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Veladero Mine Lixiviant Spill, Argentina: Replies to Federal Judge Casanello Regarding His Questions and Related Comments.

[All references to page numbers refer to electronic page numbers, unless otherwise noted.]

Summary.
1-Because of the isolated location of the mine and company-controlled access to the property, essentially all of the first-hand information and technical data relating to the 12-13 Sept. 2015 spill events and for several days and weeks after the spill were provided only by MAGSA. Much of the information most central to interpreting the details surrounding the "spill" have *not been made public*. [e.g. performance of the MAGSA personnel; early impacts to personnel and the environment; actual detailed chemical composition of the liquids spilled; detailed field measurements for pH, specific conductance, etc.; photos (also air photos, satellite images, etc.)].

2-Several other organizations conducted post-spill studies to evaluate the spill and its impacts, but many are quite limited, sometimes technically-flawed, and one of the most extensive, the final UNOPS study, has not be made public, more than six months after the spill.

3- Almost all Veladero project-area surface and ground waters are supplied by the melting of glaciers at higher elevations (some of which are not visible as snow and ice as they are covered by rock and dust—rock glaciers). These glacial melt-waters also control the locations and existence of the local wetlands – the vegas. The movement of past and present glaciers have carved the valleys that contain the Veladero facilities, filling the valleys with glacial and periglacial sediments—in places more than 100 meters thick. These sediments are extremely permeable, transporting significant volumes of ground water, given the arid nature of this region.

4- The Rio Potrerillos--Rio de las Taguas drainages flow in these valleys filled with periglacial sediments, and are impacted by MAGSA Veladero activities, which reduce the quantity of water available for downstream users, and degrade downstream surface and ground water quality.

5-The Rio Potrerillos--Rio de las Taguas drainages flow downstream (with differing names) flowing across the borders of several Argentine provinces.

6-Veladero Mine waste rock and leaching (lixiviation) facilities sit on top of the periglacial deposits, and drainage from the other operational facilities migrate toward these periglacial deposits. These periglacial sediments are extremely permeable, and are mapped in the MAGSA EIA / IIA as glacial moraines (Knight Piésold Planos 2.5, 5.0, 5.3).

7-The engineering changes made by Barrick / MAGSA in response to the September 2015 spill appear to be adequate to improve the chances *that future, **acute** spills are less likely*. [Although some of the changes are underground, thus hidden from view.]

MAGSA has incurred significant economic costs and damage to its corporate image, thus has every incentive to construct the appropriate engineering changes to minimize future impacts to water resources. However, it is the **chronic**, slow, semi-invisible, long-term releases of contaminants to the environment that will continue to occur.

8-The technical information and data MAGSA is providing (and has provided) to the general public and regulators are **not** adequate to inform them of the actual impacts that have occurred (and are occurring) to the ground and surface waters. **It is important to reiterate that all of these waters develop from the melting of the local glaciers (glacial melt-waters). Also, all of the waste rock and the leaching facilities are located on top of permeable, periglacial sediments.**

9-Increased competition for water*.* MAGSA information indicates that the mine operations use roughly 70 percent of the 110 liters per second allowed in their permits, which equals roughly *6,652,800 liters per day*. Much of the water used for routine mine operations is lost from the local water system (e.g. via evaporation, etc.), leaving less available for downstream users. Once used in Veladero operations, much of this water has degraded water quality, when compared to pre-operational conditions, thus long-term, may no longer be suitable for certain downstream uses without some form of water treatment.

10-Despite being in operation for roughly 10+ years, MAGSA has failed to make public a credible "water balance", which would quantify the actual incoming volumes of water used and those lost via various other pathways.

11-The spill water released during September 2015 contained many potentially-toxic chemical components *in addition to numerous forms of cyanide*, many of which have not been reported in publicly-available documents. These likely include significant concentrations of, as a minimum: excessively high pH, aluminum, antimony, arsenic, barium, cadmium, copper, chromium, cobalt, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, zinc, sulfate, nitrate, ammonia, boron, fluoride, chloride, and natural radioactive constituents (uranium, thorium, potassium-40, gross alpha and beta, in general), cyanide and related breakdown compounds (metal-cyanide complexes, cyanate, thiocyanate), organic carbon, oils and greases, and numerous other organic compounds, and elevated suspended sediment loads. *Many of the constituents listed above are not reported in the Veladero IIA baseline data, in routine monitoring, or summarized in a statistically-reliable manner.*

12-The routine Veladero mining, processing, and waste disposal activities, together with the impacts from the cyanide solution spill that occurred during 12-13 Sept. 2015 and after, have contaminated these waters and the associated periglacial sediments. [Contamination from cyanide leaching, waste rock drainage, metal-laden dust, explosives, fuels, etc.]

13-Chemical contaminants released by these mine operations into the local surface and ground waters migrate downstream / down-gradient in both *dissolved and particulate forms.* Additions of such contaminants increase concentrations and the total *mass* or *load* (i.e. kilograms or pounds) of chemical constituents, such as arsenic, lead, uranium, etc. in these waters and sediments, which ultimately are added to the overall environment.

Aquatic organisms, including fish, routinely ingest both dissolved and particulate (Total) forms of contaminants.

14-Both the September 2015 cyanide spill and routine mine operations, will continue to degrade the local and regional water quality and **increase the regional competition for water** into the foreseeable future. These wastes will remain on the site forever—after mine closure.

15-Argentine water quality standards and criteria are, in some instances, weaker or lacking for many important chemical constituents, when compared to those applicable in the U.S.A. and Canada, the home country of MAGSA's parent company, Barrick, e.g. uranium, natural radioactivity. [See attached table in appendices.] *The more important question is whether these various standards and criteria are actually being enforced?*

16-As of December 2012, MAGSA estimated the Veladero reclamation and closure costs to be $53.2 million (Veladero Mine, EDGAR Form 40-F, 2013). Apparently no mining companies are required to provide any form of financial assurance (bond, insurance, etc.) to the Argentine government.

17-Under present conditions, the Argentine government and taxpayers are "subsidizing" these mining activities, as many of the long-term costs are not being paid by the company.

Introduction.

Purpose & Scope.

This report is primarily intended to answer the 13 questions posed by federal judge Casanello regarding the pregnant lixiviation solution (PLS) spill of 12-13 Sept. 2015 (see end of text). However, because the background information necessary to understand the impacts of this spill is contained in so many 1000s of pages of conflicting and sometimes misleading data and reports from numerous sources, I have chosen to begin this report with a more narrative explanation of my observations, before responding to the questions directly.

While MAGSA's attorneys initially took legal action to prevent my visit to the mine site, I must add that MAGSA staff, were subsequently quite cooperative in transporting us to and from Veladero, providing food and lodging at the mine headquarters, leading us through the relevant facilities, and describing the spill events from their perspective. Following some discussion, MAGSA was also willing to provide additional documents and data, which were collected by Alberto Candia, Argentine Federal Police, and sent to Judge Casanello. My thanks go especially to Mr. Rick Baker, Executive General Manager of Veladero for his assistance and support.

