LOD	<LOD	0.3	<LOD	<LOD	<LOD	0.03	<LOD	0.016
Downstream																
Dec-28***	0.4	1418	0.011	<LOD	<LOD	<LOD	0.004	<LOD	0.005	1.6	<LOD	<LOD	<LOD	0.20	<LOD	0.129
Dec-27	0.3	1190	0.038	<LOD	<LOD	<LOD	0.010	<LOD	<LOD	0.9	<LOD	<LOD	<LOD	0.03	<LOD	0.393
Dec-26***	0.3	1091	0.003	<LOD	<LOD	<LOD	0.002	<LOD	<LOD	0.3	<LOD	<LOD	<LOD	0.08	<LOD	0.015
Dec-22	0.4	1195	0.003	<LOD	<LOD	<LOD	0.003	<LOD	0.006	0.5	<LOD	<LOD	<LOD	0.06	<LOD	0.023
Dec-6	0.2	1061	0.001	<LOD	<LOD	<LOD	0.001	<LOD	<LOD	0.4	<LOD	<LOD	<LOD	0.13	<LOD	0.015
Puvirnituq R.																
Upstream																
Puv-5	<LOD	731	0.003	<LOD	2.07	<LOD	<LOD	<LOD	0.003	0.1	<LOD	<LOD	<LOD	0.06	<LOD	0.017
Downstream																
Puv-4	<LOD	778	0.015	<LOD	4.15	<LOD	0.002	<LOD	0.007	0.5	<LOD	<LOD	<LOD	0.20	<LOD	0.080
Puv-1	<LOD	435	0.004	<LOD	2.96	<LOD	0.002	<LOD	0.005	0.1	<LOD	<LOD	<LOD	0.06	<LOD	0.032
Vachon R.																
Vac-1	<LOD	45	0.003	<LOD	1.80	<LOD	<LOD	<LOD	0.005	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.008
Vac-2	<LOD	166	0.006	<LOD	3.82	<LOD	<LOD	<LOD	0.012	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.020
Vac-3	<LOD	400	0.019	<LOD	4.22	<LOD	0.002	<LOD	0.030	0.2	<LOD	<LOD	<LOD	0.03	<LOD	0.048
Crater Lake																
Crater Lake&	<LOD	56	<LOD	<LOD	1.17	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Water quality criteria																
MENVIQ#	5	N/C	N/C	N/C	N/C	N/C	N/C	N/C	8	N/C	N/C	N/C	N/C	14.00	N/C	N/C

[a]LOD: Limit of detection in µg/L.

**Dec-30 is a monitoring station located on the Deception East River and was used a reference station for the Deception River.

***Dec-28 and Dec-26 are stations located on mining effluents.

&Average values from a set of ten randomly samples collected in different areas of the eastern part of the lake.

#MENVIQ:Critères de qualité de l'eau. Ministère de l'environnement du Québec, 1990. Calculations of Ca, Ni, Pb and Zn criteria were based on a water hardness of 12 mg of CaC03 (Roche, 1995). N/C: No criteria. Values in blue are either found high or above the chronic toxicity guidelines.

Table 2. Concentrations of ultra-trace elements (µg/L) in Crater Lake, Deception, Puvirnituq and Vachon rivers

Element	Yb	Zn	Zr	pH	Cond.	Temp.
LOD[a]	0.001	0.5	0.005			
Deception River						
Uptream						
Dec-east	0.004	1.2	0.010	7.7	10	10
Dec-west	0.004	1.3	0.037	7.3	10	10
Dec-south	0.004	2.5	0.008	7.5	10	10
Dec-30**	0.002	1.4	<LOD	7.1	30	8
Downstream						
Dec-28***	0.010	2.5	<LOD	6.9	130	10
Dec-27	0.015	**21.6**	<LOD	6.7	70	10
Dec-26***	0.002	3.3	<LOD	6.9	20	9
Dec-22	0.003	6.3	<LOD	7.0	50	8
Dec-6	0.002	3.1	<LOD	7.1	30	8
Puvirnituq R.						
Upstream						
Puv-5	0.002	<LOD	<LOD			
Downstream						
Puv-4	0.005	1.4	0.033			
Puv-1	0.004	0.4	0.005	6.8	10	10
Vachon R.						
Vac-1	<LOD	1.1	0.004	8.0	0	11
Vac-2	<LOD	1.7	0.011	7.7	0	15.5
Vac-3	0.005	1.6	0.056	7.3	0	15
Crater Lake						
Crater Lake[&]	<LOD	1.3	<LOD	6.3	3	4.1
Water quality criteria						
MENVIQ[#]	N/C	17.6	N/C	6,5-9	N/C	N/C

[a]LOD: Limit of detection in µg/L.

**Dec-30 is a monitoring station located on the Deception East River and was used a reference station for the Deception River.

***Dec-28 and Dec-26 are stations located on mining effluents.

[&]Average values from a set of ten randomly samples collected in different areas of the eastern part of the lake.

[#]MENVIQ:Critères de qualité de l'eau. Ministère de l'environnement du Québec, 1990. Calculations of Ca, Ni, Pb and Zn criteria were based on a water hardness of 12 mg of $CaCO_3$ (Roche, 1995). N/C: No criteria. Values in blue are either found high or above the chronic toxicity guidelines.

Table 3. Concentrations of elements in sediment cores collected in Laflamme Lake, Deception and Puvirnituq rivers

Element	Ag	Al	Au	As	Ba	Be	Bi	Br	Ca	Cd	Ce	Co	Cr	Cs	Cu	Eu
Unit	µg·g-1	%	ηg·g-1	µg·g-1	µg·g-1	µg·g-1	µg·g-1	µg·g-1	%	µg·g-1	µg·g-1	µg·g-1	µg·g-1	µg·g-1	µg·g-1	µg·g-1
Method	NA	ICP	NA	NA	NA	ICP	ICP	NA	ICP	ICP	NA	NA	NA	NA	ICP	NA
LOD[a]	0.4	0.01	2.0	0.5	50	2	5	0.5	0.01	0.5	3	1	5	1	1	0.2
Dec-2 core (cm)																
1	<LOD	7.1	4.0	8.1	410	<LOD	<LOD	10	2.43	<LOD	47	45	730	2	57	1.0
2	0.4	6.5	3.0	18.0	280	<LOD	<LOD	26	2.01	<LOD	52	58	680	2	103	1.2
4	<LOD	7.1	6.0	4.0	330	<LOD	<LOD	14	2.27	<LOD	54	48	810	2	103	1.2
6	<LOD	6.8	4.0	2.1	210	<LOD	<LOD	4	2.51	<LOD	28	39	790	<LOD	42	0.8
8	<LOD	7.2	3.0	9.4	350	<LOD	<LOD	32	1.42	<LOD	77	60	580	2	168	1.6
10	<LOD	7.2	<LOD	5.7	300	<LOD	<LOD	22	1.78	<LOD	56	51	680	2	141	1.3
12	<LOD	6.7	<LOD	2.0	250	<LOD	<LOD	3.6	2.79	<LOD	28	46	880	2	52	0.9
Average		6.9		**7.0**	304			16	2.17		49	50	**736**		**95**	1.1
%RSD[a]		4.0		79.4	21.8			69.2	21.6		35.0	15.0	13.6		50.2	23.6
Puv-6 core (cm)																
1	<LOD	7.0	<LOD	2.6	25	<LOD	<LOD	<LOD	7.82	<LOD	16	49	240	<LOD	23	1.0
2	<LOD	7.0	<LOD	3.9	180	<LOD	<LOD	2.6	5.18	<LOD	24	35	190	<LOD	42	0.9
6	<LOD	6.8	<LOD	3.1	230	<LOD	<LOD	2.7	4.26	<LOD	28	32	250	<LOD	37	1.0
8	<LOD	6.8	3.0	4.9	200	<LOD	<LOD	<LOD	4.27	<LOD	25	31	210	2	44	0.9
10	<LOD	6.8	<LOD	2.7	210	<LOD	<LOD	<LOD	4.76	<LOD	20	41	500	2	47	1.0
Average		6.9		**3.4**	169				5.26		23	38	**278**		**39**	1.0
%RSD		1.6		28.0	48.8				28.2		20.7	19.9	45.5		24.5	5.7
Vac-1 core (cm)																
1	<LOD	5.7	2.0	3.2	440	<LOD	<LOD	19	1.84	<LOD	65	12	58	1	47	0.9
2	0.4	6.6	<LOD	2.2	450	<LOD	<LOD	<LOD	2.43	<LOD	60	7	55	<LOD	11	1.0
4	0.4	6.5	<LOD	1.8	470	<LOD	<LOD	<LOD	2.31	<LOD	60	7	45	1	11	1.0
6	<LOD	6.6	<LOD	0.9	480	<LOD	<LOD	<LOD	2.41	<LOD	55	7	40	<LOD	9	0.9
8	<LOD	7.0	<LOD	1.1	450	<LOD	<LOD	<LOD	2.47	<LOD	77	9	55	1	14	1.1
10	<LOD	7.5	4.0	0.2	460	<LOD	<LOD	<LOD	2.52	<LOD	75	10	46	2	15	1.0
12	<LOD	7.2	<LOD	1.8	520	<LOD	<LOD	<LOD	2.27	<LOD	91	12	53	2	18	1.1
14	<LOD	7.7	<LOD	0.2	560	<LOD	<LOD	<LOD	2.23	<LOD	99	15	55	2	21	1.2
16	<LOD	8.0	2.0	1.3	600	<LOD	<LOD	1	2.16	<LOD	98	14	53	2	23	1.3
18	0.4	8.0	2.0	2.4	620	<LOD	<LOD	<LOD	2.34	<LOD	113	16	64	2	28	1.3
20	<LOD	7.7	<LOD	0.2	580	<LOD	<LOD	<LOD	2.28	<LOD	112	15	63	3	24	1.3
22	<LOD	7.8	<LOD	0.2	580	<LOD	<LOD	<LOD	2.48	<LOD	99	15	58	1	19	1.1
Average		7.2		1.3	518				2.31		84	12	54		20	1.1
%RSD		10.0		78.0	12.9				8.0		25.0	30.0	13.3		51.5	13.4
E.C.[#] level 1	N/C	N/C	N/C	3.0	N/C	N/C	N/C	N/C	N/C	0.2	N/C	N/C	55	N/C	26	N/C
E.C. level 2	N/C	N/C	N/C	6.7	N/C	N/C	N/C	N/C	N/C	0.9	N/C	N/C	55	N/C	28	N/C
E.C. level 3	N/C	N/C	N/C	17.0	N/C	N/C	N/C	N/C	N/C	3.3	N/C	N/C	102	N/C	56	N/C

[a]LOD: Limit of detection; %RSD=SD/mean x 100, not calculated for values close to LODs.

[#]Environnement Canada, 1993. Cadre législatif de gestion des sédiments au Québec. Above leve 1, 2 and 3 mean respectively negligible, minor and harmful effects on aquatic organisms. Values in blue, green and red exceed respectively levels 1, 2 , and 3. N/C: No criteria.

Table 3. Concentrations of elements in sediment cores collected in Laflamme Lake, Deception and Puvirnituq rivers

Element	Fe	Hf	Hg	Ir	K	La	Lu	Mg	Mn	Mo	Na	Nd	Ni	P	Pb	Rb
Unit	%	µg·g-1	µg·g-1	ηg·g-1	%	µg·g-1	µg·g-1	%	µg·g-1	µg·g-1	%	µg·g-1	µg·g-1	%	µg·g-1	µg·g-1
Method	NA	NA	NA	NA	ICP	NA	NA	ICP	ICP	NA	ICP	NA	ICP	ICP	ICP	NA
LOD[a]	0.01	1	1	5	0.01	0.5	0.05	0.01	1	1	0.01	5	1	0.001	4	15
Dec-2 core (cm)																
1	7.4	3	<LOD	<LOD	1.31	25.6	0.32	4.75	882	2	1.28	19	267	0.046	5	69
2	11.3	3	<LOD	<LOD	0.94	30.1	0.27	4.26	1123	1	0.85	23	288	0.224	12	58
4	7.1	3	<LOD	<LOD	0.95	29.9	0.29	5.07	830	<LOD	0.97	23	319	0.097	10	43
6	8.4	2	<LOD	<LOD	0.94	14.9	0.24	5.57	790	<LOD	1.17	13	290	0.031	6	45
8	6.4	3	<LOD	<LOD	1.19	46.0	0.26	4.06	718	<LOD	0.66	35	390	0.132	12	62
10	7.9	3	<LOD	<LOD	1.07	36.0	0.36	4.73	774	2	0.73	28	352	0.066	12	58
12	7.1	3	<LOD	<LOD	0.83	16.9	0.22	5.80	815	<LOD	1.10	17	315	0.034	5	44
Average	7.9				1.03	28.5	0.28	4.89	847		0.97	23	317	0.090		54
%RSD[a]	20.4				16.2	37.8	17.1	13.1	15.5		24.0	32.3	13.3	77.1		18.8
Puv-6 core (cm)										<LOD						
1	8.4	2	<LOD	<LOD	0.12	6.6	0.33	3.70	1204	2	1.36	8	101	0.043	<LOD	7
2	8.0	2	<LOD	<LOD	0.60	11.3	0.28	3.20	1165	<LOD	1.63	12	76	0.051	<LOD	7
6	6.5	3	<LOD	<LOD	0.84	13.5	0.25	3.08	839	<LOD	1.76	13	93	0.043	9	26
8	6.9	2	<LOD	<LOD	0.72	12.1	0.23	2.95	904	<LOD	1.88	11	79	0.046	<LOD	22
10	8.3	3	<LOD	<LOD	0.54	10.1	0.33	4.57	1161	<LOD	1.77	10	112	0.046	<LOD	7
Average	7.6				0.56	10.7	0.28	3.50	1055		1.68	11	92	0.046		14
%RSD	11.3				48.5	24.4	16.1	18.9	16.1		11.9	17.8	16.3	7.1		68.2
Vac-1 core (cm)										<LOD						
1	5.7	6	<LOD	<LOD	1.22	30.7	0.21	0.61	1098	6	2.06	28	26	0.058	16	70
2	3.4	8	<LOD	<LOD	1.45	32.3	0.26	0.68	601	1	2.42	27	13	0.115	13	78
4	2.6	7	<LOD	<LOD	1.52	33.6	0.18	0.66	503	<LOD	2.41	24	13	0.099	13	68
6	2.4	6	<LOD	<LOD	1.54	32.7	0.22	0.69	456	1	2.36	24	12	0.089	14	66
8	2.8	8	<LOD	<LOD	1.59	42.4	0.24	0.80	470	<LOD	2.52	30	15	0.081	13	80
10	2.8	6	<LOD	<LOD	1.71	43.0	0.23	0.91	517	<LOD	2.40	33	16	0.079	16	72
12	3.4	6	<LOD	<LOD	1.74	50.4	0.23	0.97	572	<LOD	2.45	33	18	0.073	14	100
14	3.8	5	<LOD	<LOD	1.86	53.7	0.23	1.11	622	1	2.33	35	22	0.076	17	110
16	3.7	5	<LOD	<LOD	1.94	57.9	0.26	1.21	583	<LOD	2.20	40	24	0.076	20	92
18	3.7	6	<LOD	<LOD	1.91	62.8	0.22	1.18	590	<LOD	2.43	41	24	0.075	17	94
20	3.8	6	<LOD	<LOD	1.85	62.5	0.26	1.16	562	<LOD	2.44	39	24	0.077	17	120
22	3.1	6	<LOD	<LOD	1.85	56.3	0.29	1.09	472	<LOD	2.59	39	21	0.067	21	100
Average	3.4				1.68	46.5	0.24	0.92	587		2.38	33	19	0.080	15.9	88
%RSD	25.2				13.1	26.3	12.2	24.6	29.0		5.9	18.9	26.7	18.5	16.8	20.3
E.C.[#] level 1	N/C	N/C	0.06	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	35	N/C	23	N/C
E.C. level 2	N/C	N/C	0.20	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	35	N/C	42	N/C
E.C. level 3	N/C	N/C	1.30	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	61	N/C	156	N/C

[a]LOD: Limit of detection; %RSD=SD/mean x 100, not calculated for values close to LODs.

[#]Environnement Canada, 1993. Cadre législatif de gestion des sédiments au Québec. Above leve 1, 2 and 3 mean respectively negligible, minor and harmful effects on aquatic organisms. Values in blue, green and red exceed respectively levels 1, 2 , and 3. N/C: No criteria.

Table 3. Concentrations of elements in sediment cores collected in Laflamme Lake, Deception and Puvirnituq rivers

Element	Sb	Sc	Se	Sm	Sn	Sr	Ta	Tb	Th	Ti	U	V	Y	Yb	W	Zn
Unit	µg·g-1	µg·g-1	µg·g-1	µg·g-1	%	µg·g-1	µg·g-1	µg·g-1	µg·g-1	%	µg·g-1	µg·g-1	µg·g-1	µg·g-1	µg·g-1	µg·g-1
Method	NA	NA	NA	NA	NA	ICP	NA	NA	NA	ICP	NA	ICP	ICP	NA	NA	ICP
LOD[a]	0.1	0.1	3	0.1	0.01	1	0.5	0.5	0.2	0.01	0.5	2	2	0.2	1.0	1
Dec-2 core (cm)																
1	0.2	26	<LOD	3.9	<LOD	78	0.8	0.7	6.6	0.42	1.4	187	18	1.9	<LOD	103
2	0.5	27	<LOD	4.8	<LOD	71	<LOD	0.7	6.5	0.51	2.1	202	24	2.0	<LOD	117
4	0.2	29	<LOD	4.9	<LOD	73	1.1	0.7	6.7	0.56	1.7	224	25	2.1	<LOD	130
6	0.3	27	<LOD	2.9	<LOD	76	<LOD	0.9	4.4	0.49	1.3	208	18	1.5	<LOD	93
8	0.5	26	<LOD	6.8	<LOD	56	0.6	0.8	8.5	0.56	2.2	213	31	2.3	<LOD	159
10	0.5	26	<LOD	5.6	<LOD	59	0.7	0.9	6.7	0.56	1.4	221	28	2.1	<LOD	138
12	0.2	29	<LOD	3.2	<LOD	77	0.7	0.8	4.4	0.50	1.4	216	19	1.6	<LOD	97
Average		27		4.6		70			6.3	0.51		210	23	1.9		**120**
%RSD[a]		5.0		29.9		12.7			23.1	10.0		6.0	22.1	14.9		20.2
Puv-6 core (cm)																
1	<LOD	39	<LOD	2.5	<LOD	240	<LOD	<LOD	0.6	0.74	0.2	294	23	1.8	<LOD	84
2	0.4	35	<LOD	3.0	<LOD	185	0.7	0.5	2.1	0.88	0.9	303	24	2.0	<LOD	101
6	0.2	29	<LOD	3.0	<LOD	164	<LOD	0.5	2.9	0.75	1.2	225	19	1.8	<LOD	84
8	0.2	32	<LOD	3.0	<LOD	147	0.7	0.6	2.8	0.80	1	256	22	1.8	<LOD	93
10	0.4	34	<LOD	2.8	<LOD	148	<LOD	0.7	2.0	0.82	0.2	289	23	1.8	<LOD	97
Average		34		2.9		177			2.1	0.80		273	22	1.8		92
%RSD		11.0		7.7		21.8			44.2	7.1		11.8	8.7	4.9		8.3
Vac-1 core (cm)																
1	0.5	10	<LOD	4.7	<LOD	307	1	<LOD	8.1	0.19	2.2	56	17	1.3	<LOD	53
2	0.1	14	<LOD	5.1	<LOD	382	0.7	0.7	9.2	0.26	2.3	66	18	1.5	<LOD	48
4	<LOD	12	<LOD	4.8	<LOD	372	<LOD	0.5	8.3	0.24	2.3	62	17	1.4	<LOD	49
6	<LOD	12	<LOD	4.6	<LOD	377	0.8	0.5	8.0	0.25	2.1	61	18	1.3	<LOD	46
8	<LOD	14	<LOD	5.7	<LOD	391	0.7	0.5	11.0	0.29	2.3	70	19	1.4	<LOD	55
10	0.1	13	<LOD	5.5	<LOD	402	0.9	0.6	11.0	0.32	2.6	76	19	1.3	<LOD	66
12	0.1	13	<LOD	6.0	<LOD	365	0.8	<LOD	12.0	0.33	3.1	79	19	1.6	<LOD	72
14	0.2	13	<LOD	6.5	<LOD	372	<LOD	<LOD	15.0	0.37	3.1	87	20	1.6	<LOD	85
16	<LOD	12	<LOD	6.5	<LOD	363	1.1	<LOD	17.0	0.40	3.4	92	22	1.5	<LOD	95
18	0.2	14	<LOD	7.2	<LOD	385	1.1	<LOD	16.0	0.39	4.3	91	23	1.8	<LOD	97
20	0.2	13	<LOD	7.1	<LOD	377	<LOD	<LOD	15.0	0.39	3.4	89	22	1.6	1.0	86
22	0.1	13	<LOD	6.5	<LOD	398	<LOD	<LOD	14.0	0.37	3.3	83	22	1.5	<LOD	75
Average		13		5.9		374			12.1	0.32		76	20	1.5		69
%RSD		8.9		15.8		6.5			27.1	22.1		16.8	10.7	10.3		27.3
E.C.[#] **level 1**	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	100
E.C. level 2	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	150
E.C. level 3	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	535

[a]LOD: Limit of detection; %RSD=SD/mean x 100, not calculated for values close to LODs.

[#]Environnement Canada, 1993. Cadre législatif de gestion des sédiments au Québec. Above leve 1, 2 and 3 mean respectively negligible, minor and harmful effects on aquatic organisms. Values in blue, green and red exceed respectively levels 1, 2 , and 3. N/C: No criteria.

Table 4. Concentrations of elements in terrestrial mosses collected near Crater Lake and Katinniq areas

		Vachon River				Deception River
Element	**LOD**	**Vac-1A**	**Vac-1B**	**Vac-2**	**Vac-3***	**Dec-26**
Au (ηg·g-1)	0.1	4.4	17.2	2.2	6.6	2.05
Ag (μg·g-1)	0.3	<LOD	<LOD	<LOD	<LOD	<LOD
As (μg·g-1)	0.01	0.42	0.72	0.41	0.52	0.66
Ba (μg·g-1)	5	58	41	75	180	20
Br (μg·g-1)	0.01	15	12	12	27	6
Ca (%)	0.01	0.36	0.49	0.65	0.92	0.25
Ce (μg·g-1)	0.1	6.7	1.6	15	50	2.4
Co (μg·g-1)	0.1	1.8	1.1	2.2	9.4	1.8
Cr (μg·g-1)	0.3	8.7	16	5.8	22	26
Cs (μg·g-1)	0.05	<LOD	<LOD	<LOD	0.41	<LOD
Eu (μg·g-1)	0.05	0.06	<LOD	0.09	0.36	<LOD
Fe (%)	0.005	0.185	0.088	0.170	1.220	0.203
Hf (μg·g-1)	0.05	<LOD	0.06	0.15	0.92	0.12
Hg (μg·g-1)	0.05	<LOD	0.32	<LOD	<LOD	<LOD
Ir (ηg·g-1)	0.1	<LOD	<LOD	<LOD	<LOD	<LOD
K (%)	0.01	0.70	0.53	0.30	1.05	<LOD
La (μg·g-1)	0.01	4.50	0.98	10	34	1.55
Lu (ηg·g-1)	1	15	<LOD	19	89	12
Mo (μg·g-1)	0.05	<LOD	0.3	<LOD	<LOD	<LOD
Na (μg·g-1)	0.5	628	515	811	4910	513
Nd (μg·g-1)	0.3	2.9	0.9	6	20	1.3
Ni (μg·g-1)	2	<LOD	<LOD	<LOD	<LOD	18.5
Rb (μg·g-1)	1	21	15	7	39	<LOD
Sb (μg·g-1)	0.005	0.065	0.120	0.067	0.100	0.073
Sc (μg·g-1)	0.01	0.230	0.130	0.300	2.400	0.725
Se (μg·g-1)	0.1	<LOD	<LOD	<LOD	0.6	<LOD
Sm (μg·g-1)	0.001	0.400	0.096	0.680	2.600	0.170
Sr (μg·g-1)	10	<LOD	<LOD	<LOD	<LOD	<LOD
Ta (μg·g-1)	0.05	<LOD	<LOD	<LOD	<LOD	<LOD
Tb (μg·g-1)	0.1	<LOD	<LOD	<LOD	0.2	<LOD
Th (μg·g-1)	0.1	0.3	0.2	0.4	3.6	0.2
U (μg·g-1)	0.01	0.17	0.31	<LOD	0.64	<LOD
W (μg·g-1)	0.05	<LOD	<LOD	<LOD	<LOD	<LOD
Yb (μg·g-1)	0.005	0.097	0.045	0.114	0.606	0.083
Zn (μg·g-1)	2	38	71	38	59	11

[a] LOD: Limit of detection.

*Moss sample from Vac-3 station was stringy compared to the others which were instead thick and branchy.

Table 5. Age, weight and length of fish collected from Deception River, Laflamme and Crater lake

	Landlocked charr (Crater Lake)			**Charr[#] (Deception River)**			**L. trout (Laflamme Lake)**
	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 2
	10-20 cm (n=14)	20-40 cm (n=3)	40-60 cm (n=14)	10-20 cm (n=14)	20-40 cm (n=11)	40-60 cm (n=5)	20-40 cm (n=25)
Total weight (g)	33 ± 19	97 ± 75	1149 ± 386	55 ± 16	175 ± 99	1294 ± 86	450 ± 119
Fork length (cm)	15 ± 3	23 ± 3	51 ± 5	18 ± 2	26 ± 5	48 ± 1	35 ± 3
Age (years)	10 ± 3 (13)*	15 ± 3	24 ± 4	9 ± 3 (8)	12 ± 3 (10)	11 ± 2 (3)	13 ± 3

*( ): Sample size is specified when not equal to the number of fish of the corresponding class.

[#]Regardless of the class, fish may either belong to an anadromous or landlocked charr stock.

Table 6. Medians and concentration ranges of metals (ηg/g wet weight) in liver of fish collected from Deception River, Laflamme and Crater lakes

		Landlocked charr (Crater Lake)		Charr[##] (Deception River)			L. trout (Laflamme Lake)
		Class 1	Class 3	Class 1	Class 2	Class 3	Class 2
Metal	LOD[#]	10-20 cm (n=14)	40-60 cm (n=14)	10-20 cm (n=14)	20-40 cm (n=11)	40-60 cm (n=5)	20-40 cm (n=25)
Al	521	21450 (10)* 15200-68610	1235 <LOD-3410	8780 (3) 3380-12400	6025 (4) 1670-10900	<LOD (4) <LOD-1160	2815 (24) 1760-8500
As	1.97	35 (1) 35	7.5 4-18	21,5 (8) <LOD-85	15 (9) 5-24	373 329-667	7 4-17
Be**	1.3	<LOD <LOD	<LOD <LOD	<LOD <LOD	<LOD <LOD	<LOD <LOD	<LOD <LOD
Cd	0.22	584 296-1800	494.5 214-1920	174.5 88-448	201 118-347	80 60-114	717 393-1880
Co	0.1	240 44-523	103 31-331	338 199-636	318 86-550	32 24-57	195 104-434
Cr	228	19400 (1) 19400	<LOD <LOD-304	N/D[###] N/D	N/D N/D	<LOD <LOD	269 (9) <LOD-398
Cu	13	6755 3080-15000	4430 742-11000	6170 2630-17700	4910 2850-9890	2410 812-2970	4060 1250-8580
Fe	174	302000 46300-627000	360500 23200-1140000	199000 75500-492000	231000 91400-1280000	192000 103000-461000	480000 207000-1130000
Hg	0.4	55 12-162	87.5 2,1-199	87.5 30-286	163 14-641	18 12-24	69 2,5-168
Ni	13	65 (1) 65	88 43-164	266 (13) 93-770	213 108-333	102 74-118	70 (24) 43-172
Pb	2.6	57 (8) <LOD-269	35 16-88	45 (2) 12-78	4,5 (4) <LOD-15	3 3-6	10,5 (24) <LOD-27
V	2.24	49 (5) 25-120	4 <LOD-11	35 (3) 19-43	20 (8) 10-99	12 (5) 8-88	13 (23) 4-79
Zn	79	33150 26400-47400	20100 12100-24300	36200 26400-53000	35500 22100-51600	24700 18600-28300	29800 19100-53900

*( ): Sample size is specified when not equal to the number of fish of the corresponding class.

**Beryllium was not detected from all fish samples, including liver, muscle and kidney tissues; the majority were below 3 ηg/g.

[#]LOD: limit of detection in ηg/g.

[##]Regardless of the class, fish may either belong to an anadromous or landlocked charr stock.

[###]N/D: No data. Certain values were reported as not detected at a higher detection limit (>3SD + blank) due to insufficient amount of materials required for the complete set of analysis. These values were not included in the descriptive statistics.

Table 7. Medians and concentration ranges of metals (ηg/g wet weight) in muscle tissue of fish collected from Deception River, Laflamme and Crater lakes

		Landlocked charr (Crater Lake)		Charr[##] (Deception River)			L. trout (Laflamme Lake)
		Class 1	Class 3	Class 1	Class 2	Class 3	Class 2
Metal	LOD[#]	10-20 cm (n=14)	40-60 cm (n=14)	10-20 cm (n=14)	20-40 cm (n=11)	40-60 cm (n=5)	20-40 cm (n=26)
Al	521	6750 (6)[*] 1660-12500	792 <LOD-5400	2360 (5) 1380-7940	1200 (7) 799-3230	531 <LOD-1050	987 (25) <LOD-4400
As	1.97	9,5 (10) 5-17	6 3-15	11 (12) 6-25	8 3-14	622 311-742	9.5 5-17
Be**	1.3	<LOD <LOD	<LOD <LOD	<LOD <LOD	<LOD <LOD	<LOD <LOD	<LOD <LOD
Cd	0.22	4.75 2,2-54	2.65 1,4-11	2.65 1,5-6,6	1.6 1-5.3	0.9 0.7-3	2.85 1.8-109
Co	0.1	27.5 7,5-55	8.15 4,3-11	57.5 24-110	35 9.6-74	5.1 4.4-8	14 7-30
Cr	228	N/D[###] N/D	<LOD (13) <LOD-274	N/D N/D	<LOD (2) <LOD	<LOD <LOD	<LOD (21) <LOD-398
Cu	13	350.5 250-1110	341.5 198-647	456.5 349-549	377 309-707	396 342-421	211.5 131-639
Fe	174	6675 2850-27500	4975 2850-6810	4895 3770-8550	4760 2750-8630	3950 3220-4780	3480 2340-32600
Hg	0.4	10.85 1,8-72	24.5 1,5-106	35.5 7,3-78	47 3.7-108	14 9.4-20	36 1.2-184
Ni	13	55 (5) 5-73	23.5 <LOD-50	68 (13) 39-175	43 (10) 28-64	37 25-48	21.5 <LOD-49
Pb	2.6	30 (13) <LOD-90	4.5 <LOD-18	93 (13) 5-286	6 <LOD-61	42 19-112	4.5 <LOD-60
V	2.24	5 (3) 4-28	<LOD <LOD-4	<LOD (2) <LOD	<LOD (7) <LOD-4	3 <LOD-4	<LOD (25) <LOD-5
Zn	79	11200 9130-28300	4340 3050-6990	18800 9030-23200	13200 8190-21500	6290 3950-7720	4760 3250-10100

[*] ( ): Sample size is specified when not equal to the number of fish of the corresponding class.

**Beryllium was not detected from all fish samples, including liver, muscle and kidney tissues; the majority were below 3 ηg/g.

[#]LOD: limit of detection in ηg/g.

[##]Regardless of the class, fish may either belong to an anadromous or landlocked charr stock.

[###]N/D: No data. Certain values were reported as not detected at a higher detection limit (>3SD + blank) due to insufficient amount of materials required for the complete set of analysis. These values were not included in the descriptive statistics.

Table 8. Medians and concentration ranges of metals (ηg/g wet weight) in kidney of fish collected from Deception River, Laflamme and Crater lakes

		Landlocked charr (Crater Lake)		Charr[##] (Deception River)			L. trout (Laflamme Lake)
		Class 1	Class 3	Class 1	Class 2	Class 3	Class 2
Metal	LOD[#]	10-20 cm (n=14)	40-60 cm (n=14)	10-20 cm (n=14)	20-40 cm (n=11)	40-60 cm (n=5)	20-40 cm (n=26)
Al	521	18500 (7)[*] <LOD-623000	866.5 473-1710	62450 (2) 58800-66100	2865 (6) 908-4670	<LOD (4) <LOD-497	1145 (22) <LOD-4450
As	1.97	58,5 (4) <LOD-67	14 8-51	35 (10) 17-65	37,5 (10) 11-116	350 302-447	13 7-22
Be**	1.3	<LOD <LOD	<LOD <LOD	<LOD <LOD	<LOD <LOD	<LOD <LOD	<LOD <LOD
Cd	0.22	1070 306-2620	760 343-1080	352.5 179-850	353 202-733	200 126-242	1530 735-4420
Co	0.1	448.5 84-1140	228 111-733	483.5 312-1130	475 160-373	48 35-70	278 107-466
Cr	228	3780 (1) N/D[###]	<LOD (13) <LOD-278	N/D N/D	N/D N/D	<LOD (4) <LOD-408	<LOD (6) <LOD-382
Cu	13	1970 (13) 769-5510	737.5 515-1110	1440 (13) 744-2440	1110 782-1930	616 507-745	632.5 463-902
Fe	174	156500 93800-1450000	221000 93900-418000	117000 80600-177000	122500 65100-254000	232000 182000-427000	132000 46000-230000
Hg	0.4	80 10-424	120 1,6-356	98.5 49-219	112 8,8-294	41 35-52	106 2,4-332
Ni	13	620 (9) 152-1640	366 187-718	781 (13) 452-2420	1070 527-1470	344 272-402	444.5 181-1240
Pb	2.6	202 (11) 94-560	473 181-1110	54 (5) 10-1580	6 (4) 5-14	3 (5) <LOD-3	23.5 <LOD-85
V	2.24	73 (5) 51-1400	4.5 <LOD-41	31 (5) 25-41	40 (9) 13-82	38 18-160	10 3-32
Zn	79	35050 23000-264000	16200 11200-24600	34950 23100-53000	29300 16500-47100	16900 12900-26300	19350 12900-34200

[*] ( ): Sample size is specified when not equal to the number of fish of the corresponding class.

**Beryllium was not detected from all fish samples, including liver, muscle and kidney tissues; the majority were below 3 ηg/g.

[#]LOD: limit of detection in ηg/g.

[##]Regardless of the class, fish may either belong to an anadromous or landlocked charr stock.

[###]N/D: No data. Certain values were reported as not detected at a higher detection limit (>3SD + blank) due to insufficient amount of materials required for the complete set of analysis. These values were not included in the descriptive statistics.

Table 9. Age, length and weight of blue mussels collected from three different beds of Deception Bay

	Decbay-1 (n=30)	**Decbay-2** (n=30)	**Decbay-3** (n=30)
Total weight (g)*	17,2 ± 3,1	17,1 ± 3,5	6,4 ± 1,9
Length (cm)	62,1 ± 5,3	57,7 ± 4,2	42,9 ± 4,2
Age (years)	11,2 ± 3,7	8,9 ± 2,6	2,7 ± 0,7

* Measurements were performed on 30 mussels per station but the average total weight of Decbay-3 station was calculated with 19 mussels.