As I am a hydrogeologist / geochemist, my comments are largely focused on aspects of the spill relating to water quantity, water quality, and geochemistry. My comments are based on:

- travel in Argentina from April 5 through April 13, 2016, which included a site visit to the Veladero Mine led by the new general manager, Mr. Rick Baker, and a Barrick attorney from San Juan, Esteban Mercado Beer. Attendance at MAGSA technical presentations.
- Review of most of the relevant Veladero Sept. 2015 spill documents, many supplied by MAGSA to Judge Casanello, and other relevant documents;
- Discussions with numerous Argentine technical, regulatory and academic experts that have had experience with the 2015 spill situation;
- More than 45 years of applied hydrogeology and geochemical experience at hundreds of sites, worldwide. My detailed resume and most publicly-available papers (several in castellano) are available at: **remwater.org**.

Background: Spill Event.

MAGSA and other investigators agree that a spill of pregnant lixiviant solution (PLS) occurred on 12-13 September 2015. The PLS is normally circulated from the leaching piles to the other processing facilities in a system of large-diameter pipes that contain valves. MAGSA stated that, on 12September, one of the vent valves was damaged, apparently by the cold temperatures, causing PLS to be discharged into the North Diversion Canal. This North Canal contains a gate, which, Mr. Baker stated, normally would be closed, diverting any solutions into a contingency (emergency overflow) pool. On these dates the gate was open, thus the PLS flowed eastward into the Rio Potrerillos and then into the Rio Taguas.

The authors of the Argentine Federal Police report, 2016 (29 Feb.), have calculated that approximately 1,072,600 liters of PLS were released into the local surface waters. *I am unclear as to how much time elapsed before the general public was notified of the spill.*

MAGSA staff have stated that the North Diversion Canal was constructed to collect surface water running off the *waste rock piles*, and divert it around the leaching facilities, discharging into the Rio Potrerillos and then into the Rio Taguas. MAGSA representatives stated that the gate in the North Canal was open on these dates because high volumes of water were entering the North Canal due to spring snowmelt, and the water level in the contingency pool was already too high to safely receive additional volumes of snowmelt runoff water.

As the waste rock piles are constructed directly on top of the periglacial sediments, *with no form of liner underneath*, it is clear that acidic, contaminant-laden drainage from these piles is entering the surface and shallow ground waters. Thus, whenever the gate in the North Canal is open, such acidic drainage is discharged directly into the local rivers.

When I visited the mine operations, MAGSA had already made all of their post-spill engineering changes. In fact most of these changes had already been made before most of the outside investigators arrived on the site in late September – early October 2015 (e.g. the contaminated sediments had been removed and disposed; the faulty valve and original gate had been replaced, etc.).

Comments & Discussion.

Earliest Post-spill Information. The explanation for the spill provided by MAGSA seems reasonable, but is complicated by several factors. Firstly, at the time of the spill *only MAGSA staff* was present to witness details, make flow and water quality measurements, collect samples and record observations.

One must assume that the original spill details were documented with photos, possibly also air photos, satellite images, etc. No such photos or images were shown to us during our site visit, nor have I discovered any in reviewing the relevant reports by numerous outside parties.

PLS solution is normally quite alkaline, having a pH usually above 10, and contains an extremely toxic mix of hundreds of chemical constituents in addition to numerous forms of cyanide. The spill PLS likely included significant concentrations of, as a minimum: excessively high pH, aluminum, antimony, arsenic, barium, cadmium, copper, chromium, cobalt, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, vanadium, zinc, sulfate, nitrate, ammonia, boron, fluoride, chloride, and natural radioactive constituents (uranium, thorium, potassium-40, gross alpha and beta, in general), cyanide and related breakdown compounds (metal-cyanide complexes, cyanate, thiocyanate), organic carbon, oils and greases, and numerous other organic compounds.

Once the PLS was released into the North Canal, it would have begun to react chemically with the local sediments and release volatile substances into the air. Once the pH of the PLS solution drops below about 9.0, some of the dissolved cyanide begins to convert to a toxic gas, hydrogen cyanide, which is the lethal agent often used in prison execution chambers and to execute prisoners in the Nazi death camps (Moran 2002).

Were the first MAGSA workers that entered the spill area on 13Sept. 2015 wearing protective clothing and respirators? Did they experience any negative health consequences? Did they add any additional chemicals to the spilled sediments in an attempt to "neutralize" the chemicals—as is often done. No answers to these questions seem to have been made public.

Note: When chlorine-containing compounds, such as bleach (sodium hypochlorite) have been added to cyanide-containing waters and sediments, they can produce another toxic gas, cyanogen chloride, which was used as a chemical warfare agent in World War 1. This occurred near the Kumtor Mine in Kyrgyzstan in 1998 (Moran 1998, 2000, 2002, 2011).

<u>Fate of Contaminated Sediments.</u> Many days had passed before most of the outside observers arrived at Veladero, and by this time the contaminated sediments had already been excavated and disposed of somewhere, but specific details of the disposal location are not public (Federal Police report 29 Feb. 2016). We were simply told by MAGSA the contaminated wastes were disposed of in the leach piles / facilities.

<u>Chemical Composition of PLS.</u> While MAGSA had routinely collected <u>detailed</u> historical water quality information for years (see, for example, Knight Piésold, 2016, Mar. 7, Informe de Monitoreo), following the spill, *publicly-available* water quality data was limited to free and total cyanide, and mercury. *Apparently, no detailed data on field measurements for pH, electrical conductance (EC), or the detailed chemical composition of the spilled PLS have been released to the general public.*

The first chemical composition data (totally inadequate) for the PLS that were released publicly, appear to have been reported in the AMEC Foster Wheeler report (16 Feb. 2016, Table 1-1, electronic pg. 48, Casanello envelope 10) from a <u>sample taken on 17 September 2105</u>—four days after the spill was discovered. This table reports only a few chemical constituents; the majority of the PLS components mentioned previously are not shown in this table. In addition, the data lack the details necessary to reliably evaluate either the quality of the analysis, or the extent of future impacts or risk. Where are detailed water chemical analytical data for the 13 Sept. through the next two weeks?

It's important to note that the chemical compositions of all water samples, especially very complex solutions such as PLS, begin to change almost immediately once they are released into the environment. Thus, by delaying the public reporting of detailed data, MAGSA ensured that most outside observers were unable to see the original chemical compositions, and focused mainly on the cyanide in the spill---neglecting any early focus on the other toxic PLS components.

It is also relevant to notice that MAGSA consultants, such as AMEC Foster Wheeler, did not collect any of these original spill samples (waters and sediments); they simply relied on the incomplete data provided to them by MAGSA.

<u>Other Spill Uncertainties.</u> Several other uncertainties exist. AMEC Foster Wheeler (16 Feb. 2016, electr. Pg. 411) states that most Veladero "precipitation occurs mainly in winter (May through October)". Thus, the spill date, 12-13 Sept. is winter, when most precipitation should fall as snow. Which is consistent with the explanation for the frozen valve. However, this raises questions regarding the explanation that the North Canal gate was open because the contingency pool could not receive additional water due to excessive runoff. Runoff volumes (from waste rock and other facilities) would be expected to be *relatively* low during winter.

A participant on one of the other "independent" investigation teams (who prefers to remain unidentified) confirms that the level of the PLS was too high, but that the North Canal gate had actually been open continuously since 17 August 2015, roughly 3 weeks prior to the spill. Apparently several such details were made public in the judicial proceedings of Provincial Judge Oritja.