Table 10. Medians and concentration ranges of metals (ηg/g wet weight) in blue mussels collected from three different beds of Deception Bay

Metal	LOD#	Decbay-1	Decbay-2	Decbay-3
		62.1 ± 5.3 mm (30)	57.7 ± 4.2 mm (29)	42.9 ± 4.2 mm (30)
Al	521	5490 2520-13900	3720 1050-29000	9110 2610-42700
As	1.97	1900 641-3620	2120 873-2910	2005 1560-2750
Be**	1.3	<LOD <LOD	<LOD <LOD	<LOD <LOD
Cd	0.22	306.5 140-711	306 118-485	322.5 205-577
Co	0.1	107.5 34-160	83 35-123	94 67-149
Cr	2.28	240 (26)* <LOD-436	<LOD (26) <LOD-285	<LOD (3) <LOD-922
Cu	13	816.5 235-1120	766 309-1070	900.5 703-1260
Fe	174	39350 14700-120000	33900 10500-59000	33850 19800-111000
Hg	0.4	18 <LOD-185	15 1,3-30	15 8,1-21
Ni	13	422.5 131-642	349 155-506	439 220-755
Pb	2.66	75.5 18-199	44 16-94	46.5 34-72
Zn	79	8120 2500-18700	7570 4150-23800	10900 7100-17000
V	2.24	88.5 39-280	79 31-130	91.5 53-250

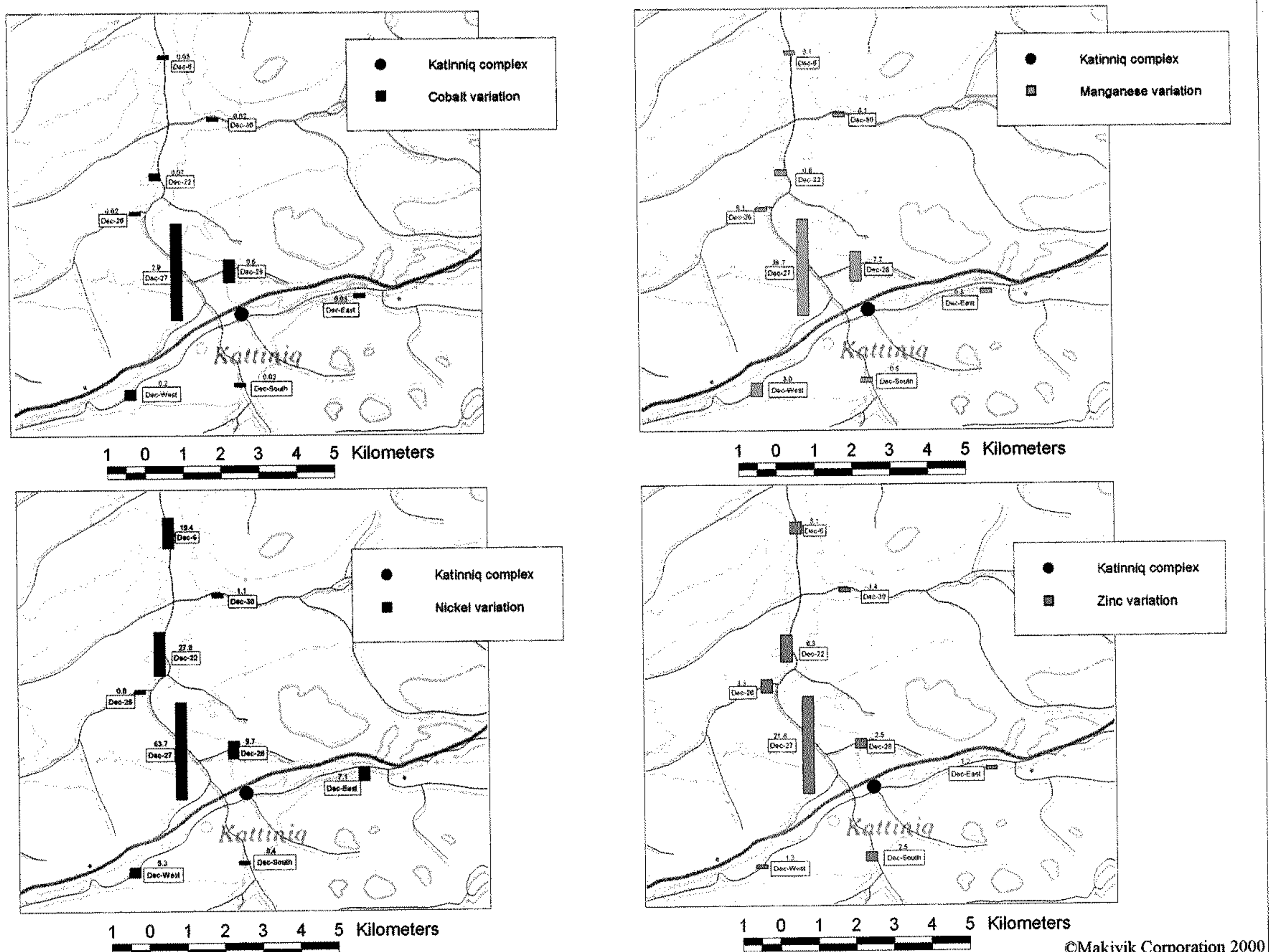
*( ): Sample size is specified when not equal to the number of mussels of the corresponding group.

Certain values were reported as not detected at a higher detection limit (>3SD + blank) due to insufficient amount of tissus required for the complete set of analysis. These values were not included in the descriptive statistics.

**Beryllium was not detected from all mussels (soft tissue); the majority were below 2 ηg/g.

#LOD: limit of detection in ηg/g.

Figure 1 Metal concentration (ppb) in Deception River waters: upstream versus downstream



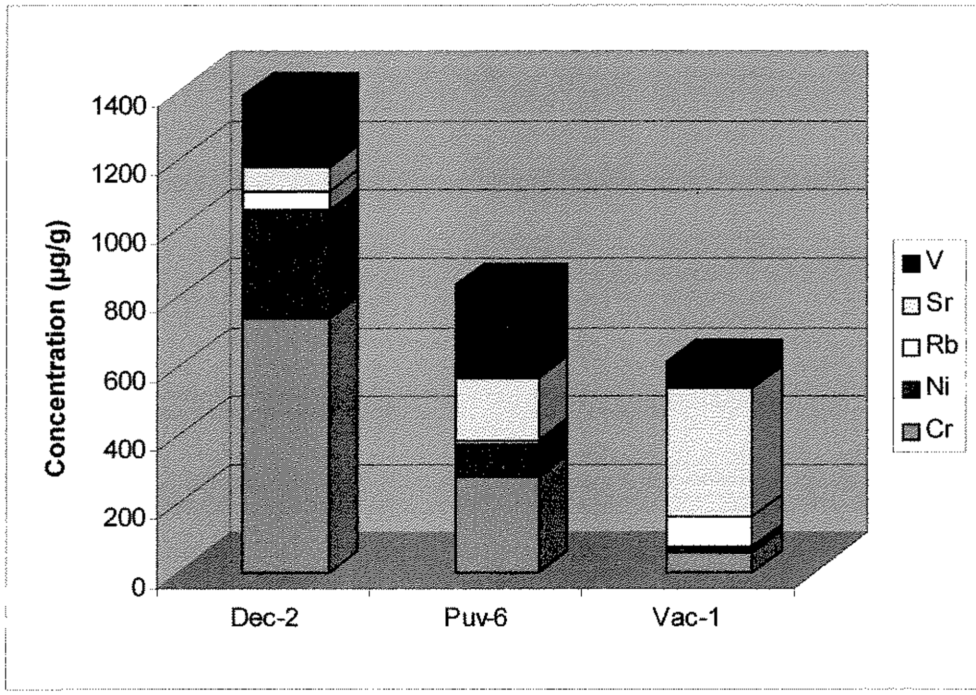


Figure 2. Proportions of chromium, nickel, rubidium, strontium and vanadium in three cores of different geological settings.

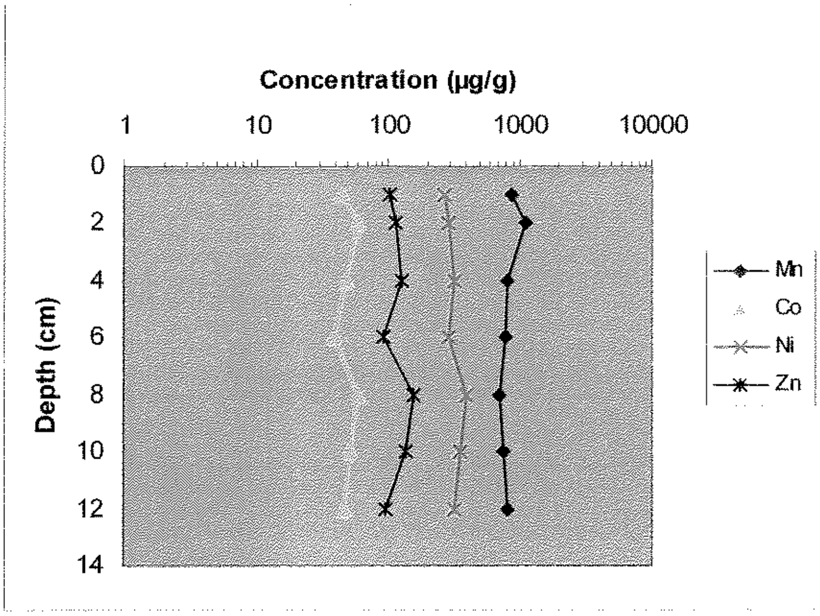


Figure 3. Variations of cobalt, manganese, nickel and zinc concentrations in Dec-2 core (Deception River) according to depth.

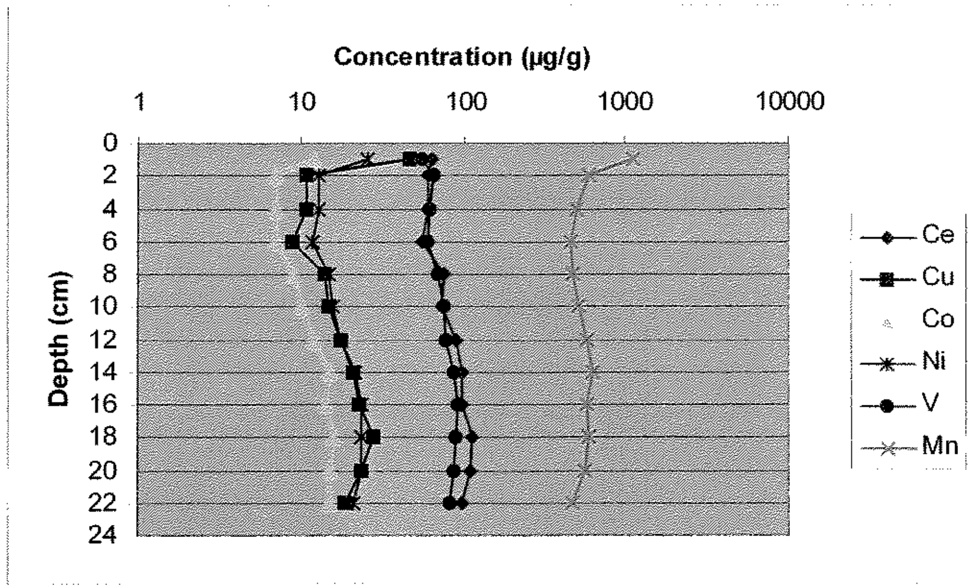
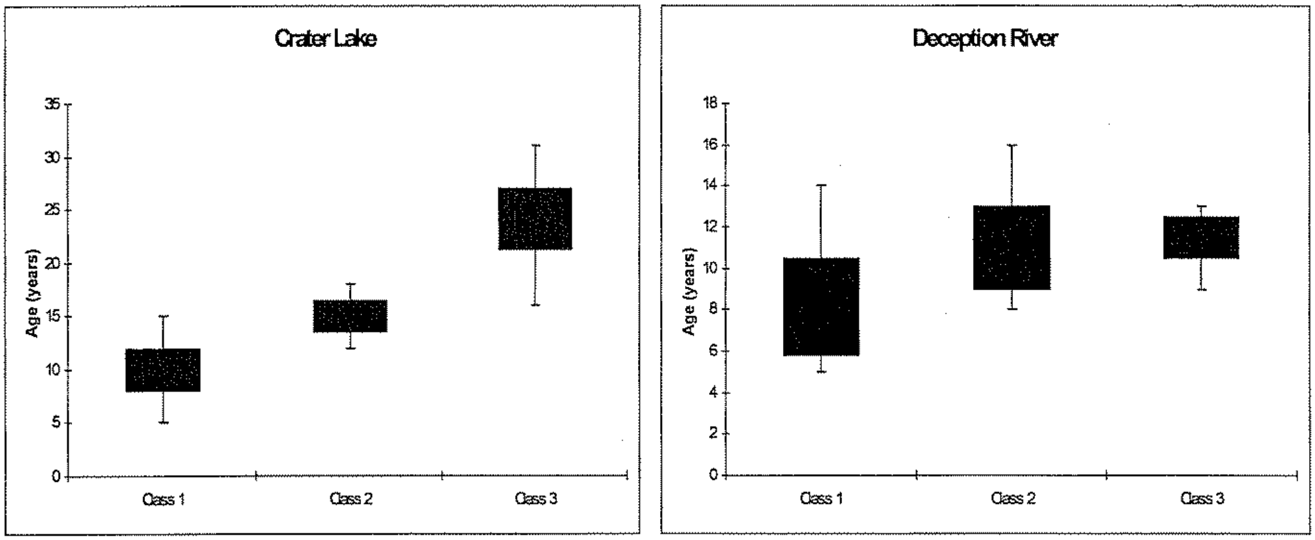


Figure 4. Profiles of cesium, cobalt, copper, manganese, nickel and vanadium concentrations in Vac-1 core (Lake Laflamme).



Figuere 5 Age variation of three length classes of charr from Deception River and Crater Lake

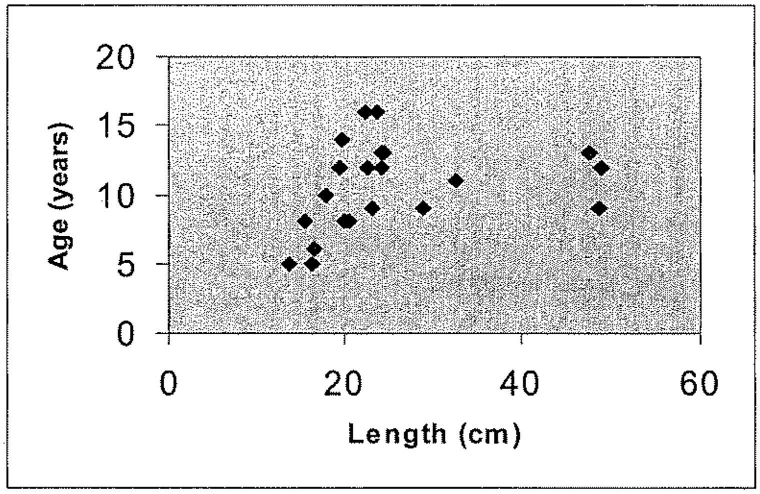
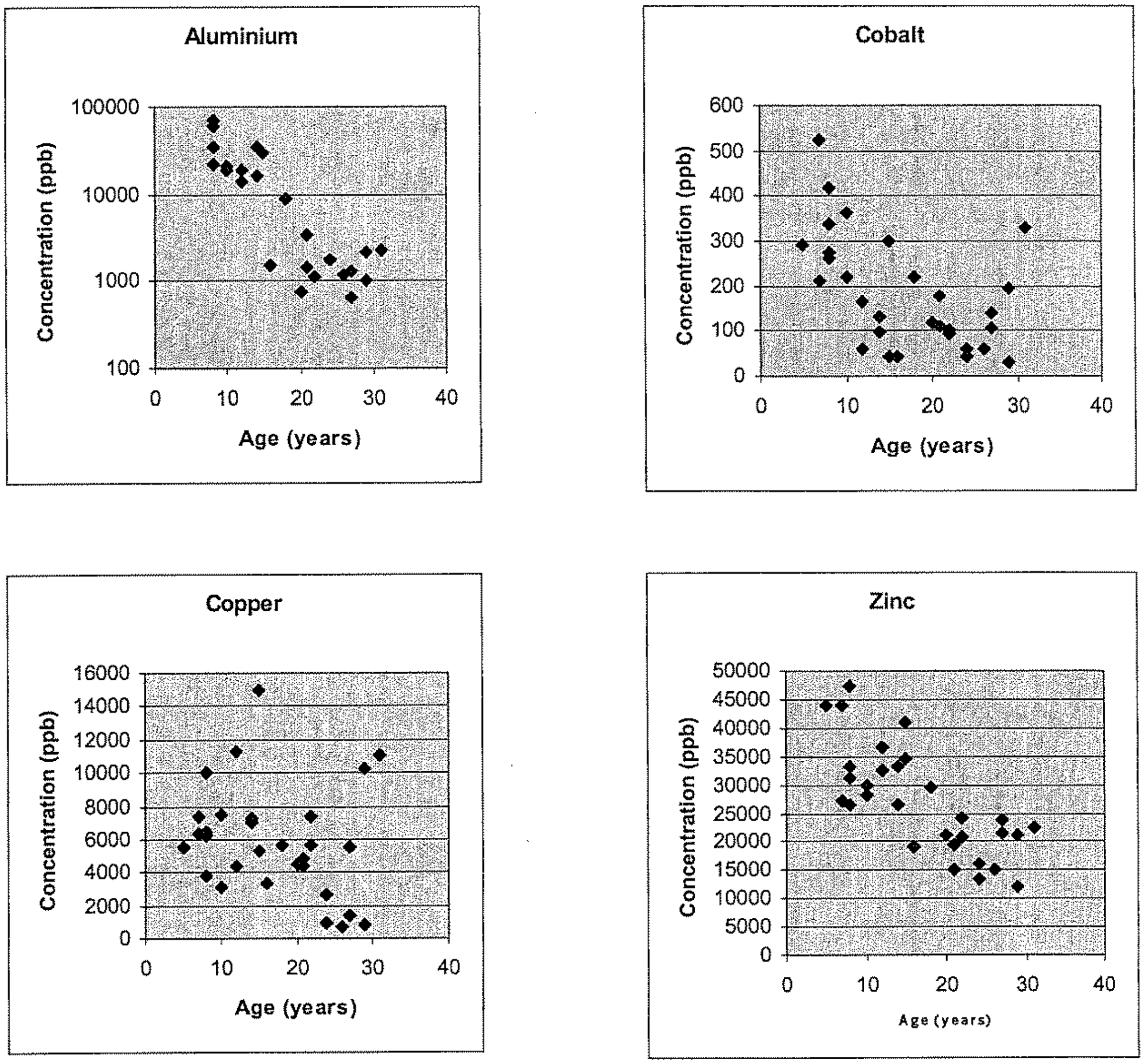
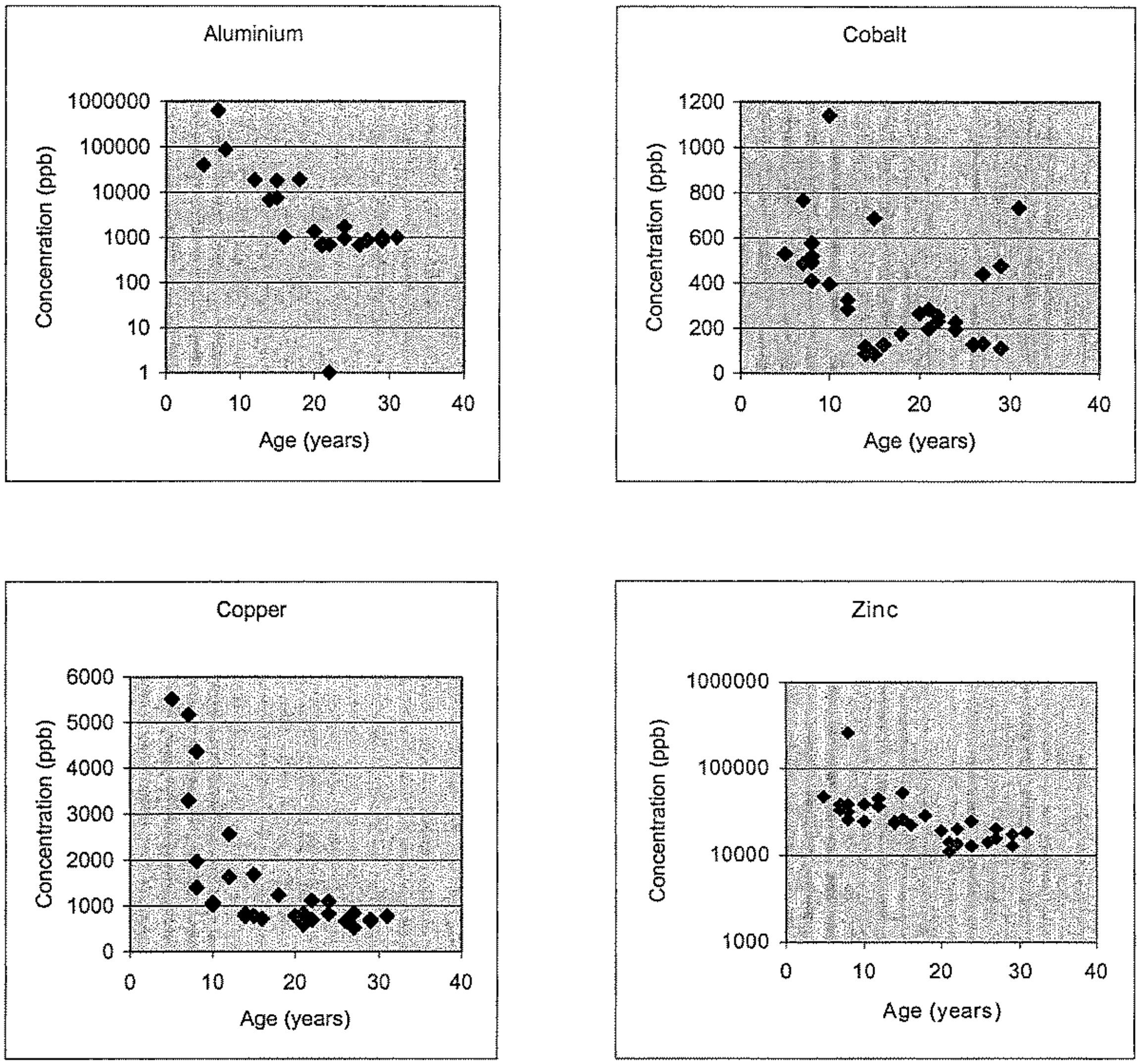


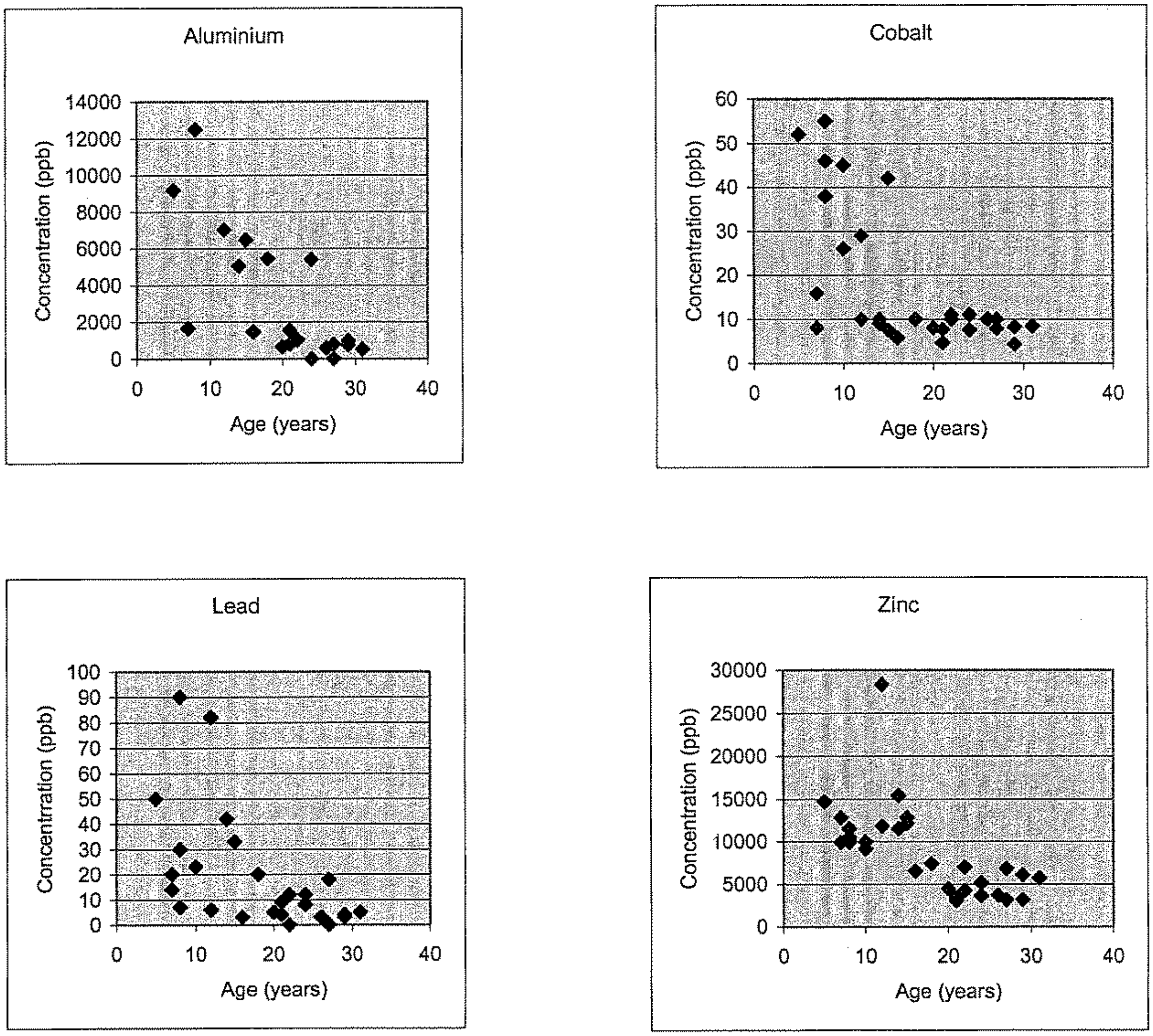
Figure 6. Age-length relationship for the Deception River charr. Note the clear bimodal pattern



Figue 7. Relationship of aluminium, cobalt, copper and zinc concentrations with age in livers of landlocked charr from Crater Lake



Figue 8. Relationship between age and aluminium, cobalt, copper and zinc concentrations in kidneys of landlocked charr from Crater Lake



Figue 9. Relationship between age and aluminium, cobalt, lead and zinc concentrations in muscles of landlocked charr from Crater Lake

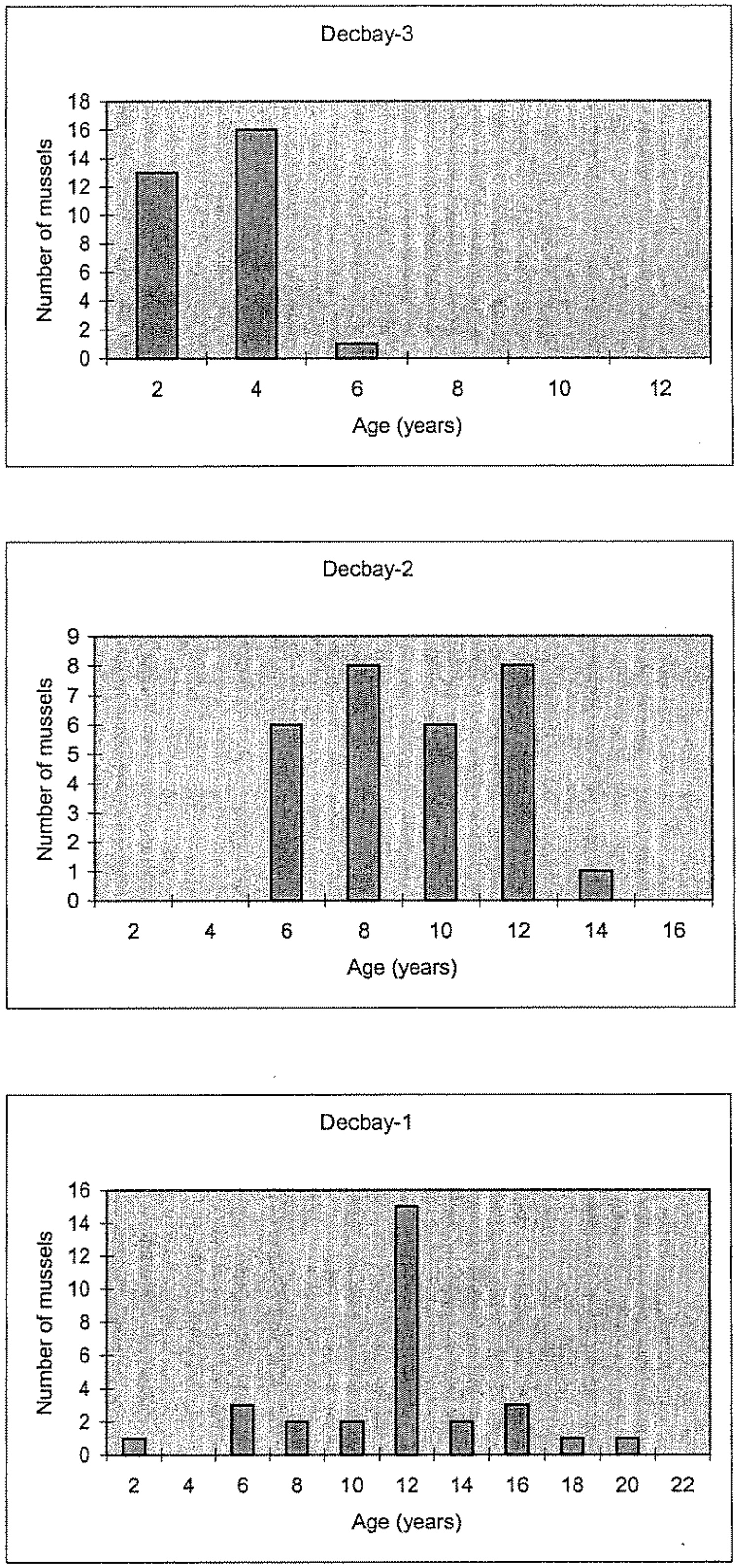


Figure 10. Age frequency distribution of blue musseld collected from three different beds of Deception Bay. Note the different age distribution in Decbay-3 characterised by young mussels

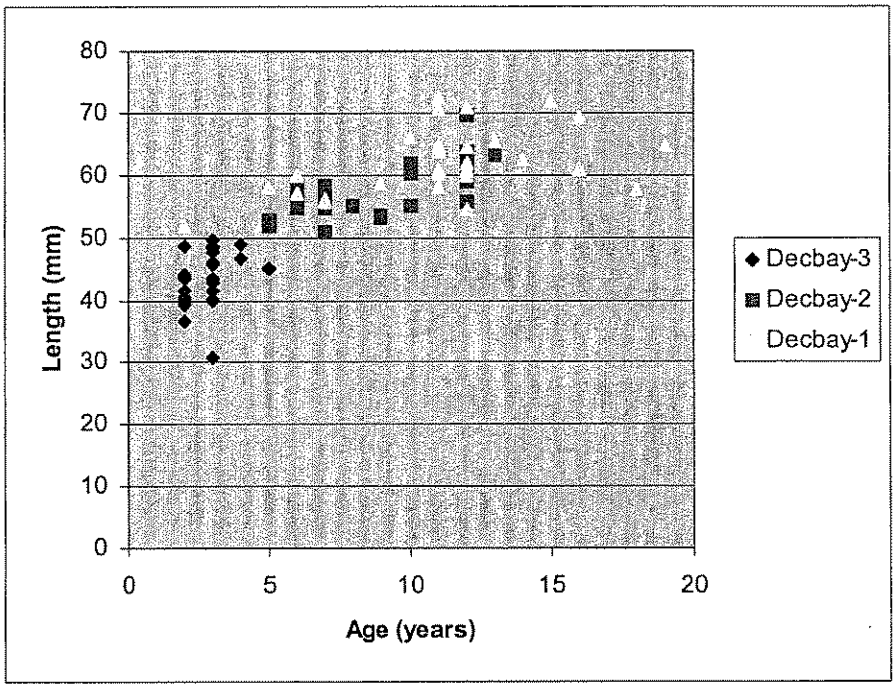


Figure 11. Age-length relationship of blue mussels collected from three different beds of Deception Bay