<u>Corporate "Control" of Publicly-Available Information.</u>
Like most similar modern, open-pit metal mines, Veladero is located in a remote area, where all access to the mine facilities and essentially all technical information are closely controlled by the corporation. Thus, the corporation "controls" most information given to the general public, regulators, MAGSA consultants and outside observers. Most importantly, they control which "facts" are released, and which are withheld---to all parties.

The overall picture presented by the MAGSA reports and those of their paid consultants present a misleading and incomplete impression of the spill events and their impacts, and the longer-term impacts to the local and regional water resources.

MAGSA chooses, directs and pays all of its consultants who collect much of the data mentioned in the Veladero reports. In my experience, such corporate staffs often define the scope of the consultant's activities and even edit their reports. *Because most such consultants receive the majority of their incomes working for the mining industry, they are extremely reluctant to author "unpleasant" opinions.* Several of the recent MAGSA spill-related reports suffer from this dilemma.

None of the staff or authors of the MAGSA consultant's reports (or outside parties, such as the Federal Police, UNOPS, etc.) were present on site at the time of the PLS (pregnant lixiviant solution) spill on Sept.12-13, 2015, nor did they observe the site for several days or weeks after the spill. Thus, all of the information and monitoring data concerning the first few days after the spill was discovered came only from MAGSA.

Many of the Veladero senior managers and other staff have been replaced following the September 2015 spill. Thus, the historical continuity is destroyed and responsibility for the spill impacts is compromised.

<u>Increased Competition for Water.</u> The Veladero Project area is extremely dry; even at the high mine elevations it receives extremely limited amounts of yearly precipitation, predominantly as snow. At Jachal, the *average annual precipitation is approximately 14 cm, (about 5.5 inches), and has decreased since 2009 due to drought conditions* [AMEC Foster Wheeler, 17 Feb. 2016].

Veladero has permits to take and use 100 liters per second from the Rio Taguas surface waters, and permits for an additional 10 liters per second from shallow wells.

110 liters per second = 9,504,000 liters per day **(9.5 million liters per day)** = 2,471,040 gallons (U.S.) per day.

Emiliano Campanella, Veladero Process Manager, stated that they presently use only 70% of the permitted water volumes (oral presentations, Apr. 7-8, 2016).

70% of 9,504,000 liters per day = **6,652,800 liters per day** = water volumes presently used at Veladero.

It appears that Argentine regulators / controllers do not have the authority and / or capacity to independently-verify these water use volumes.

<u>Water Balance.</u> No actual, detailed **water balance** is presented in any publicly-available MAGSA documents, to my knowledge. R. Baker said that they had such a water balance, but they were still not confident of many aspects of the balance--more than 10 years after commencing mine operations. Although I requested information showing a detailed water balance, none was provided at the 8 April 2016 Veladero meetings.

All Veladero information I have reviewed states that the open pits are dry. However, we did not visit any of the pits, and given their depth, it is imperative that Argentine regulators verify that no significant volumes of ground water (or rain, snow or surface waters) are being pumped from these pits.

A detailed water balance is required to evaluate the overall fate of water resources used by MAGSA and to determine the overall impacts MAGSA operations may be having on downstream users (Golder Assoc., 2011(Dec. 19), Guidance Document on Water and Mass Balance Models for the Mining Industry; ICMM, 2012 (May), Water Management in Mining).

<u>Baseline.</u> Baseline data are considered to be data from samples collected *prior to the beginning of mine operations.* As my comments focus largely on aspects related to water resources, baseline here refers specifically to water-related information /data (samples, measurements and testing) *collected pre-mining*.

Reliable baseline data are absolutely crucial to allow one (the company, regulators, and the public) to determine whether changes in water quality or quantity have occurred since mining activities began. In fact, it is also clear that even early *exploration and construction activities* can degrade the pre-existing water quality--and sometimes spring flows.

Unfortunately it is common at modern open-pit operations similar to Veladero, to find that inadequate water quality baseline data exist, *so that it is extremely difficult to demonstrate that changes have occurred years after the commencement of operations.*

The publicly-available, baseline water quality data at Veladero are inadequate for reliably defining the pre-mining conditions in surface and ground waters. Baseline water quality data are referred to often in numerous Veladero reports, usually those authored by MAGSA or their consultants, but these data are not statistically-reliable for drawing the necessary conclusions.

At our April 7-8, 2016 meetings at Veladero, MAGSA staff (R. Baker and Esteban Mercado Beer) showed me “baseline data” from one of the annexes to the 2003 EIA. It contained only Min. (minimum) and Max. (maximum) concentrations for numerous water quality constituents, but not the details necessary to reliably interpret such data. [For example: the (n)—number of analytical determinations; the median concentrations; specific sample locations; statistical methods used for interpreting values reported as below detection limits (< values)].

As a result, several reports [i.e. MAGSA (2015, Dec.); AMEC Foster Wheeler (2016, 16 Feb.; Knight Piésold, (2016, Mar. 7)] prepared by MAGSA and its consultants following the Sept. 2015 spill, have resorted to “technically-tortured” measures to argue that the actual baseline (pre-operational) concentrations were either:

- equal to the **maximum** concentrations from the EIA baseline data, or
- that they were **calculated** from historical, pre-spill, monitoring data.

In either case, the authors have chosen not to use the actual baseline data reported in the 2003 EIA. When interpreting the data on present and future impacts to water quality, it makes a great difference if one chooses to use the maximum (max.), or minimum (min.) baseline concentration as the pre-mining starting point. Clearly, a far more defensible approach is to report the number of pre-operational samples analyzed at any baseline site, and calculate both arithmetic means and medians to determine baseline concentrations—assuming the sample population sizes are statistically adequate.

In my experience, it is obvious that MAGSA possesses detailed baseline water quality data, including detailed statistics, but they have failed to provide them to these consultants, and / or have directed their consultants not to use them. The usual explanation is that, during operations and after, the actual preoperational baseline concentrations are considered too low to be attained without employing expensive water treatment technologies.

MAGSA's 2003 EIA does contain baseline data on the preoperational presence of springs (Vertientes) together with field measurements of their water quality—water temperature, pH, and electrical conductivity (EIA, Vol. 1, Table 1.10). Several of the springs had field pHs that were naturally acid, several between pH 2.6 to 5.0.

Clearly these data demonstrate that these rocks are capable of developing acid rock drainage, which almost certainly is being produced within, and released from the Veladero waste rock piles and walls of the open pits.

These baseline water quality pages from the Veladero EIA (2003) were apparently sent with the other envelopes to Judge Casanello, but I had not received the contents of that envelop at the time this report was prepared.

As I was finalizing this report, I discovered an Appendix G to the EIA (2003), Vol. 2, "Tablas Hidroquímicas de Linea Base", but it contains no summary statistics for the stations relevant to the Sept. 2015 spill, nor is it mentioned in any of the other MAGSA reports cited above.

Waste Rock Piles: Impacts on Water Quality. The Veladero waste rock piles are obviously generating acidic drainage, based on the depressed pHs (waters and sediments) presented in several of the MAGSA and other reports cited in the references to this report. Clearly, these acidic, contaminant-laden waters have discharged into the Veladero-area surface waters for years, and will continue to do so. Likewise, these contaminated waste rock drainages are degrading the water quality of the ground water in the local periglacial sediments—which are clearly in hydrogeologic connection with the surface waters.