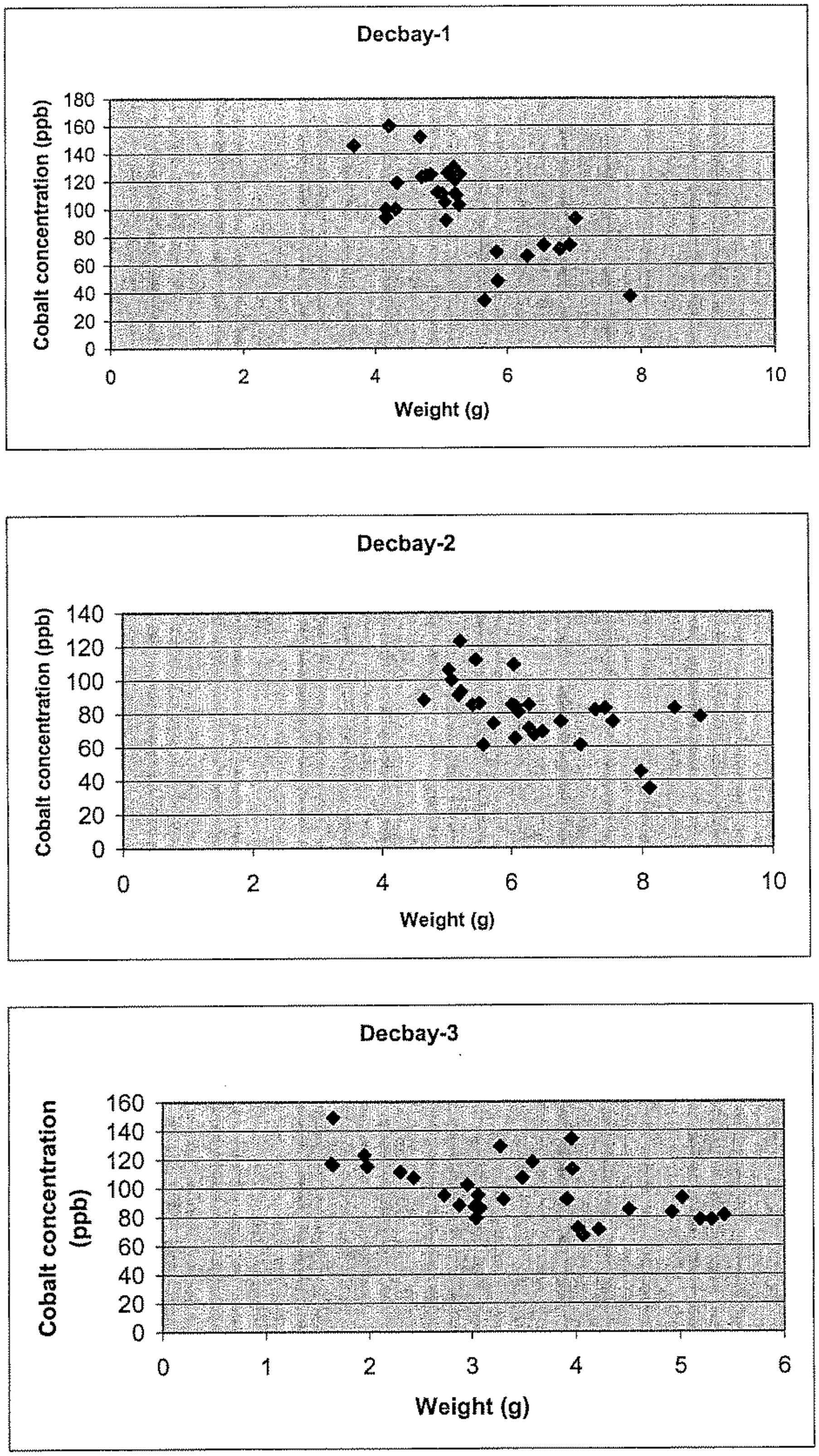
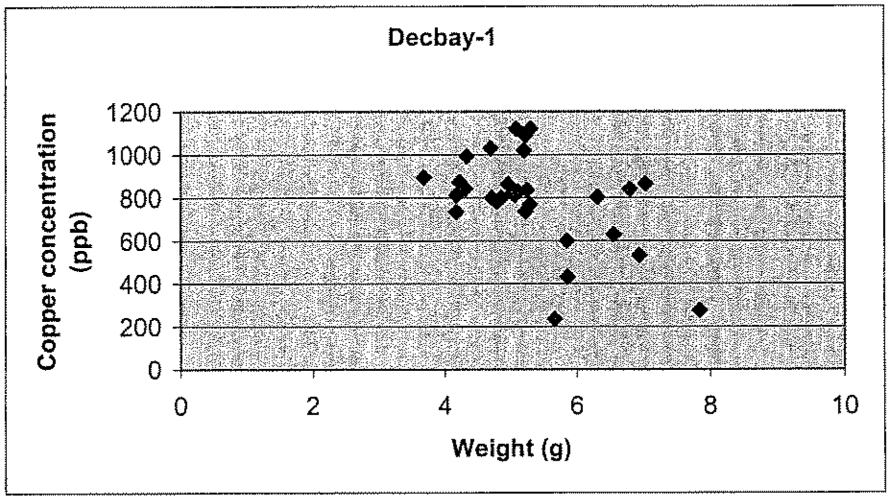
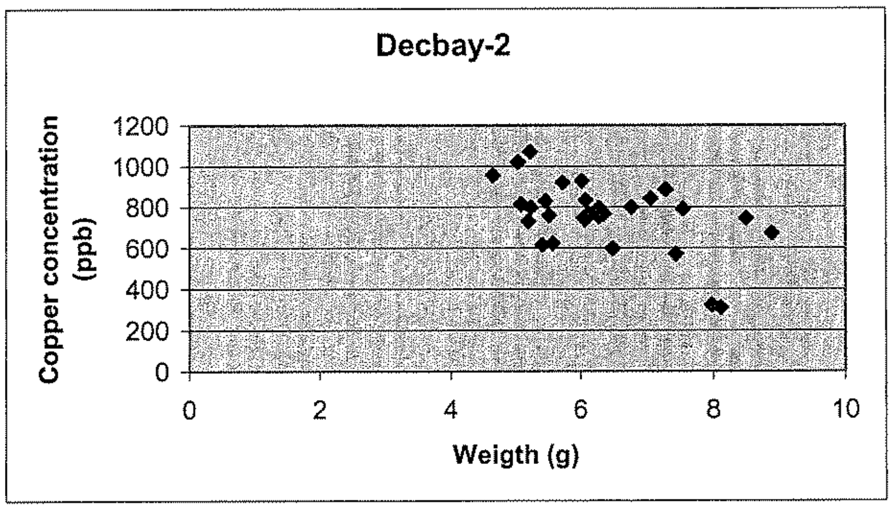


Figure 12. Relationship between weight and cobalt concentration in blue mussels collected from three different beds of Deception Bay





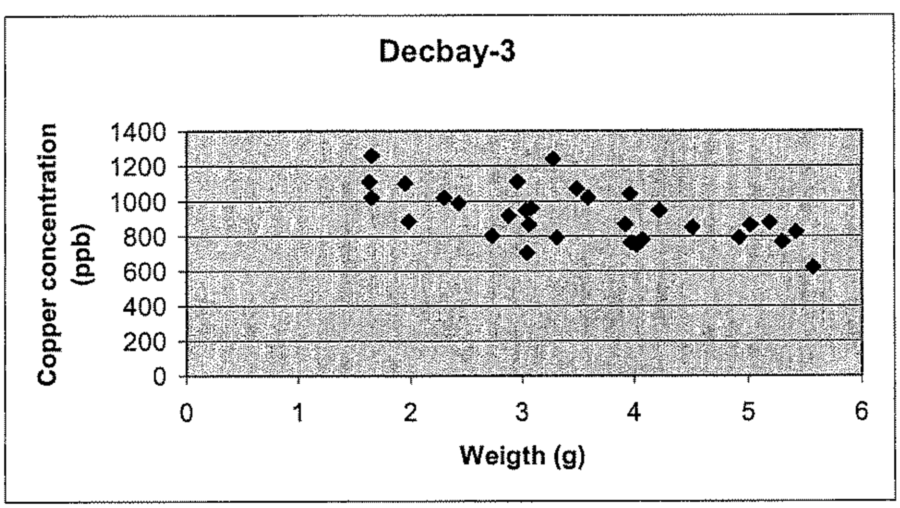


Figure 13. Relationship between weight and copper concentration in blue mussels collected from three different beds of Deception Bay

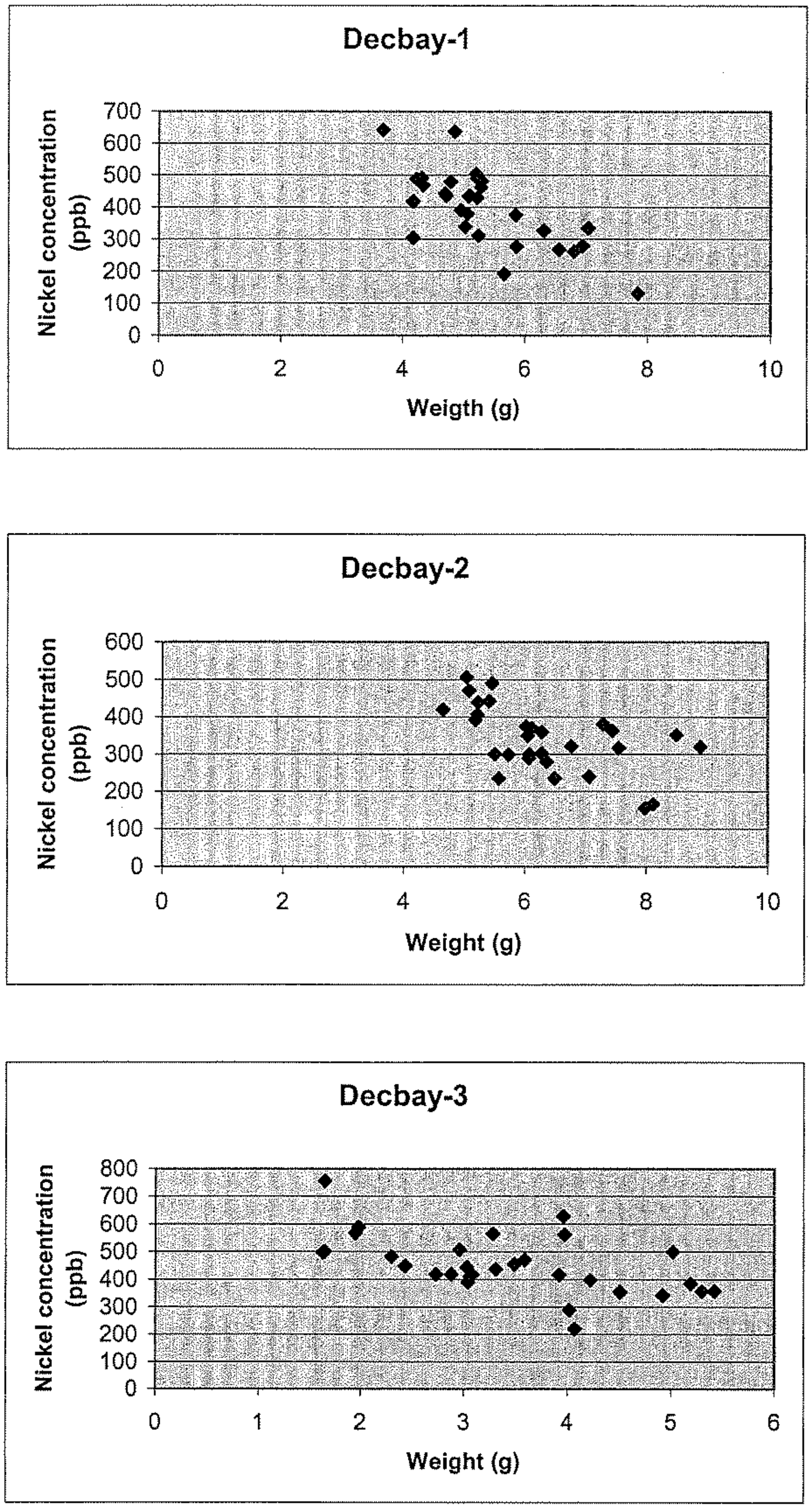
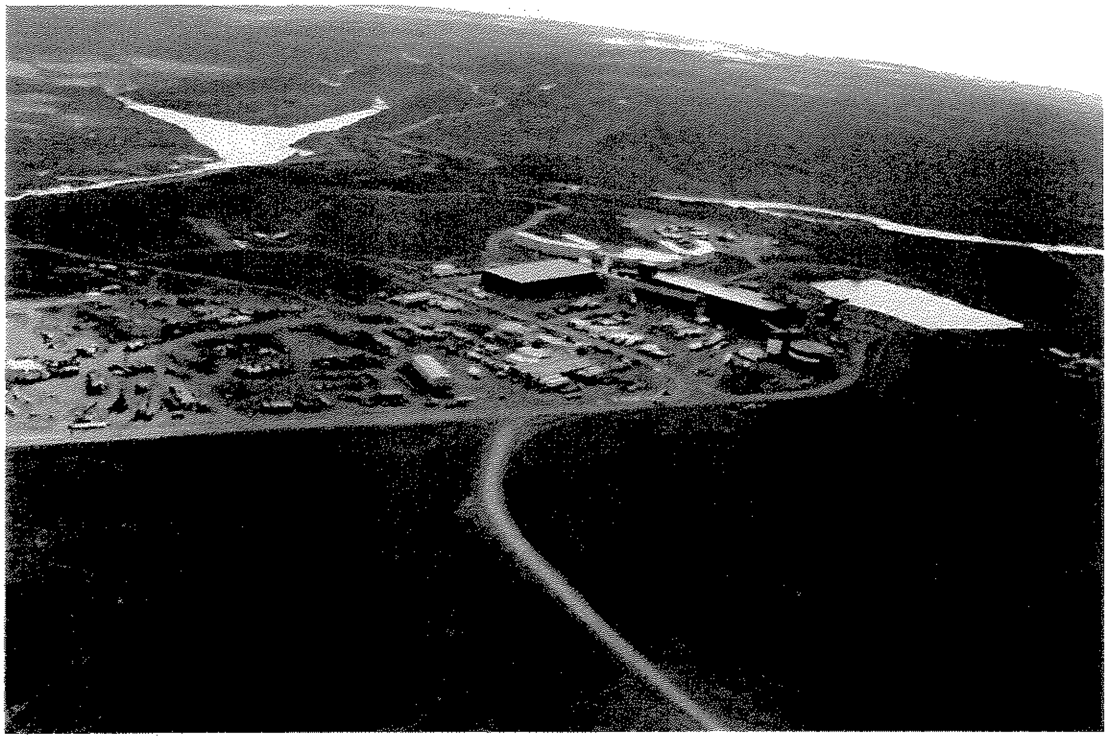
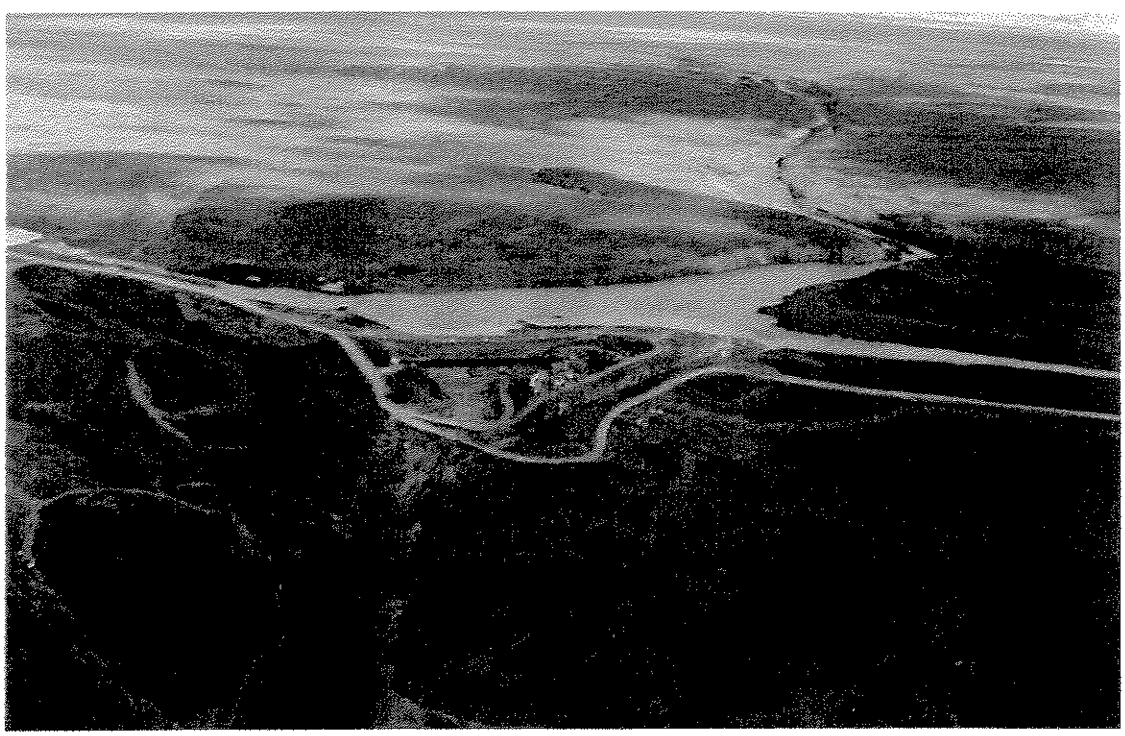


Figure 14. Relationship between weight and copper concentration in blue mussels collected from three different beds of Deception



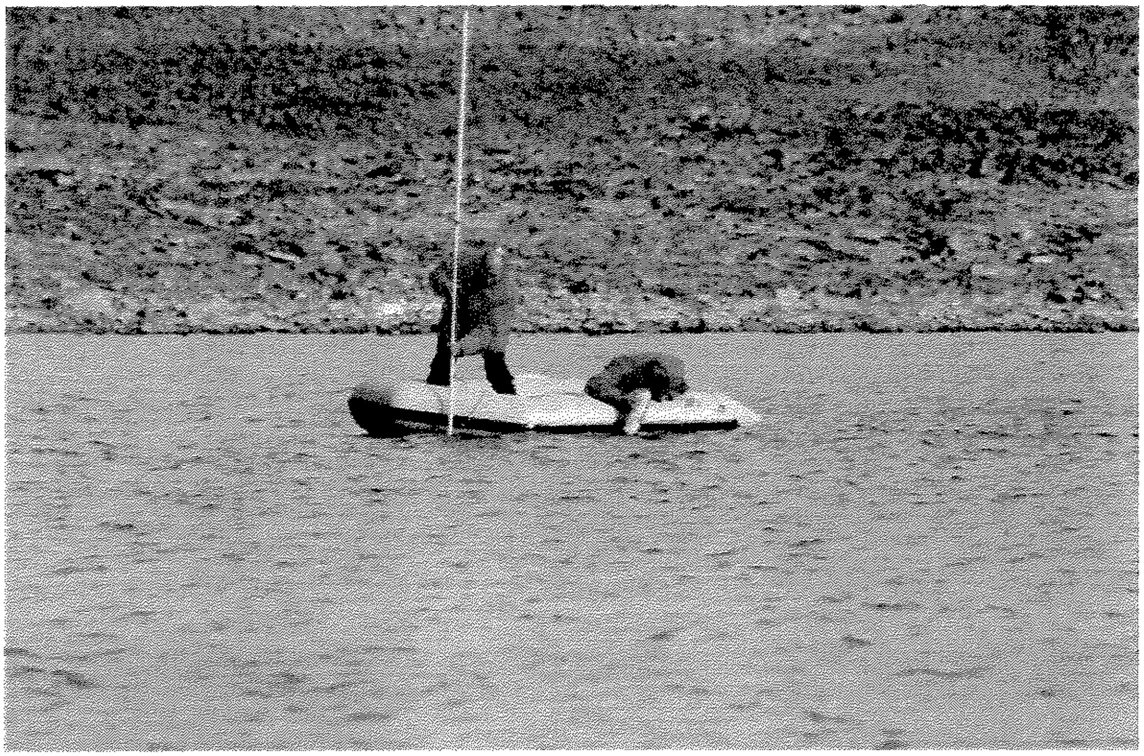
Photograph 1. Katinniq mining complex located near the confluence of the west, east, and south branches of the Deception River.



Photograph 2. Water reservoir created at the confluence of the west, east, and south branches of the Deception River.

Photograph 3 Rapids on the Deception River (87 km from the mouth of the river) which do not limit the upstream migration of charr. Note the marked rocky environment beside the river.

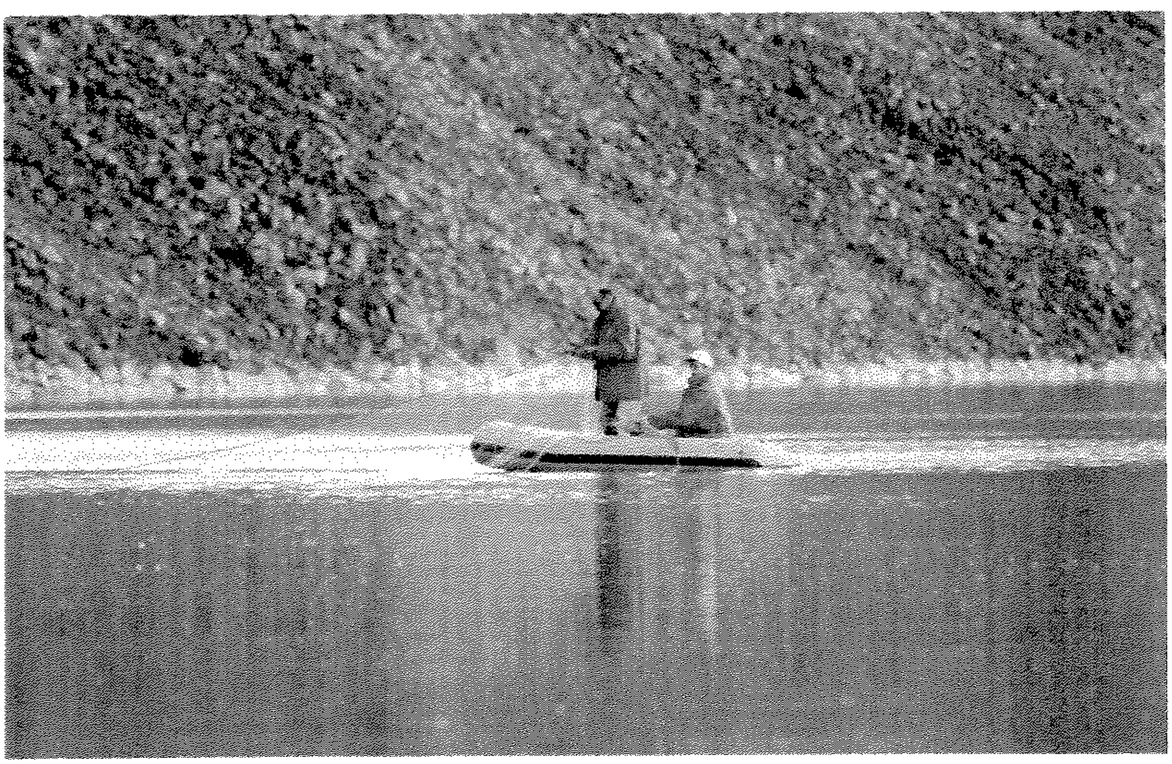
Photograph 4 Closer view of the rapids.



Photograph 5. Collecting fine sediment core from the Deception River.

Photograph 6. View of the sediment core collected from the Lake Laflamme.

Photograph 7 Temporary camp site at Crater Lake.



Photograph 8 Checking nets for landlocked charr at Crater Lake.

Photograph 9. Weighing landlocked charr at Crater Lake.

Photograph 10. Landlocked charr collected at Crater Lake.

References

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Appendix 1. Geographic positions of sampling stations.

Monitoring station	Aquatic system	Location	Latitude (N)	Longitude (W)
Surface water				
Dec-east	Deception River	Eastern branch	61° 41' .018'	73° 37' .086'
Dec-south	Deception River	Southern branch	61° 39' .933'	73° 40' .803'
Dec-west	Deception River	Western branch	61° 39 .576'	73° 44' .146'
Dec-28*	Deception River	Mining effluent	61° 41' .464'	73° 41' .934'
Dec-27	Deception River	Main river	61° 41' .578'	73° 42' .627'
Dec-26	Deception River	Mining effluent	61° 42' .340'	73° 43' .587'
Dec-22	Deception River	Main river	61° 42' .917'	73° 43' .074'
Dec-30	Deception River	Deception East River	61° 43' .612'	73° 41' .388'
Dec-6	Deception River	Main river	61° 44' .484'	73° 42' .743'
Puv-1	Puvirnituq River	Raglan Lake	61° 39' .460'	73° 16' .370'
Puv-4**	Puvirnituq River	Tributary	61° 39' .900'	73° 16' .730'
Puv-5**	Puvirnituq River	Tributary	61° 41' .350'	73° 16' .480'
Vac-1	Vachon River	Laflamme Lake	61° 19' .094'	73° 41' .178'
Vac-2	Vachon River	Main river	61° 08' .476'	73° 19' .695'
Vac-3	Vachon River	Tributary	61° 08' .076'	73° 14' .413'
Crater Lake 1	Crater Lake	East part	61° 16' .785'	73° 38' .724'
Crater Lake 2	Crater Lake	East part	61° 16' .746'	73° 38' .985'
Crater Lake 3	Crater Lake	East part	61° 16' .644'	73° 39' .232'
Crater Lake 4	Crater Lake	East part	61° 16' .623'	73° 39' .267'
Crater Lake 5	Crater Lake	East part	61° 16' .542'	73° 39' .355'
Crater Lake 6	Crater Lake	East part	61° 16' .502'	73° 39' .371'
Crater Lake 7	Crater Lake	East part	61° 16' .433'	73° 39' .155'
Crater Lake 8	Crater Lake	East part	61° 16' .454'	73° 38' .791'
Crater Lake 9	Crater Lake	East part	61° 16' .566'	73° 38' .791'
Crater Lake 10	Crater Lake	East part	61° 16' .752'	73° 38' .104'
Sediment cores				
Dec-2**	Deception River	Main river	61° 42' .210'	73° 43' .440'
Puv-6	Puvirnituq River	Main river	61° 42' .165'	73° 43' .538'
Vac-1	Vachon River	Laflamme Lake	61° 19' .094'	73° 41' .178'
Terrestrial mosses				
Dec-26	Deception River	Tributary	61° 42' .340'	73° 43' .587'
Vac-1	Vachon River	Laflamme Lake	61° 19' .094'	73° 41' .178'
Vac-2	Vachon River	Main river	61° 08' .476'	73° 19' .695'
Vac-3	Vachon River	Tributary	61° 08' .076'	73° 14' .413'
Fish				
Dec-1**	Deception River	Main river	61° 46' .350'	73° 42' .700'
Dec-2**	Deception River	Main river	61° 42' .210'	73° 43' .440'
Vac-1	Vachon River	Laflamme Lake	61° 19' .094'	73° 41' .178'
Crater Lake 1	Crater Lake	Eastern part	61° 16' .785'	73° 38' .724'
Mussels				
Decbay-1**	Deception Bay.	Southwest bank	62° 07' .220'	74° 36' .630'
Decbay-2**	Deception Bay.	East bank	62° 10' .110'	74° 40' .880'
Decbay-3**	Deception Bay.	Northeast bank	62° 13' .270'	74° 43' .450'

*The GPS position was taken by Blandine Arsenautl from the SMRQ on July 6, 1997

**The positions were taken from the helicopter's GPS.

Annex 2. Metal levels in kidneys of fish from the Deception River, Crater Lake and Lake Laflamme.

ID#	Al	As	Be	Cd	Co	Cr	Cu	Fe	Hg
Crater Lake, landlocked charr*									
RF-214K	39600	-140	-88	835	529	-15400	5510	217000	85
RF-016K	-52500	-200	-140	1170	493	-23000	4360	152000	248
RF-017K	-33100	-130	-83	768	577	-14500	1970	154000	135
RF-001K	-112000	-430	-280	1720	487	-48800	5170	551000	424
RF-022K	86800	-280	-180	306	410	-31500	-1800	162000	345
RF-211K	623000	67	-44	744	767	-7630	3290	1450000	75
RF-020K	-67300	-260	-170	1070	520	-29500	1400	144000	256
RF-007K	-8870	-34	-23	1070	395	-3880	1020	148000	29
RF-004K	9030	32	-20	2540	387	-3350	2010	159000	60
RF-014K	6690	-23	-16	824	117	3780	769	93800	10
RF-023K	-9390	-36	-24	988	85	-4110	824	118000	27
RF-013K	-15000	-57	-38	2330	1140	-6540	1060	214000	108
RF-220K	17900	65	-35	2620	84	-6140	1680	231000	59
RF-217K	18500	52	-21	2590	326	-3670	2560	129000	70
RF-010K	7440	41	-11	685	687	-1820	778	225000	54
RF-019K	-10200	-39	-26	2230	285	-4440	1630	164000	74
RF-208K	19000	22	-6	1420	175	-1080	1230	147000	33
RF-222K	1710	14	-2	1070	194	-220	817	303000	138
RF-205K	1350	8	-1	1080	265	-150	777	199000	1,6
RF-003K	856	13	-1	611	132	206	831	111000	118
RF-002K	1000	23	-2	865	733	-280	765	338000	309
RF-009K	877	10	-1	433	440	-160	515	216000	122
RF-202K	1020	51	-1	885	126	278	710	418000	356
RF-006K	676	17	-1	522	127	237	658	93900	89
RF-011K	473	11	-1	418	230	166	691	111000	66
RF-213K	657	9	-1	343	197	150	588	179000	44
RF-008K	685	18	-1	999	255	174	1110	248000	98
RF-219K	946	17	-1	1040	226	145	1090	386000	227
RF-005K	1010	16	-1	655	477	-190	694	375000	75
RF-012K	840	13	-1	364	111	232	667	226000	203
RF-216K	710	14	-1	1040	283	120	827	162000	180

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 2. Metal levels in kidneys of fish from the Deception River, Crater Lake and Lake Laflamme.

ID#	Al	As	Be	Cd	Co	Cr	Cu	Fe	Hg
Deception River, charr*									
RF-320K	-68600	-260	-180	347	319	-30000	-1720	80600	163
RF-318K	66100	-140	-89	850	998	-15700	2440	177000	149
RF-323K	-18800	-71	-47	442	485	-8190	1930	116000	101
RF-310K	-5150	65	-13	194	761	-2260	1330	95200	91
RF-315K	58800	-190	-130	815	1130	-21100	2440	144000	107
RF-316K	-4800	21	-12	358	442	-2100	1160	119000	82
RF-307K	-5300	51	-14	192	312	-2320	1630	94000	71
RF-313K	-4050	17	-11	216	408	-1770	827	91700	49
RF-321K	-3800	59	-10	731	391	-1670	1425	174000	101
RF-304K	-5420	36	-14	375	442	-2380	2260	131000	176
RF-301K	-3780	28	-10	254	682	-1660	1290	105000	66
RF-303K	-3800	34	-10	675	482	-1670	1440	175000	90
RF-306K	-4040	44	-11	297	488	-1770	744	111000	219
RF-324K	-6790	28	-17	179	1030	-2980	1820	118000	96
RF-319K	-3720	17	-10	202	373	-1630	782	142000	75
RF-317K	2620	58	-4	733	475	-640	1140	254000	280
RF-322K	2430	37	-4	601	574	-600	1010	223000	294
RF-404K	-2800	-11	-7	321	210	-1230	811	111000	22
RF-410K	3960	116	-7	484	742	-1110	1470	219000	112
RF-314K	4670	42	-4	259	760	-690	1110	182000	201
RF-407K	-1640	57	-5	353	556	-720	1080	132000	161
RF-401K	-3480	38	-9	367	1100	-1520	1930	155000	12
RF-312K	3110	17	-5	279	161	-760	1400	65100	8,8
RF-413K	908	12	-2	276	245	-310	1260	123000	123
RF-309K	-660	11	-2	422	160	-290	1040	103000	112
RF-305K	-460	350	-2	167	48	-200	616	256000	37
RF-311K	-380	310	-1	242	35	-170	596	232000	41
RF-308K	-550	302	-2	200	51	-240	745	213000	43
RF-302K	497	405	-1	126	70	408	507	427000	52
RF-416K	-500	447	-2	217	42	-220	653	182000	35

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 2. Metal levels in kidneys of fish from the Deception River, Crater Lake and Lake Laflamme.

ID#	Al	As	Be	Cd	Co	Cr	Cu	Fe	Hg
Laflamme Lake, lake trout*									
RF-112K	-74200	-290	-190	710	155	-32500	-1860	48000	280
RF-118K	-1610	7	-4	1140	276	-710	896	170000	58
RF-117K	4450	17	-5	735	210	-870	771	85600	53
RF-210K	1830	9	-4	1940	385	-580	902	163000	97
RF-105K	-940	19	-3	2730	339	-410	700	216000	72
RF-124K	-600	9	-2	1120	212	-260	661	46000	2,4
RF-121K	1290	13	-2	1520	278	-260	657	112000	101
RF-207K	2540	11	-2	1460	236	-240	657	116000	65
RF-109K	932	15	-2	1480	264	-270	556	188000	142
RF-111K	751	11	-2	1040	217	-270	553	130000	103
RF-114K	1490	22	-4	4420	433	-550	778	230000	325
RF-201K	1370	11	-2	1540	172	-280	594	100000	70
RF-115K	1690	14	-3	2470	285	-400	632	122000	126
RF-103K	1940	10	-2	1460	466	-320	593	122000	78
RF-107K	1370	13	-2	2090	338	-310	543	112000	175
RF-204K	4160	9	-2	2070	316	-240	733	123000	109
RF-104K	957	9	-2	947	107	-220	629	149000	21
RF-116K	997	12	-2	1720	186	-240	719	109000	93
RF-110K	-715	14	-2	1150	198	-320	463	123000	235
RF-119K	768	12	-2	1370	374	-220	552	144000	109
RF-106K	535	17	-2	1320	261	-200	649	192000	132
RF-122K	818	13	-2	2450	293	-300	608	137000	166
RF-123K	1000	19	-2	2140	287	-290	823	134000	163
RF-102K	-490	19	-2	2100	169	-220	633	208000	166
RF-108K	573	14	-2	877	160	-230	609	78000	98
RF-120K	2360	17	-1	2020	374	382	548	192000	214
RF-113K	668	16	-2	2230	164	-290	478	188000	332
RF-024K	1140	32	-2	2570	221	-240	759	493000	525
RF-018K	2230	88	-1	3540	1100	-170	971	253000	128
RF-015K	1320	20	-2	760	638	-200	738	222000	309
RF-021K	1040	19	-1	3170	643	202	626	111000	317

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 2. Metal levels in kidneys of fish from the Deception River, Crater Lake and Lake Laflamme.

ID#	Ni	Pb	V	Zn
Crater Lake, landlocked charr*				
RF-214K	-880	114	-160	47000
RF-016K	152	404	-230	264000
RF-017K	-830	202	-150	39100
RF-001K	-2790	-280	-480	33800
RF-022K	-1800	-180	-310	25300
RF-211K	1640	517	1400	38200
RF-020K	-1680	-170	-290	32300
RF-007K	642	94	-38	24800
RF-004K	903	322	73	31700
RF-014K	376	162	51	23000
RF-023K	386	148	-40	24700
RF-013K	394	263	73	38300
RF-220K	620	175	-60	52400
RF-217K	1020	560	84	36300
RF-010K	1250	543	120	26300
RF-019K	954	481	61	45500
RF-208K	798	372	41	28500
RF-222K	519	533	5	24600
RF-205K	323	205	3	18900
RF-003K	444	573	6	20000
RF-002K	718	1030	7	18500
RF-009K	225	181	5	15400
RF-202K	567	843	41	22200
RF-006K	240	341	4	14000
RF-011K	187	239	2	13400
RF-213K	229	222	3	14300
RF-008K	487	384	4	20100
RF-219K	299	879	4	13100
RF-005K	372	701	9	17000
RF-012K	407	413	3	12700
RF-216K	360	1110	5	11200

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 2. Metal levels in kidneys of fish from the Deception River, Crater Lake and Lake Laflamme.

ID#	Ni	Pb	V	Zn
Deception River, charr*				
RF-320K	-1710	1580	-300	29800
RF-318K	2420	280	-160	53000
RF-323K	1020	-47	-81	34300
RF-310K	723	-13	-23	34500
RF-315K	1340	-120	-210	42800
RF-316K	557	-12	-21	29800
RF-307K	614	54	25	24100
RF-313K	452	-11	-18	24900
RF-321K	1690	-10	41	36000
RF-304K	483	-14	28	35400
RF-301K	781	10	-17	37900
RF-303K	2010	-10	31	36700
RF-306K	948	47	39	23100
RF-324K	550	-17	-30	36200
RF-319K	527	-10	-16	27700
RF-317K	1070	-4	58	36200
RF-322K	1080	5	28	32700
RF-404K	581	-7	-12	16500
RF-410K	1430	-7	82	47100
RF-314K	852	-4	40	26700
RF-407K	810	-5	15	29300
RF-401K	1270	14	19	33000
RF-312K	543	-5	54	18600
RF-413K	1470	5	43	17200
RF-309K	1340	7	13	33500
RF-305K	347	6	38	17800
RF-311K	344	4	30	12900
RF-308K	402	2	53	16900
RF-302K	282	2	160	26300
RF-416K	272	3	18	14900

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 2. Metal levels in kidneys of fish from the Deception River, Crater Lake and Lake Laflamme.