Chemical Constituent Loads. Chemical contaminants released by these mine operations into the local surface and ground waters migrate downstream / down-gradient in both *dissolved and particulate forms.* Additions of such contaminants increase the total *mass* or *load* (i.e. kilograms or pounds) of chemical constituents, such as arsenic, lead, uranium, etc. in these waters, which ultimately are added to the overall environment. This increase in arsenic load, for example, occurs even where dissolved concentrations of arsenic, determined from filtered water samples, are low or less than the analytical detection limits—because much of the arsenic being transported is filtered out of these samples—but is actually transported as colloidal (very tiny particles) or sediment particles.

Reliability of Spill Data. As has been mentioned, I have numerous concerns about the limited data that have been made public. In addition, the various reports cited have little or no discussion on the detailed sampling and sample handling procedures employed. The reliability of water quality samples is most often compromised by inadequate field procedures. Occasionally there are concerns with laboratory procedures, independence and results, but my experience is that errors made in the field are generally more significant.

The authors of many of the spill reports I have cited (usually unnamed), often simply state that they followed internationally-acceptable procedures. This sort of simple phrase, in the absence of details, often covers a great many “sins”. For example, it is often unclear whether all samples were immediately “preserved” in the field. Likewise, it is frequently unclear whether many / most / all of the samples were filtered in the field, prior to the addition of preservatives, or later in the laboratory.

In a similar vein, I would normally expect two different teams sampling such a spill event to collect “split” samples. That is, a large volume of surface or ground water is collected according to accepted procedures, mixed thoroughly, and then split into separate aliquots, and given to each team. This ensures that the samples are comparable—assuming they are then preserved and handled correctly-- before they are sent to the respective laboratories.

In instances where MAGSA sampled jointly with the UNOPS team, the Federal Police, and other outside teams, they conducted “parallel” sampling (e.g. see MAGSA, 2015 Dec., Parallel Sampling Results with UNOPS.). Rather than collecting one composited sample and splitting it between the teams, each team collected their own samples from the same location (approximately) at the same time (approximately).

This is a very strange approach, in my years of experience, especially where legal issues may be involved. Mr. Baker told me that UNOPS would not allow true "split" sampling.

These spill-related reports fail to describe the sorts of internal checks on sampling / analytical quality necessary to provide me (and most similar scientists) confidence in the reported results. These would normally include such checks as: Cation-anion balances; comparisons of field EC (electrical conductance) versus total dissolved solids; comparisons of Dissolved versus Total determinations for the same constituents; comparisons of results generated by the different teams.

In most instances, the PLS spill information is inadequate to perform such "checks", and / or they simply have not been reported. **This calls into question the reliability of many of the conclusions stated in these reports.** All similar projects encounter the problem of sampling and analytical "error". One must, however, attempt to quantify such routine errors. This is especially important when an investigator is attempting to show that "no change has occurred", and the concentrations being discussed are reported in units of:
milligrams per liter = parts per million, or
micrograms per liter = parts per billion

It appears that the sum of the expected sampling and analytical errors in these spill reports is likely to be greater than would allow detailed interpretations, especially in downstream locations where concentrations are very low.

<u>Water Quality Standards & Criteria—Comparisons.</u>
Argentine water quality standards and criteria are, in some cases weaker or lacking for important chemical constituents, when compared to those applicable in the U.S.A. and Canada, the home country of MAGSA's parent company, Barrick. [See attached table in appendices.] A significant example is uranium, which occurs commonly in gold-bearing, volcanic rocks. The Canadian drinking water standard is 20 micrograms per liter (μg/L); that for Argentina is 100 μg/L. Argentina has no standards or guidelines for alpha or beta radioactivity, for any water use. These are relevant to gold mining because the alkaline PLS solutions tend to mobilize and concentrate uranium and other naturally-occurring radioactive substances. *The more important question is whether these various standards and criteria are actually being enforced?*

<u>AMEC Risk Assessment Report (2016).</u> The AMEC Foster Wheeler report (2016) is a *theoretical* assessment of the potential impacts and risks, based on data provided to them by MAGSA. The AMEC staff had no role in the collection of the actual water and sediment data. Their findings, like those of all similar risk assessments, are based on a great many simplifying assumptions, which, of course, determine whether any risk is reported.

One of the main weaknesses of this risk assessment is that it is incapable of considering the actual, combined risks from all of the hundreds of different chemical constituents in these waters and sediments as they act synergistically on humans or any other organisms. For example, Table 3-4, entitled "Pregnant Leach Solution Chemistry" is so limited and simplistic as to be laughable. It presents PLS data (sampled only on 17 September, 4 days after the spill was detected) for only 2 measured parameters, pH and conductivity (but the reader must assume these are lab measurements, not the more accurate field measurements), and concentrations for only 11 chemical constituents of the literally dozens of PLS constituents that should have been reported. In fact, most of the potentially-toxic PLS constituents are not included (e.g. arsenic, lead, uranium, cadmium, selenium, etc.).

In my roughly 45 years of working on similar projects, I have never seen a commercial risk assessment performed for a mining company that ever reported any significant risk. Thus, I see no reason to take these conclusions very seriously.

In addition, AMEC makes several pronouncements regarding the environmental behavior of cyanide that are misleading and incorrect. If the authors had bothered to consider technical literature from a wider range of sources, especially non-industry sources, they might have been forced towards different statements.

For example, AMEC attempts to show (electronic pg. 420) that cyanide is produced naturally by all sorts of plants and organisms, which is correct, but fail to mention that cyanide concentrations in natural waters, unimpacted by any sort of human activity, are *seldom above analytical detection limits* (references cited in Moran 1998, 2000, 2002). On the same page, AMEC states "cyanide has low persistence in the environment..", which is clearly discounted in many of the studies I have encountered (e.g. references cited in Moran 1998, 2002, etc.) and has clearly be disproven by numerous studies conducted by the U.S. Geological Survey (e.g. Johnson, Craig, A., 2015, etc.). The *preliminary* UNOPS-PNUMA report (9Dec. 2015) also makes similarly misleading and incorrect statements about the behavior of cyanide in nature (e.g. pg. 9).

In section 4.3.1 AMEC begins the discussion on cyanide toxicity guidelines by focusing on the World Health Organization drinking water guideline (legally non-enforceable) of 0.5 mg/L, without mentioning that the Canadian drinking water standard (legally enforceable) is less than half that concentration, 0.2 mg/L.