ID#	Ni	Pb	V	Zn
Laflamme Lake, lake trout*				
RF-112K	-1860	-190	-320	25400
RF-118K	411	12	14	20700
RF-117K	181	8	9	19200
RF-210K	610	25	15	22500
RF-105K	482	22	32	21900
RF-124K	240	-2	3	15300
RF-121K	597	48	10	16300
RF-207K	390	23	11	17300
RF-109K	343	25	7	26300
RF-111K	258	21	10	16500
RF-114K	1240	85	22	26300
RF-201K	466	20	7	22000
RF-115K	580	51	9	18200
RF-103K	447	22	8	14500
RF-107K	407	28	10	15800
RF-204K	834	24	13	19400
RF-104K	340	17	4	15600
RF-116K	442	31	9	14700
RF-110K	238	21	8	16200
RF-119K	284	14	8	21400
RF-106K	386	21	11	24200
RF-122K	840	30	14	19300
RF-123K	543	29	25	34200
RF-102K	723	30	12	20100
RF-108K	250	20	8	26700
RF-120K	912	38	22	13700
RF-113K	905	71	9	23200
RF-024K	1300	113	29	27200
RF-018K	1770	23	120	22400
RF-015K	1090	61	22	16900
RF-021K	1700	36	8	27100

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 3. Metal levels in liver of fish from the Deception River, Crater Lake and Lake Laflamme.

ID #	Al	As	Be	Cd	Co	Cr	Cu	Fe	Hg
Crater Lake, landlocked charr*									
RF-214L	-13300	-50	-33	447	292	-5790	5500	46300	44
RF-016L	35200	-68	-45	560	273	-7850	9980	408000	113
RF-017L	68610	-64	-42	450	340	-7320	6450	283000	91
RF-001L	-35900	-140	-90	526	523	-15700	6280	312000	162
RF-022L	22200	-66	-44	296	260	-7570	3760	292000	122
RF-211L	-11300	-43	-29	564	210	-4940	7370	247000	61
RF-020L	60800	-66	-44	675	417	-7640	6230	627000	130
RF-007L	19300	-35	-23	690	220	-4040	3080	600000	77
RF-004L	15200	-20	-13	717	139	-2260	5670	204000	36
RF-014L	34400	-42	-28	753	96	-4820	7060	487000	41
RF-023L	16200	-20	-13	597	131	19400	7270	179000	21
RF-013L	20700	-21	-14	571	362	-2320	7520	493000	45
RF-220L	-3300	35	-9	1800	44	-1430	15000	97000	12
RF-217L	18880	-17	-11	1040	165	-1990	11300	340000	49
RF-010L	30500	-12	-8	773	302	-1360	5240	563000	45
RF-019L	14200	-12	-8	647	61	-1320	4430	230000	34
RF-208L	9000	6	-3	919	218	-520	5660	67400	47
RF-222L	1790	6	-1	689	43	-150	2690	525000	82
RF-205L	752	8	-1	515	118	-170	4490	248000	2,1
RF-003L	637	9	-2	375	104	-200	1420	351000	93
RF-002L	2310	7	-1	1600	331	-170	11000	1140000	131
RF-009L	1280	12	-1	600	141	290	5480	347000	78
RF-202L	1540	7	-1	792	44	114	3340	863000	159
RF-006L	1190	18	-1	214	58	201	742	89800	48
RF-011L	1100	10	-1	474	93	304	5600	417000	93
RF-213L	3410	12	-1	334	109	104	4370	370000	54
RF-008L	420	16	-1	344	102	177	7410	334000	69
RF-219L	496	7	-1	361	60	131	923	35200	11
RF-005L	1040	7	-1	1920	194	-180	10200	1036000	166
RF-012L	2190	4	-1	254	31	264	755	23200	164

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 3. Metal levels in liver of fish from the Deception River, Crater Lake and Lake Laflamme.

ID #	Al	As	Be	Cd	Co	Cr	Cu	Fe	Hg
Deception River, charr*									
RF-320L	-22100	-84	-56	448	290	-9680	6310	431000	130
RF-318L	-13600	-52	-34	413	594	-5930	17700	447000	227
RF-323L	-3300	-13	-9	121	340	-1450	2630	75700	80
RF-310L	-4300	85	-11	176	468	-1880	6730	108000	88
RF-315L	12400	-28	-19	307	636	-3180	6030	175000	30
RF-316L	-5080	54	-13	173	256	-2230	9110	173000	71
RF-307L	-2840	16	-8	96	199	-1240	4450	176000	78
RF-313L	-4280	23	-11	138	336	-1880	5170	99300	87
RF-321L	-7700	-30	-20	311	289	-3370	16500	492000	64
RF-304L	3380	20	-8	136	212	-1370	6840	87500	185
RF-301L	-2910	17	-8	170	394	-1270	4170	231000	77
RF-303L	8780	-15	-10	370	331	-1670	10000	417000	286
RF-306L	-3870	-15	-10	238	359	-1700	2810	222000	259
RF-324L	-3550	25	-9	88	635	-1560	4760	244000	96
RF-319L	-3110	19	-8	130	220	-1360	4150	91400	103
RF-317L	-1920	15	-5	347	396	-840	4910	650000	271
RF-322L	-1580	18	-4	179	318	-690	5700	272000	174
RF-404L	-2450	-10	-7	234	182	-1070	3010	141000	89
RF-410L	10900	24	-9	324	550	-1450	7540	1280000	641
RF-314L	3330	13	-5	201	479	-730	9890	362000	163
RF-407L	8720	20	-7	184	490	-1100	5420	412000	191
RF-401L	-2020	14	-5	232	496	-890	7740	231000	165
RF-312L	-600	7	-2	118	144	-260	4090	178000	30
RF-413L	1670	5	-2	122	141	-220	2850	156000	62
RF-309L	-4200	-16	-11	210	86	-1830	4720	214000	14
RF-305L	-340	329	-1	75	57	-150	2720	244000	18
RF-311L	-400	395	-1	80	32	-180	812	192000	17
RF-308L	373	345	-1	114	24	-160	2970	103000	24
RF-302L	-260	667	-1	108	51	-120	2410	461000	12
RF-416L	1160	373	-1	60	28	-150	1150	189000	19

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 3. Metal levels in liver of fish from the Deception River, Crater Lake and Lake Laflamme.

ID #	Al	As	Be	Cd	Co	Cr	Cu	Fe	Hg
Laflame Lake, lake trout*									
RF-112L	-32000	-130	-80	299	183	-14000	3320	179000	160
RF-118L	2050	4	-3	488	178	-480	4230	207000	58
RF-117L	4790	11	-5	393	146	-770	4380	497000	50
RF-210L	5250	12	-4	884	330	398	8580	365000	80
RF-105L	8500	17	-4	935	273	-620	4550	1130000	69
RF-124L	-1100	7	-3	576	135	-480	6570	387000	53
RF-121L	2150	4	-2	489	165	-250	2410	250000	2,5
RF-207L	3940	5	-2	620	135	-350	4900	273000	34
RF-109L	7630	10	-3	692	195	-520	4400	571000	107
RF-111L	3340	10	-2	519	235	-350	4230	412000	92
RF-114L	3780	7	-2	1750	242	-260	2960	596000	90
RF-201L	2740	5	-2	900	217	269	4070	436000	56
RF-115L	2030	6	-2	709	181	-190	2420	482000	48
RF-103L	4590	5	-2	880	397	360	2060	433000	69
RF-107L	2530	5	-2	712	220	-290	1250	405000	32
RF-204L	2890	6	-2	1130	215	291	7570	558000	52
RF-104L	2730	6	-2	695	104	-280	2190	250000	36
RF-116L	6060	6	-2	961	161	-290	4060	480000	56
RF-110L	1760	10	-2	954	195	-290	2220	768000	168
RF-119L	2560	9	-2	483	240	-320	3880	370000	104
RF-106L	3870	9	-3	720	188	-370	4570	572000	116
RF-123L	2050	6	-2	717	238	-310	3340	493000	97
RF-102L	2660	11	-2	947	130	-320	7170	609000	146
RF-108L	2190	9	-2	400	107	-300	3130	247000	110
RF-120L	2930	9	-2	1390	434	304	3170	983000	165
RF-113L	2560	11	-2	1880	147	-200	3070	797000	160
RF-024L	1660	14	-2	1860	152	-220	18400	1250000	174
RF-018L	3280	36	-2	1790	861	-210	11300	1490000	34
RF-015L	2630	16	-1	619	354	192	8070	772000	121
RF-021L	1940	11	-1	1490	639	197	7450	946000	172

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 3. Metal levels in liver of fish from the Deception River, Crater Lake and Lake Laflamme.

ID #	Ni	Pb	V	Zn
Crater Lake, landlocked charr*				
RF-214L	-330	-33	-57	43800
RF-016L	-450	-45	-77	31100
RF-017L	-420	269	-72	33200
RF-001L	-900	-90	-160	27200
RF-022L	-440	-44	-75	26400
RF-211L	-290	73	78	43800
RF-020L	-440	45	120	47400
RF-007L	-230	24	-40	28200
RF-004L	-130	-13	25	34400
RF-014L	-280	-28	-47	33100
RF-023L	-130	31	-22	26500
RF-013L	-140	69	49	29800
RF-220L	-82	-9	-14	40800
RF-217L	65	97	27	36600
RF-010L	-78	42	69	34400
RF-019L	-75	47	13	32500
RF-208L	55	21	20	29600
RF-222L	66	45	4	16000
RF-205L	96	16	2	21300
RF-003L	69	31	4	21400
RF-002L	164	77	11	22500
RF-009L	101	30	5	23700
RF-202L	89	86	5	19200
RF-006L	50	22	4	15200
RF-011L	87	37	3	20700
RF-213L	103	24	5	19500
RF-008L	116	23	3	24300
RF-219L	43	46	3	13500
RF-005L	137	88	6	21200
RF-012L	66	33	2	12100
RF-216L	76	59	6	15100

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 3. Metal levels in liver of fish from the Deception River, Crater Lake and Lake Laflamme.

ID #	Ni	Pb	V	Zn
Deception River, charr*				
RF-320L	564	-56	-95	46800
RF-318L	770	-34	-58	53000
RF-323L	173	-9	-15	29100
RF-310L	299	-11	-19	32800
RF-315L	330	-19	-32	38300
RF-316L	-130	-13	-22	39200
RF-307L	147	-8	-12	26400
RF-313L	186	-11	-19	34200
RF-321L	485	-20	35	42300
RF-304L	93	78	-14	35400
RF-301L	203	-8	-13	35600
RF-303L	339	-10	19	36800
RF-306L	266	12	43	31400
RF-324L	209	-9	-16	39500
RF-319L	108	-8	-14	36700
RF-317L	213	-5	38	33900
RF-322L	148	-4	15	33800
RF-404L	205	-7	-11	35500
RF-410L	298	9	99	51600
RF-314L	126	-5	17	38300
RF-407L	225	15	15	44300
RF-401L	247	-5	10	41300
RF-312L	197	-2	23	33600
RF-413L	275	2	30	22100
RF-309L	333	-11	-18	30100
RF-305L	102	6	16	28300
RF-311L	118	3	12	24300
RF-308L	74	5	12	26600
RF-302L	83	3	88	24700
RF-416L	112	3	8	18600

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 3. Metal levels in liver of fish from the Deception River, Crater Lake and Lake Laflamme.

ID #	Ni	Pb	V	Zn
Laflame Lake, lake trout*				
RF-112L	-800	-80	-140	45200
RF-118L	57	4	-5	24600
RF-117L	-44	-5	12	38700
RF-210L	108	8	15	28400
RF-105L	73	18	79	28900
RF-124L	50	4	-5	34700
RF-121L	51	2	5	19100
RF-207L	77	4	9	23800
RF-109L	106	7	14	42500
RF-111L	69	12	16	42100
RF-114L	126	27	20	31100
RF-201L	54	9	7	21500
RF-115L	71	13	8	20200
RF-103L	172	17	13	21200
RF-107L	43	11	8	29800
RF-204L	106	11	13	24300
RF-104L	167	11	4	25200
RF-116L	48	11	11	26000
RF-110L	43	16	16	46300
RF-119L	77	4	9	53900
RF-106L	64	10	17	40900
RF-123L	46	6	15	34500
RF-102L	91	8	11	40900
RF-108L	51	6	7	42900
RF-120L	159	23	33	20700
RF-113L	69	22	13	48500
RF-024L	91	26	39	47900
RF-018L	78	62	200	21200
RF-015L	126	19	36	18700
RF-021L	264	12	11	24900

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 4. Metal levels in muscle tissues of fish from the Deception River, Crater Lake and Lake Laflamme.

ID #	Al	As	Be	Cd	Co	Cr	Cu	Fe	Hg
Crater Lake, landlocked charr*									
RF-214M2	9180	-18	-11	54	52	-1990	1100	27500	27
RF-016M2	-1650	15	-5	8,5	55	-730	466	6310	9,7
RF-017M2	-1840	12	-5	2,2	38	-810	281	4880	12
RF-001M2	-1990	-8	-5	6	8	-870	381	6500	14
RF-022M2	-1870	17	-5	3,1	55	-820	339	6850	13
RF-211M2	1660	9	-5	8,5	15,8	-960	582	4760	1,8
RF-020M2	12500	11	-5	3,2	46	-860	310	8710	7,3
RF-007M2	-1230	6	-4	4,2	26	-540	416	8310	5,8
RF-004M2	-1190	5	-3	4,7	22	-520	362	6060	6,1
RF-014M2	-1500	6	-4	3	10	-660	250	4310	72
RF-023M2	5050	-10	-7	4,8	9	-1090	250	5680	6,8
RF-013M2	-1870	9	-5	4	45	-820	296	8140	14
RF-220M2	6470	10	-3	6	7,5	-410	301	7710	4,5
RF-217M2	7030	-10	-7	37	29	-1140	1110	25800	23
RF-010M2	-1270	6	-4	3,9	42	-560	195	4650	6,4
RF-019M2	-830	5	-3	2,9	10	475	249	4280	2,5
RF-208M2	5450	6	-2	2,2	10	-270	307	3550	1,4
RF-222M2	5400	6	-2	3,2	11	-270	389	5950	6
RF-205M2	657	4	-1	1,5	8,1	-170	331	3260	106
RF-003M2	-370	5	-1	1,7	7,9	-160	221	2850	56
RF-002M2	524	4	-1	5,8	8,4	-150	216	5620	78
RF-009M2	781	9	-1	2,4	10	-160	409	4790	21
RF-202M2	1470	5	-1	2,9	5,8	-140	329	6260	5,4
RF-006M2	578	15	-1	1,6	10	158	353	3670	29
RF-011M2	1020	9	-1	5,8	10	215	647	6810	20
RF-213M2	803	6	-1	2,9	7,7	111	330	3850	2,1
RF-008M2	1050	6	-2	1,7	11	-190	433	5110	40
RF-219M2	429	6	-1	11	7,6	207	352	5500	42
RF-005M2	747	5	-1	4,9	8,2	-170	321	6170	17
RF-012M2	966	11	-1	1,4	4,3	274	455	4840	28
RF-216M2	1560	3	-1	1,9	4,7	-180	198	3750	1,5

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 4. Metal levels in muscle tissues of fish from the Deception River, Crater Lake and Lake Laflamme.

ID #	Al	As	Be	Cd	Co	Cr	Cu	Fe	Hg
Deception River, charr*									
RF-320M2	-3220	-13	-8	6,6	44	-1410	484	5940	30
RF-318M2	-2810	-11	-7	4,6	62	-1230	481	8050	15
RF-323M2	-1590	9	-4	2,7	53	-700	532	5820	36
RF-310M2	2770	11	-3	2,2	110	-420	549	4840	58
RF-315M2	2360	6	-4	2	96	-660	349	3950	7,3
RF-316M2	7940	8	-5	1,9	69	-830	398	4030	76
RF-307M2	1850	12	-4	2	52	-680	476	4950	78
RF-313M2	-1080	12	-3	2,6	63	-470	429	4070	66
RF-321M2	-2510	25	-7	3,1	24	-1100	454	8550	35
RF-304M2	-790	14	-2	2,1	37	-350	445	3770	30
RF-301M2	1380	12	-3	3,2	81	-410	441	4300	27
RF-303M2	-1130	11	-3	3	46	-500	470	7700	75
RF-306M2	-1120	9	-3	2,9	51	-490	422	6640	60
RF-324M2	-840	8	-3	1,5	86	-370	459	4420	28
RF-319M2	-1090	7	-3	1	38	-480	377	2750	3,7
RF-317M2	1670	9	-3	1,4	35	-520	453	5790	28
RF-322M2	-1050	9	-3	1,6	68	-460	323	3650	102
RF-404M2	799	5	-2	3,6	21	-230	457	5870	47
RF-410M2	3230	14	-3	5,3	39	-430	373	7740	108
RF-314M2	2140	13	-2	2,8	74	-280	707	8630	78
RF-407M2	-760	8	-2	1,3	34	-340	368	4250	74
RF-401M2	1030	8	-2	1,7	49	-310	439	5720	70
RF-312M2	-530	6	-2	0,7	11	-230	400	3240	22
RF-413M2	1200	5	-2	2	23	-210	341	4760	42
RF-309M2	-460	3	-2	0,8	9,6	-210	309	3500	21
RF-305M2	-510	622	-2	0,9	4,8	-230	417	3950	14
RF-311M2	536	646	-2	3	8	-200	421	4780	13
RF-308M2	1050	427	-1	0,9	5,1	-180	382	3360	20
RF-302M2	412	311	-1	0,7	4,4	-170	342	3220	9,4
RF-416M2	531	742	-2	2,9	6	-200	396	4500	17

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 4. Metal levels in muscle tissues of fish from the Deception River, Crater Lake and Lake Laflamme.