<u>Cyanide Code.</u> Several of the spill-related reports authored by MAGSA and its consultants make mention of the fact that selected Veladero staff have been certified according to the procedures of the International Cyanide Management Institute. [See http://www.cyanidecode.org/about-cyanide-code/faq].
They fail to mention, however, that this Code and Institute were totally developed by the mining industry and **funded by the gold mining industry, cyanide**

suppliers and manufacturers, and that compliance with the Code is voluntary, not legally enforceable. Likewise, these reports fail to mention that many of Cyanide Code guidelines sanction the discharge of mine wastewaters that contain cyanide concentrations that would be toxic to many forms of fish and other aquatic life. In addition, the Code contains no viable recommendations or procedures for detoxifying the spilled liquids and protecting aquatic life once a spill of PLS has occurred into water (Moran 2002). *Clearly, such Cyanide Code training did not prevent the September 2015 spill.*

UNEP Relationships with the Mining Industry. Following a series of disastrous mining industry accidents that involved cyanide, the industry organized to attempt to improve cyanide handling procedures and to improve their overall public image, in early 2000. The Code was developed "under the auspices of" the United Nations Environment Programme (UNEP) and the industry-funded International Council on Metals & the Environment (ICME). The first meeting to promote the development of a cyanide code was held in Paris in May 2000, at a joint UNEP/ICME-sponsored international workshop. [See more at: http://www.cyanidecode.org/about-cyanide-code/faq#sthash.VL20xbt8.dpuf] I was an invited attendee at that meeting, at which the UNEP played only a cosmetic role. All subsequent Code-related activities were developed without significant participation of the U.N., except by members of the mining industry who had been seconded onto the U.N. Paris staff.

Another U.N.- related agency, UNOPS (U.N. Office for Project Services), has conducted studies at Veladero, apparently at the request of the Argentine Ministry of Mines (contacted 18September 2015). In general, consultants to industry conduct such U.N.-sponsored activities. The sources of the funds used to conduct this UNOPS-UNEP spill assessment are unknown to me. **It is now more than six months following the PLS spill and neither the final UNOPS report or their final data have been made public.**

Veladero Operations—Industry Context. Despite the critical comments I make in this report, the Veladero Project seems to be well run when compared to similar gold open-pit operations, worldwide. Nevertheless, the cyanide spill event has made public several fundamental weaknesses, the most important of which are: 1-a lack of transparency on the part of both the corporation and their regulators / controllers; 2- almost all important data and information are provided by financially-interested parties—not independent parties; and 3-the relevant regulatory agencies (controllers) have failed to provide adequate oversight and "checks and balances" on MAGSA's environmental operations, especially those related to water resources.

Judge Casanello's Questions: Moran Responses.
Judge Casanello's original questions and my responses are presented below. Because I am predominantly an expert in issues related to hydrogeology, water quality, and geochemistry, and because I am a single member of an overall

commission team appointed by Judge Casanello, I am restricting my responses to selected questions.

1- Explain step by step the process of extraction of gold and other metals by means of leaching and the use of cyanide.

This explanation comes largely from various Barrick / Veladero website sources and from comments made and documents supplied during our meetings at the mine on April 7-8, 2016 (see contents of Casanello envelope #2). The processes are summarized in the Barrick presentation materials submitted to Judge Casanello in envelope #2.

Veladero is a conventional open-pit operation in which economically-valuable rock, ore, is removed from the open pits by blasting, and then transported to the crushers via truck or conveyor belts. Ore is then crushed using a two-stage crushing process, which break the rocks into smaller particles. Crushed ore is then transported via overland conveyor and trucks to the leach pad area. At the leach pads, a dilute cyanide solution is dripped through the ore via drip emitters. The alkaline cyanide solution (pH usually greater than 10) combines with the gold and silver—and most other metals in the leach pile---forming what is called the pregnant (or rich) leach solution (PLS). The PLS is collected at the bottom of the pile and circulated through several chemical steps which separate the gold, silver and other metals from the cyanide, which is re-circulated and reused through numerous leaching cycles. The separated gold, silver and other metals are filtered out of solution and smelted into a metal bar (bar doré), which is transported to another country for refining.

The leach pad area is constructed on top of and within, permeable, periglacial sediments (a valley-fill leach pad). The base of the leach pad is composed of one or more layers of synthetic geo-membrane liner, which ideally, act to catch any fluids moving downward through the ore. *In fact, most such synthetic liners leak at least small volumes of liquid into the surrounding ground water over the long-term.*

2- Indicate if you found fault in the aforesaid process that could cause environmental damage and / or leakage of cyanide into the Potrerillos River.

As mentioned above, the leaching process produces a chemically-complex PLS solution that contains many substances in addition to cyanide that are potentially toxic. All of these substances will be included in any fluids that leak through the liner, or are released in a spill, such as at Veladero.

Leach piles at all *modern* gold leach operations, worldwide, are constructed with at least one layer of liner at the base of the piles. Sometimes there will be two layers, sometimes a combination of synthetic membranes together with a layer of compacted clay. These are constructed with a collection system intended to collect all of the fluids, which percolate downward through the piles. Hence, the industry likes to refer to these systems, disingenuously, as “zero-discharge” systems. However, it is my experience that they all generate some degree of uncontrolled leakage into the local ground waters, long-term. [Small holes develop in the liner material, either when it is originally emplaced, using heavy equipment, and / or the weight of the overlying sediments in the piles gradually pushes down on the liner, creating such small holes.] This occurs slowly over time, and is a chronic problem. Some such leakage is undoubtedly passing through the Veladero leach liner system into the shallow ground water within the periglacial sediments.

Secondly, the pipes in which the PLS circulates can leak via several processes: the pipe seams can degrade; breaks or cracks often develop; the valves in these pipelines can malfunction; or these pipes may be severely damaged if heavy equipment collides with them, for example, or in steep areas, rockfalls or avalanches can damage the pipes.

Relatively small “releases” of PLS occur at similar mine sites much more frequently than is advertised. Because of the remote locations of most such mines, and because this industry is largely self-monitoring, the public seldom hears about most of these “accidents”.

At the time of my site visit, all leaching-related facilities appeared to be functioning correctly.

After my return to the U.S.A., a Canadian activist emailed me information relating to a claim filed in Ontario, Canada courts (27March 2015) by a former Veladero worker, Raman Autar, against Barrick. In the claim he alleged that he was fired and bullied because he spoke openly about the poor state of equipment at the Veladero mine. As this suit was filed months before the September 2015 spill, the details of this claim seem relevant to the present efforts. [Ontario Superior Court of Justice, Court File No. CV-15-524886].

3- Enumerate and describe the measures that were adopted and any modification made by the enterprise when the spill happened.

All modifications made by MAGSA following the September 2015 spill are described in the contents of “envelope” 2 sent by MAGSA to Judge Casanello. I assume that the engineers on the commission team are better able to describe these modifications than I can.

4- Determine the function of the contingency pool and of the gate located in the North Channel.

The contingency pool is intended to function as storage for runoff water coming from the waste rock piles and other portions of the facilities. It functions as emergency storage when too much water is flowing across the project site, especially during spring snowmelt times. The gate simply diverts water from the diversion channel (North Canal) when necessary; otherwise it is open, allowing stormwater and drainage from the waste rock areas to flow into the Rio Potrerillos and then to the Rio Taguas.

5- Indicate if the aforesaid gate needs to be normally closed or open.
It appears to me that the gate is normally left open, discharging these waters (described above) into the local surface waters, causing some degree of chronic degradation of the surface water quality.

I will let the Commission engineers comment on the needed design changes. However, it is clear that most alternative designs will still increase the loads of contaminants flowing into the local surface waters.

6-Establish if that mechanism is sufficiently safe.
Again, I will leave this response to the engineers, except to say that any viable solution requires actual oversight / enforcement by the appropriate government regulators.

7- State if reforms are needed in the procedures and with what goal.
My most important suggested reforms center around: 1-actual, meaningful oversight by the appropriate regulators, and 2-public disclosure of the detailed operational and environmental information.

8- Indicate if the north channel needs to be waterproof due to the fact that its proximity to the waste dumps might make it gather contact water in case of ice melting and/or rain.
The engineers should comment on this. However, if reliable water quality and flow data for the North Channel were made public, regularly, the appropriate answers to this question would probably become obvious.

9- Verify where the ice melt water circulates.
As far as I could determine, most of the ice melt waters are collected by the North Diversion Channel—at least in the area of the leaching facilities and nearby waste rock piles. It is unclear where the ice melt waters in other distant areas, including the open pits, circulate.

10- Determine the fatigue of the material comprising the valves, the ducts through which the cyanide solution circulates and of other elements employed in the leaching and indicate if they are well kept or not.
Commission engineers should provide details to this question. However, all such materials gradually degrade with use over the many years of such a mine. Thus, an outside regulatory agency should be routinely checking the state of all such materials—especially those that come in contact with toxic substances.

11- Determine if the way in which the enterprise detects incidents is effective and if the time taken to detect a problem is adequate.
Appropriate response should come from Commission engineers.

12- Verify if the training of the operators is adequate and satisfying and verify the number of staff that the enterprise assigns to incident detection and

Again, I defer to the engineers' expertise. Clearly, detailed, private (confidential) interviews with many of the MAGSA workers might provide insight to useful answers.

13- Suggest in case the adequate procedures do not succeed in neutralizing in an absolute way the risks associated with the activity, the adequate ones.

There are no "absolute" remedies to such a situation where human error is always involved, especially in such extreme weather and physical conditions. Again, actual, competent, pro-active oversight by parties independent of MAGSA is required. If the routine monitoring data were rapidly made public, this would improve the chances of viable oversight. In addition, it might be useful to construct a team of private citizens to be trained to assist MAGSA in some of their monitoring activities. This would allow the public insight into the activities at the mine, might indirectly improve the procedures, and also might improve both communication and trust between MAGSA and the communities. It must be said, however, that few mines willingly bring outsiders onto their site to conduct any sort of routine activity.

References.

AMEC Foster Wheeler, 2016, 16 Feb., Assessment of Potential Impacts, Risks, and Mitigations; Veladero Mine.

Argentine Federal Police, 2016 (29 Feb.), Informe Sobre la Visita al Emprendamiento Minero "Veladero" Como Consequencia del Derrame de Solución Cianurada Denunciado y la Información Técnica Proporcionada pr la Empresa. Informe Técnico Conjunto DRP-DPyRA-DGARH 02/ 2016.

BARRICK GOLD CORP., 2013, FORM 40-F; (Annual Report (foreign private issuer)); Filed 03/28/13 for the Period Ending 12/31/12; EDGAR Online. http://www.barrick.com/files/agm/Barrick-40F-2012.pdf

Barrick Veladero Website, April 2016. http://www.barrick.com/operations/argentina/veladero/default.aspx

Golder Assoc., 2011(Dec. 19), Guidance Document on Water and Mass Balance Models for the Mining Industry; submitted to Yukon Government, Whitehorse, Yukon, 248 pg. http://www.env.gov.yk.ca/publications-maps/documents/mine_water_balance.pdf

ICMM, 2012 (May), Water Management in Mining: A Selection of Case Studies; 32 pgs.

https://www.icmm.com/document/3660

ICMI (Int'l. Cyanide Mgmt. Institute), 2015, International Cyanide Management Code—for the Gold Mining Industry.
http://www.cyanidecode.org/about-cyanide-code/faq

Knight Piésold, 2003, Veladero EIA.

Knight Piésold, 2016, Mar. 7, Informe de Monitoreo de Calidad de Agua Superficial y Subterránea de la Mina Veladero Periodo Julio 2014-Junio 2015.

Johnson, Craig, A., 2015, The Fate of Cyanide in Leach Wastes at Gold Mines: An Environmental Perspective. Applied Geochemistry 57 (2015) 194–205.

MAGSA, 2015 Dec., Parallel Sampling Results with UNOPS.

MAGSA, DATE?, Informe Técnico (Referencia: Informe de la División Operaciones del Departamento de Delitos Ambientales de Policía Federal Argentina (DO PFA). No specific date or author(s) shown. Must have been after 29 Feb. 2016.

Moran, Robert E., 1998, Cyanide Uncertainties—Observations on the Chemistry, Toxicity, and Analysis of Cyanide in Mining-Related Waters: Mineral Policy Center Issue Paper No.1, 16 pg., Wash., D.C. [Incertidumbres Sobre el Cianuro]. (available at:
http://www.earthworksaction.org/pubs/cyanideuncertainties.pdf
http://www.portaec.net/library/pollution/observations_on_the_chemistry.html
http://www.isse.ucar.edu/prediction/report1/case_histories.html
http://www.earthworksaction.org/ewa/pubs/cyanideuncertainties.pdf
and at: http://www.mineralresourcesforum.org/technical/cyanide/cyanidem.htm
http://www.conflictosmineros.net/biblioteca/estudios-e-informes/sustancias-toxicas/cianuro/incertidumbres-sobre-el-cianuro/download.).

Moran, Robert E., 2000, Cyanide in Mining: Some Observations on the Chemistry, Toxicity and Analysis of Mining-Related Waters: *in* Proc. Central Asia Ecology—99, Lake Issyk Kul, Kyrgyzstan, June,1999. (El Cianuro en La Minería: Algunas Observaciones Sobre La Química, Toxicidad y Análisis De Las Aguas Asociadas con La Minería) [Available at:
http://www.earthworksaction.org/publications.cfm?pubID=60

www.zpok.hu/cyanide/baiamare/docs/ MoranCyanidePaper0799.rtf

www.claim-gv.org/docs/morancyanidepaper.pdf

Moran, Robert E., 2002, De-coding Cyanide. A Submission to the European Union and the United Nations Environment Programme: Sponsored by Hellenic Mining Watch, Ecotopia, CEE Bankwatch, FOE Europe, FOE Hungary, FOE

Czech Republic, Food First Information and Action Network, Minewatch UK, and Mineral Policy Center, 25 pg. (Decodificando el Cianuro).

Available at: http://www.hnutiduha.cz/publikace/studie/kyanidova_studie.pdf , www.mineralpolicy.org/publications/,

http://www.eireview.org/eir/eirhome.nsf/(DocLibrary)/15583282B873481185256BFB00609501/$FILE/Decoding%20Cyanide%20(Feiler).pdf

http://aa.ecn.cz/img_upload/8b4cb37fba47da1c76cf3e44aa940cd2/decodingcyanide.pdf

http://www.scribd.com/doc/62758433/Decoding-Cyanide

http://pratclif.com/sustainability/decoding-cyanide.pdf

Moran, Robert E., 2011, Kumtor Gold Facilities, Kyrgyzstan: Comments on Water, Environmental and Related Issues: September 2011. Prepared for Human Development Center "Tree of Life" (Bishkek) and Bankwatch (Kiev) and the Kyrgyz Government. http://bankwatch.org/sites/default/files/Kumtor-MoranReport-31Jan2012.pdf
http://bankwatch.org/sites/default/files/REM%20Kumtor%20report%20FINAL_ru.pdf (Russ).
Related video: http://www.youtube.com/watch?v=uvfWwgEEFJ8
http://www.neweurasia.net/business-and-economics/rare-photos-of-kumtor-mine-and-environs/

UNEP / OCHA, 2000, CYANIDE SPILL AT BAIA MARE, ROMANIA, 60 PG. http://reliefweb.int/sites/reliefweb.int/files/resources/43CD1D010F030359C12568CD00635880-baiamare.pdf

UNOPS, 2015 Dec. 9, [Preliminary Report] Dossier Informativo del Estudio Sobre la Calidad de los Cuerpos de Agua en la Area de Influencia de la Mina Veladero, Posterior al Incidente Ambiental del 13/09/15.