ID #	Al	As	Be	Cd	Co	Cr	Cu	Fe	Hg
Laflame Lake, lake trout*									
RF-112M2	-1740	3	-5	9	20	-770	363	5160	32
RF-118M2	710	6	-2	2,5	14	-270	269	3440	28
RF-117M2	-590	7	-2	2,8	18	-260	207	5450	32
RF-210M2	3990	5	-2	2,3	21	398	300	4370	8,7
RF-105M2	825	5	-2	109	30	-260	639	32600	62
RF-124M2	4400	16	-1	3,5	7	114	242	6850	29
RF-121M2	2170	8	-1	21	14	-180	204	4020	5
RF-207M2	1260	8	-1	2,9	11	201	242	3150	1,2
RF-109M2	-450	16	-2	2,7	13	-200	210	3140	106
RF-111M2	523	9	-2	1,9	18	-220	202	2810	70
RF-114M2	2110	16	-2	4,7	19	-210	131	4210	40
RF-201M2	1090	7	-2	4,2	11	228	213	4200	1,9
RF-115M2	1990	10	-1	2,8	10	-180	195	3490	6,8
RF-103M2	2190	7	-2	3	18	295	231	3470	2,5
RF-107M2	987	12	-2	2,1	17	-210	192	3490	10
RF-204M2	1830	8	-2	6,1	21	-190	253	6110	5,1
RF-104M2	-410	8	-1	5,7	9	181	264	4390	54
RF-116M2	2360	8	-2	2,4	7,3	-200	224	2730	5,1
RF-110M2	-470	17	-2	3,1	14	-210	214	4050	184
RF-119M2	-510	10	-2	2,2	20	-230	224	2730	119
RF-106M2	845	13	-1	2,6	11	-180	193	2930	97
RF-122M2	662	8	-1	3,1	13	-170	166	3100	14
RF-123M2	461	12	-2	2,9	14	-200	215	3330	97
RF-102M2	2350	13	-2	3,1	10	-220	169	2840	128
RF-108M2	1340	10	-2	1,8	11	-250	143	2340	96
RF-120M2	476	12	-1	2,4	18	215	190	4060	128
RF-113M2	-460	17	-2	2,7	9,2	-200	151	2710	141
RF-024M2	-460	22	-2	3,2	11	-210	174	3440	174
RF-018M2	407	14	-1	5	85	190	355	6660	20
RF-015M2	-325	18	-1	3	37	177	338	5500	55
RF-021M2	670	20	-2	3,1	27	239	183	2420	120

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 4. Metal levels in muscle tissues of fish from the Deception River, Crater Lake and Lake Laflamme.

ID #	Ni	Pb	V	Zn
Crater Lake, landlocked charr*				
RF-214M2	-120	50	28	14700
RF-016M2	-42	30	-7	9930
RF-017M2	-46	7	-8	10500
RF-001M2	18	20	-9	9890
RF-022M2	71	30	-8	11500
RF-211M2	-54	14	-9	12800
RF-020M2	55	90	-8	10200
RF-007M2	-31	23	-5	9130
RF-004M2	-30	7	5	10900
RF-014M2	-38	-4	-6	11500
RF-023M2	-62	42	-11	15400
RF-013M2	-57	23	-8	9980
RF-220M2	73	33	4	12100
RF-217M2	5	82	-11	28300
RF-010M2	-32	-4	-5	12800
RF-019M2	-21	6	-4	11800
RF-208M2	20	20	5	7380
RF-222M2	28	8	-3	5140
RF-205M2	15	5	-2	4450
RF-003M2	26	-1	-2	3150
RF-002M2	16	5	2	5690
RF-009M2	28	18	4	6810
RF-202M2	26	3	2	6530
RF-006M2	17	3	-1	3690
RF-011M2	28	12	1	4230
RF-213M2	10	9	1	3420
RF-008M2	26	-2	2	6990
RF-219M2	20	12	1	3610
RF-005M2	50	4	-2	6070
RF-012M2	21	3	1	3150
RF-216M2	-10	4	-2	3050

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 4. Metal levels in muscle tissues of fish from the Deception River, Crater Lake and Lake Laflamme.

ID #	Ni	Pb	V	Zn
Deception River, charr*				
RF-320M2	175	24	-14	18100
RF-318M2	121	286	-12	19500
RF-323M2	66	124	-7	20900
RF-310M2	66	17	-4	16400
RF-315M2	74	113	-6	10300
RF-316M2	58	-5	-8	10400
RF-307M2	110	101	-7	9030
RF-313M2	39	8	-5	14000
RF-321M2	74	136	-11	15700
RF-304M2	-20	5	-3	18800
RF-301M2	68	29	-4	12300
RF-303M2	75	112	-5	23200
RF-306M2	55	84	-5	13700
RF-324M2	50	93	-4	13200
RF-319M2	29	8	-5	9310
RF-317M2	36	4	-5	21300
RF-322M2	-27	6	-5	21500
RF-404M2	47	11	-2	10300
RF-410M2	48	61	-4	19300
RF-314M2	55	31	4	18500
RF-407M2	28	-2	-3	13800
RF-401M2	39	4	-3	13200
RF-312M2	34	3	-2	8540
RF-413M2	64	8	-2	8190
RF-309M2	56	-2	-2	9930
RF-305M2	45	42	3	6300
RF-311M2	48	112	4	7720
RF-308M2	25	58	-2	4550
RF-302M2	26	22	3	3950
RF-416M2	37	19	3	6290

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 4. Metal levels in muscle tissues of fish from the Deception River, Crater Lake and Lake Laflamme.

ID #	Ni	Pb	V	Zn
Laflame Lake, lake trout*				
RF-112M2	17	9	-8	9730
RF-118M2	22	4	-3	5070
RF-117M2	25	11	3	8260
RF-210M2	38	14	5	4350
RF-105M2	21	4	3	5700
RF-124M2	29	13	4	10100
RF-121M2	16	-1	-2	3540
RF-207M2	23	3	3	6360
RF-109M2	19	15	-2	4770
RF-111M2	17	4	-2	4900
RF-114M2	22	-2	-2	6730
RF-201M2	19	3	-2	6140
RF-115M2	14	2	-2	4380
RF-103M2	33	2	-2	4690
RF-107M2	22	-2	-2	4050
RF-204M2	28	7	-2	5500
RF-104M2	12	1	4	4420
RF-116M2	20	13	-2	3530
RF-110M2	29	21	3	5520
RF-119M2	16	-2	-2	4990
RF-106M2	23	9	2	4370
RF-122M2	13	3	-2	4240
RF-123M2	18	13	3	5100
RF-102M2	24	60	3	4120
RF-108M2	19	9	-2	4750
RF-120M2	49	16	-2	3250
RF-113M2	-12	5	-2	3570
RF-024M2	28	20	3	4390
RF-018M2	19	2	4	4780
RF-015M2	35	4	2	3430
RF-021M2	21	2	-2	3630

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 5. Metal levels in blue mussels collected from three different beds of Deception Bay.

ID #	Al	As	Be	Cd	Co	Cr	Cu	Fe	Hg
Decbay-3 station*									
RB-001M1	4020	2000	-3	362	79	-390	703	20000	16
RB-001M2	4910	1990	-2	222	93	-350	863	26800	11
RB-001M3	12300	1830	-3	326	95	-420	802	37500	15
RB-001M4	9210	1560	-3	376	83	-390	791	30600	15
RB-001M5	9250	1970	-2	205	81	-300	824	31400	13
RB-001M6	28000	2580	-3	563	134	922	1040	79400	16
RB-001M7	20300	2410	-3	395	111	-500	1020	61300	18
RB-001M8	4030	1610	-2	319	71	-270	945	22200	12
RB-001M9	9120	1800	-2	226	78	-300	877	40100	13
RB-001M10	27300	2100	-4	359	118	-560	1020	90500	16
RB-001M11	9100	1930	-3	329	85	-370	849	29400	14
RB-001M12	3400	1710	-3	243	92	-390	791	23800	13
RB-001M13	4600	1900	-2	361	92	-360	866	27000	12
RB-001M14	6170	2020	-3	389	86	-410	959	35400	16
RB-001M15	2610	2130	-2	240	67	-280	780	19800	15
RB-001M16	3860	2100	-3	315	88	-450	916	20100	15
RB-001M17	6970	1840	-3	275	113	-410	762	34700	14
RB-001M18	42700	2720	-3	577	129	-520	1240	111000	21
RB-001M19	6000	1990	-2	293	78	-220	767	24200	13
RB-001M20	4700	1670	-2	254	72	-290	749	21400	13
RB-001M21	6100	1950	-4	240	87	-540	946	28600	13
RB-001M22	4200	2230	-3	283	95	-390	867	26100	13
RB-001M23	19000	2010	-3	418	107	-510	988	53600	16
RB-001M24	14100	1900	-4	326	115	-610	885	42000	19
RB-001M25	8880	2020	-3	287	107	-490	1070	35600	19
RB-001M26	16100	2750	-5	354	116	-830	1260	63300	20
RB-001M27	9970	2060	-3	237	102	-420	1110	33000	12
RB-001M28	22500	2190	-4	285	123	-670	1100	67800	15
RB-001M29	20600	2560	-5	511	149	-770	1020	60300	8,1
RB-001M30	17000	2100	-5	389	117	-800	1110	46200	16

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 5. Metal levels in blue mussels collected from three different beds of Deception Bay.

ID #	Al	As	Be	Cd	Co	Cr	Cu	Fe	Hg
Decbay-2 station*									
RB-004M1	2420	1670	-2	257	61	-220	621	20400	12
RB-004M2	7000	2040	-2	295	93	-240	797	34800	15
RB-004M3	3430	1640	-2	151	65	-190	738	23400	11
RB-004M4	2230	2300	-1	306	61	-150	841	16100	2,7
RB-004M5	3630	1930	-2	312	81	231	766	25800	18
RB-004M6	7770	2120	-1	385	75	182	790	41000	10
RB-004M7	3480	2880	-1	340	82	221	885	34500	16
RB-004M8	6190	2410	-1	370	67	238	766	52300	18
RB-004M9	12800	2330	-1	356	84	-180	833	59000	2,1
RB-004M10	29000	2910	-2	485	112	-200	828	53400	17
RB-004M11	5130	2740	-1	254	83	217	744	34300	14
RB-004M12	3000	2440	-2	291	74	249	920	22400	13
RB-004M13	1050	1490	-1	330	45	217	322	18500	17
RB-004M14	3570	2110	-2	236	86	214	757	33400	16
RB-004M15	3100	1990	-2	319	88	-240	955	25200	14
RB-004M16	5280	2410	-1	237	78	218	672	36800	15
RB-004M17	13780	1800	-2	313	123	-220	1070	50580	17
RB-004M18	2450	873	-1	118	35	-140	309	10500	14
RB-004M19	6930	1860	-2	370	91	210	730	35100	15
RB-004M20	3110	1790	-2	232	75	-200	798	24800	12
RB-004M21	2570	2480	-2	287	85	-200	751	24500	1,3
RB-004M22	2420	2660	-1	300	71	-180	796	24000	12
RB-004M23	13400	1720	-1	360	109	-400	745	32200	23
RB-004M24	5660	2200	-2	314	85	285	927	35100	30
RB-004M25	3480	1500	-2	455	85	-220	613	33900	20
RB-004M26	3720	1730	-1	238	69	-170	596	28200	16
RB-004M27	7000	2400	-2	381	106	270	1020	36100	20
RB-004M28	5660	2270	-2	255	100	225	812	39800	20
RB-004M29	7470	2430	-1	269	83	213	570	43800	15

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 5. Metal levels in blue mussels collected from three different beds of Deception Bay.

ID #	Al	As	Be	Cd	Co	Cr	Cu	Fe	Hg
Decbay-1 station*									
RB-007M1	4550	1640	-2	377	100	-270	734	41700	20
RB-007M2	11000	1810	-2	414	124	278	782	50000	17
RB-007M3	4680	2690	-2	259	110	-210	836	39100	17
RB-007M4	2610	1840	-2	314	94	-270	811	20900	16
RB-007M5	3900	1450	-1	275	74	172	531	33100	12
RB-007M6	4230	1950	-2	252	112	211	863	33500	17
RB-007M7	2700	1830	-2	369	105	-220	812	32200	18
RB-007M8	7370	3620	-2	711	152	436	1030	120000	19
RB-007M9	7480	1990	-2	365	146	-330	894	47200	31
RB-007M10	3260	1950	-2	297	111	-220	821	31900	185
RB-007M11	7790	1680	-2	369	111	243	737	44900	27
RB-007M12	4030	2500	-2	235	100	-250	842	35700	21
RB-007M13	11000	1800	-2	284	119	280	992	50600	19
RB-007M14	9200	2180	-2	287	121	241	1090	54200	15
RB-007M15	5220	2100	-2	468	103	-200	768	43600	6,3
RB-007M16	13900	1720	-2	276	125	298	800	72100	22
RB-007M17	6420	1750	-2	271	126	228	830	39200	0
RB-007M18	2580	1830	-1	377	37	271	275	18200	14
RB-007M19	11800	2890	-2	406	130	252	1020	58800	18
RB-007M20	2520	1740	-1	297	71	-150	840	23500	11
RB-007M21	9210	3200	-2	467	92	240	1120	42700	25
RB-007M22	10900	2000	-2	542	160	291	872	65400	156
RB-007M23	6420	1870	-1	299	69	-180	599	28100	16
RB-007M24	4000	3410	-1	484	93	262	864	39500	0
RB-007M25	5190	1930	-1	381	66	224	803	31900	15
RB-007M26	5980	1640	-1	253	74	245	628	50700	20
RB-007M27	3510	1100	-1	140	48	-190	430	14700	25
RB-007M28	5220	2200	-2	267	123	240	800	35400	20
RB-007M29	8400	1980	-2	376	125	285	1120	44200	22
RB-007M30	5760	641	-2	144	34	-190	235	15100	13

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 5. Metal levels in blue mussels collected from three different beds of Deception Bay.

ID #	Ni	Pb	V	Zn
Decbay-3 station*				
RB-001M1	389	44	66	10500
RB-001M2	499	34	74	9410
RB-001M3	418	39	100	12400
RB-001M4	342	40	86	7100
RB-001M5	357	61	92	9840
RB-001M6	628	53	190	14600
RB-001M7	482	53	150	7870
RB-001M8	396	38	53	9470
RB-001M9	383	40	97	9160
RB-001M10	470	59	150	12800
RB-001M11	353	41	82	11800
RB-001M12	436	45	70	10900
RB-001M13	415	45	71	10900
RB-001M14	416	70	110	11500
RB-001M15	220	58	59	12500
RB-001M16	418	55	77	10400
RB-001M17	561	48	80	10600
RB-001M18	564	72	250	12800
RB-001M19	356	56	71	8810
RB-001M20	288	35	71	9730
RB-001M21	442	38	73	13700
RB-001M22	410	44	65	12300
RB-001M23	448	48	130	12200
RB-001M24	588	53	100	14800
RB-001M25	454	45	100	14600
RB-001M26	500	52	120	17000
RB-001M27	507	42	91	10000
RB-001M28	566	63	170	9100
RB-001M29	755	41	140	11400
RB-001M30	497	65	140	9900

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 5. Metal levels in blue mussels collected from three different beds of Deception Bay.

ID #	Ni	Pb	V	Zn
Decbay-2 station*				
RB-004M1	235	27	71	5780
RB-004M2	439	56	110	7860
RB-004M3	289	21	50	5650
RB-004M4	239	32	51	7570
RB-004M5	370	52	97	7670
RB-004M6	316	30	85	6140
RB-004M7	380	65	81	5810
RB-004M8	279	94	83	8980
RB-004M9	300	43	110	8980
RB-004M10	490	84	130	9180
RB-004M11	351	46	82	6870
RB-004M12	298	33	67	7030
RB-004M13	155	51	46	5040
RB-004M14	300	44	74	8930
RB-004M15	419	34	72	10100
RB-004M16	319	54	80	5480
RB-004M17	406	47	130	8660
RB-004M18	166	16	31	4150
RB-004M19	391	35	75	6300
RB-004M20	321	36	69	10400
RB-004M21	359	24	66	9160
RB-004M22	301	40	65	8080
RB-004M23	349	58	96	23800
RB-004M24	374	57	77	9400
RB-004M25	442	75	79	5190
RB-004M26	235	40	52	5700
RB-004M27	506	52	130	7540
RB-004M28	470	70	110	6670
RB-004M29	362	41	93	10500

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.

Annex 5. Metal levels in blue mussels collected from three different beds of Deception Bay.

ID #	Ni	Pb	V	Zn
Decbay-1 station*				
RB-007M1	417	91	86	14100
RB-007M2	479	74	120	9040
RB-007M3	310	114	77	9380
RB-007M4	304	59	58	9460
RB-007M5	278	63	64	5680
RB-007M6	390	55	84	18700
RB-007M7	379	80	92	8690
RB-007M8	442	144	280	14300
RB-007M9	642	96	110	6270
RB-007M10	338	91	74	9390
RB-007M11	490	109	78	8380
RB-007M12	491	100	81	7860
RB-007M13	468	54	110	9280
RB-007M14	428	65	110	17900
RB-007M15	461	116	95	7530
RB-007M16	636	89	140	6630
RB-007M17	436	71	96	7060
RB-007M18	131	67	51	4500
RB-007M19	503	77	130	10200
RB-007M20	261	63	62	6850
RB-007M21	433	52	110	11700
RB-007M22	488	199	120	7310
RB-007M23	375	53	91	5860
RB-007M24	333	101	91	6690
RB-007M25	326	72	77	7200
RB-007M26	267	104	85	4840
RB-007M27	276	18	46	4470
RB-007M28	435	68	77	13100
RB-007M29	481	86	110	17200
RB-007M30	192	26	39	2500

*Trace element values are in parts per billion. Negative values equal not detected at that lower limit.