Appendices.

Appendix 1. Moran's original one-page responses given to Judge Casanello, 12 Apr. 2016.

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Veladero: Suggested Comments: Officials in B.A.

--Where are the photos / satellite images of the actual spill clean-up activities during the days immediately following 12-13 Sept. 2015?

1-The engineering changes made by Barrick / MAGSA appear to be adequate to improve the chances that future spills are less likely. [Although some of the changes are underground, thus hidden from view.]

2-However, the technical information and data MAGSA is providing (and has provided) to the general public and regulators are NOT adequate to inform them of the actual impacts that have occurred (and are occurring) to the ground and surface waters. **It is important to note that all of these waters develop from the melting of the local glaciers (glacial melt-waters). Also, all of the waste rock and the leaching facilities are located on top of permeable, periglacial sediments.**

3-The spill water released during September 2015 contained many potentially-toxic chemical components in addition to numerous forms of cyanide, many of which have not been reported in publicly-available documents. These likely include significant concentrations of, as a minimum: excessively high pH, aluminum, antimony, arsenic, barium, cadmium, copper, chromium, cobalt, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, zinc, sulfate, nitrate, ammonia, boron, fluoride, chloride, and natural radioactive constituents (uranium, thorium, potassium-40, gross alpha and beta, in general), cyanide and related breakdown compounds (metal-cyanide complexes, cyanate, thiocyanate), organic carbon, oils and greases, and numerous other organic compounds. Many of the constituents listed above are not reported in the Veladero IIA baseline data, or in a statistically-reliable manner.

4-The routine mining / process and waste disposal activities, together with the impacts from the cyanide solution spill that occurred during 12-13 Sept. 2015 have contaminated these waters and the associated periglacial sediments. [Contamination from cyanide leaching, waste rock drainage, metal-laden dust, explosives, fuels, etc.]

5-These MAGSA operations, from both the cyanide spill and the routine mine operations, will continue to degrade the local and regional water quality and **increase the regional competition for water** into the foreseeable future. **These wastes will remain on the site forever—after mine closure.**

6-Argentine water quality Standards (and criteria) are much weaker or lacking for many important chemical constituents, when compared to those applicable in the U.S.A. and Canada—the home country of MAGSA's parent company, Barrick. [See attached table.]

7-Under present conditions, the Argentine government and taxpayers are "subsidizing" these mining activities, as many of the long-term costs are not being paid by the company.

Appendix 2. Water Quality Standards & Criteria: U.S.A., Canada, Argentina.

Parámetro	**Unidades**	**U.S.A. (EPA)**			**Canada**					**Argentina**			
		Agua consumo humano[5]	**Agua dulce para vida acuática**		**Guía para Agua potable**[3]	**Guía para riego**[2]	**Guía para ganadería**[2]	**Agua dulce para vida acuática**		**Agua para consumo humano**[18]	**Agricultura**[9]	**Ganadería**[9]	**Agua pa protecci de la vi acuátic Agua du superfic**
			Guía (Agudo)[1]	**Guía (Crónico)**[1]				**Guía (Agudo)**[4, 6]	**Guía (Crónico)**[4, 6]				
pH	Un.	6.5-8.5[7]		6.5-9	6.5-8.5				6.5-9.0	6,5 – 8,5			
Alpha, Total		15 pCi/L			0.5 Bq/L								
Beta, Total		4 mrem/yr			1.0 Bq/L								
Aluminio	µg/l	50-200[7]	750	87	<100-200	5000	5000		5.0-100	200	5000	5000	5
Amonío (N)	mg/l		2.9 to 5.0	0.26-1.8					0.017-190[10]	0.2[19]			1.37
Antimonio	µg/l	6.0			6.0					20			16
Arsénico	µg/l	10	340	150	10	100	25		5.0	10	100	500	50
Boro	mg/l				5.0	0.5-6.0	5.0	29	1.5	0.5	0.5	5	0.75
Cadmio	µg/l	5.0	2.0	0.25	5.0	5.1	80		0.018[11]	5	10	20	0.2
Cloruro	mg/l	250[7]	860	230	≤250[9]	100-900		640	120	350			
Cromo (tot)	µg/l	100	16-570	11-74	50	4.9-8.0	50		1.0-8.9	50	100	1000	2
Cromo (hex)	µg/l		16	11		8.0	50		1.0	50[23]			
Cloruro	mg/l	4.0[13]	0.019	0.011	See[16]			0.0005[17]		≥0.2[22]			
Cobre	mg/l	1.0 [7]-1.3 [8]	0.013[12]	0.009[12]	≤1.0[9]	0.2-1.0	0.5-5.0		0.002[11]	1	0.2	1	0.002
Cianuro (total)	µg/l		22	5.2	200					100			5
Cianuro (libre)	µg/l	200							5.0				
Coliformes Fecales	MPN/ 100ml	See[14]				100				0			
Coliformes Totales	MPN/ 100ml	See[15]			0	1000				≤3			
Fluoruros	mg/l	2.0[7]-4.0			1.5	1.0	1.0-2.0		0.12	0.6-1.7[20]	1	1	
Hierro	mg/l	0,3 [7]		1.0	≤0,3[9]	5,0			0,3	0,3	5		
Plomo	µg/l	15[8]	65	2.5	10	200	100		1.0[11]	50	200	100	1
Manganeso	mg/l	0.05[7]			≤0.05[9]	0.2				0,1	0.2		0.1
Mercurio	µg/l	2.0	1.4	0.77	1.0		3.0		0.026	1		3	0.1
Molibdeno	mg/l					0.01-0.05	0.50		0.073		0.01	0.5	

Parámetro	Unidades	U.S.A. (EPA)			Canada					Argentina			
		Agua consumo humano[5]	Agua dulce para vida acuática		Guía para Agua potable[3]	Guía para riego[2]	Guía para ganadería[2]	Agua dulce para vida acuática		Agua para consumo humano[18]	Agricultura[9]	Ganadería[9]	Agua pa protecci de la vi acuátic Agua du superfic
			Guía (Agudo)[1]	Guía (Crónico)[1]				Guía (Agudo)[4, 6]	Guía (Crónico)[4, 6]				
Níquel	mg/l		0.47	0.052		0.2	1.0		0.025[11]	0,02	0.2	1	0.025
Nitratos	mg/l	10			45; 10 as N		100	550	13	45			
Nitritos	mg/l	1.0			3.2; 1.0 as N[9]		10		0.060	0,1			0.06
Fenoles	mg/l						0.002		0.004	0.01[21]			0.001
Radio	pCi/L	5.0			0.5								
Selenio	mg/l	0.05		0.005	0.01	0.02-0.05	0.05		0.001	0.01	0.02	0.05	0.001
Plata	mg/l	0.10[7]	0.0032						0.0001	0.05			0.0001
Sodio	mg/l				≤200[9]								
Sulfatos	mg/l	250[7]			≤500[9]		1000			400			
Sulfuros	mg/l			0.002	≤0.05[9]								
TDS	mg/l	500[7]	250	250	≤500[9]	500-3500	3000						
Talio	mg/l	0.002							0.0008	0.018[23]			0.0004
Turbiedad	UNT	0.3-5.0 NTU			≤0.1-1.0 NTU[9]			8-80 NTU		3 NTU			
Uranio	µg/l	30			20	10	200	33	15	100[23]	10	200	20
Vanadio						0.1	0.1				0.1 mg/l	0.1 mg/l	0.1 mg
Zinc	mg/l	5[7]	0.12	0.12	≤5.0[9]	1.0-5.0	50		0.03	5	2	0,05	0.03
Bario	mg/l									1[23]			
Trihalometanos Totales	THMs												
Hidrocarburos Aromáticos Policíclicos (HAP)	HAP												
Carbono Orgánico Total	COT												

1. U.S. Environmental Protection Agency (US EPA). 2009. National Recommended Water Quality Criteria: http://water.epa.gov/scitech/swguidance/standards/criteria/current/upload/nrwqc-2009.pdf.

2. Canadian Council of Ministers of the Environment. 2005. Canadian water quality guidelines for the protection of agricultural water uses: Summary table. Updated October 2005. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg. http://st-ts.ccme.ca/.

3. Health Canada. 2012. Guidelines for Canadian Drinking Water Quality—Summary Table. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. http://publications.gc.ca/collections/collection_2013/sc-hc/H129-24-2012-eng.pdf.

4. Canadian Council of Ministers of the Environment. 2007. Canadian water quality guidelines for the protection of aquatic life: Summary table. Updated December, 2007. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg. http://www.halifax.ca/environment/documents/CWQG.PAL.summaryTable7.1.Dec2007.pdf.

5. US EPA. 2009. National Primary Drinking Water Regulations: http://water.epa.gov/drink/contaminants/upload/mcl-2.pdf.

6. Canadian Council of Ministers of the Environment. 2012. Canada Environmental Quality Guidelines Summary Table, Water Quality Guidelines for the Protection of Aquatic Life. http://st-ts.ccme.ca/.

7. US EPA National Secondary Drinking Water Regulations: non-enforceable guidelines regarding contaminants that may cause cosmetic effects or aesthetic effects. See [5]

8. Action level to control corrosiveness.

9. República Argentina. Ley de Residuos Peligrosos 24.051 Decreto 831/93.
Anexo II Tabla 2 Niveles guia de calidad de agua para protección de vida acuática. Agua dulce superficial. http://www2.medioambiente.gov.ar/mlegal/residuos/dec831/dec831_anxII_t2.htm
Anexo II Tabla 5 Niveles guia de calidad de agua para irrigación. http://www2.medioambiente.gov.ar/mlegal/residuos/dec831/dec831_anxII_t5.htm
Anexo II Tabla 6 Niveles guia de calidad de agua para bebida de ganado. http://www2.medioambiente.gov.ar/mlegal/residuos/dec831/dec831_anxII_t6.htm

10. Guideline for total ammonia is temperature and pH dependent, please consult factsheet for more information.

11. Guidelines are hardness-dependent, values given are if water hardness is not known; see links to equations in [6]

12. US EPA. 2007. AQUATIC LIFE AMBIENT FRESHWATER QUALITY CRITERIA – COPPER. Office of Water.
http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/copper/upload/2009_04_27_criteria_copper_2007_criteria-full.pdf
Presents copper guidelines for specific plant and animal species. General guidelines given from: Quality Criteria for Water, 1986 (Gold Book).

13. Represents the Maximum Residual Disinfectant Level (MRDL) regulation: The highest level of a disinfectant allowed in drinking water.

14. A routine sample that is fecal coliform-positive or E. coli-positive triggers repeat samples--if any repeat sample is total coliform-positive, the system has an acute MCL violation. A routine sample that is total coliform-positive and fecal coliform-negative or E. coli-negative triggers repeat samples—if any repeat sample is fecal coliform-positive or E. coli-positive, the system has an acute MCL violation.

15. No more than 5.0 percent samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or E. coli. If two consecutive TC-positive samples, and one is also positive for E. coli or fecal coliforms, system has an acute MCL violation.

16. Canada has no required maximum acceptable concentration for chlorine in drinking water, but free chlorine concentrations in most Canadian drinking water systems range from 0.04 to 2.0 mg/L.

17. Includes multiple reactive chlorine species: total residual chlorine, combined residual chlorine, total available chlorine, hypochlorous acid, chloramine, combined available chlorine, free residual chlorine, free available chlorine, chlorine-produced oxidants.

18. Código Alimentario Argentino de la República Argentina (Capítulo XII). Aprobado por Ley 18.284. http://www.anmat.gov.ar/alimentos/codigoa/Capitulo_XII.pdf

19. The data corresponds to Amonia (NH_4^+)

20.Fluoride (F^-): For fluoride, the maximum quantity depends on the average temperature of the area, taking into account the daily drinking water intake
(Fluoruro (F^-): para los fluoruros la cantidad máxima se da en función de la temperatura promedio de la zona, teniendo en cuenta el consumo diario del agua de bebida):
- Temperatura media y máxima del año (°C) 10,0 - 12,0, contenido límite recomendado de Flúor (mg/l), límite inferior: 0,9: límite superior: 1, 7:
- Temperatura media y máxima del año (°C) 12,1 - 14,6, contenido límite recomendado de Flúor (mg/l), límite inferior: 0,8: límite superior: 1,5:
- Temperatura media y máxima del año (°C) 14,7 - 17,6. contenido límite recomendado de Flúor (mg/l), límite inferior: 0,8: límite superior: 1,3:
- Temperatura media y máxima del año (°C) 17,7 - 21,4, contenido límite recomendado de Flúor (mg/l), Límite inferior: 0,7: límite superior: 1,2:
- Temperatura media y máxima del año (°C) 21,5 - 26,2, contenido límite recomendado de Flúor (mg/l), límite inferior: 0,7: límite superior: 1,0:
- Temperatura media y máxima del año (°C) 26,3 - 32,6, contenido límite recomendado de Flúor (mg/l), límite inferior: 0,6; límite superior: 0,8:

21. El dato corresponde al Pentaclorofenol, máximo: 10 ug/l;

22. Residual active chlorine (Cloro activo residual) (Cl) minimum: 0,2 mg/l. Argentina has no required maximum acceptable concentration for chlorine in drinking water, but Argentina has required minimum acceptable 0,2 mg/l.

23. Decreto 831/93 de la República Argentina **ANEXO II** TABLA 1 - Niveles guía de calidad de agua para fuentes de agua de bebida humana con tratamiento convencional. (Ley de Residuos Peligrosos 24.051) http://www2.medioambiente.gov.ar/mlegal/residuos/dec831/dec831_anxII_t1.htm