Arsenic in Baja California Sur: Occurrence in Soil, Water, and Mineral Deposits and Remediation Technologies and Their Estimated Costs

Foro Agua y Arsenico: Problematica de Baja California Sur/
Water and Arsenic Forum: Problems in Baja California Sur
La Paz, BCS, Mexico, December 9-10, 2011

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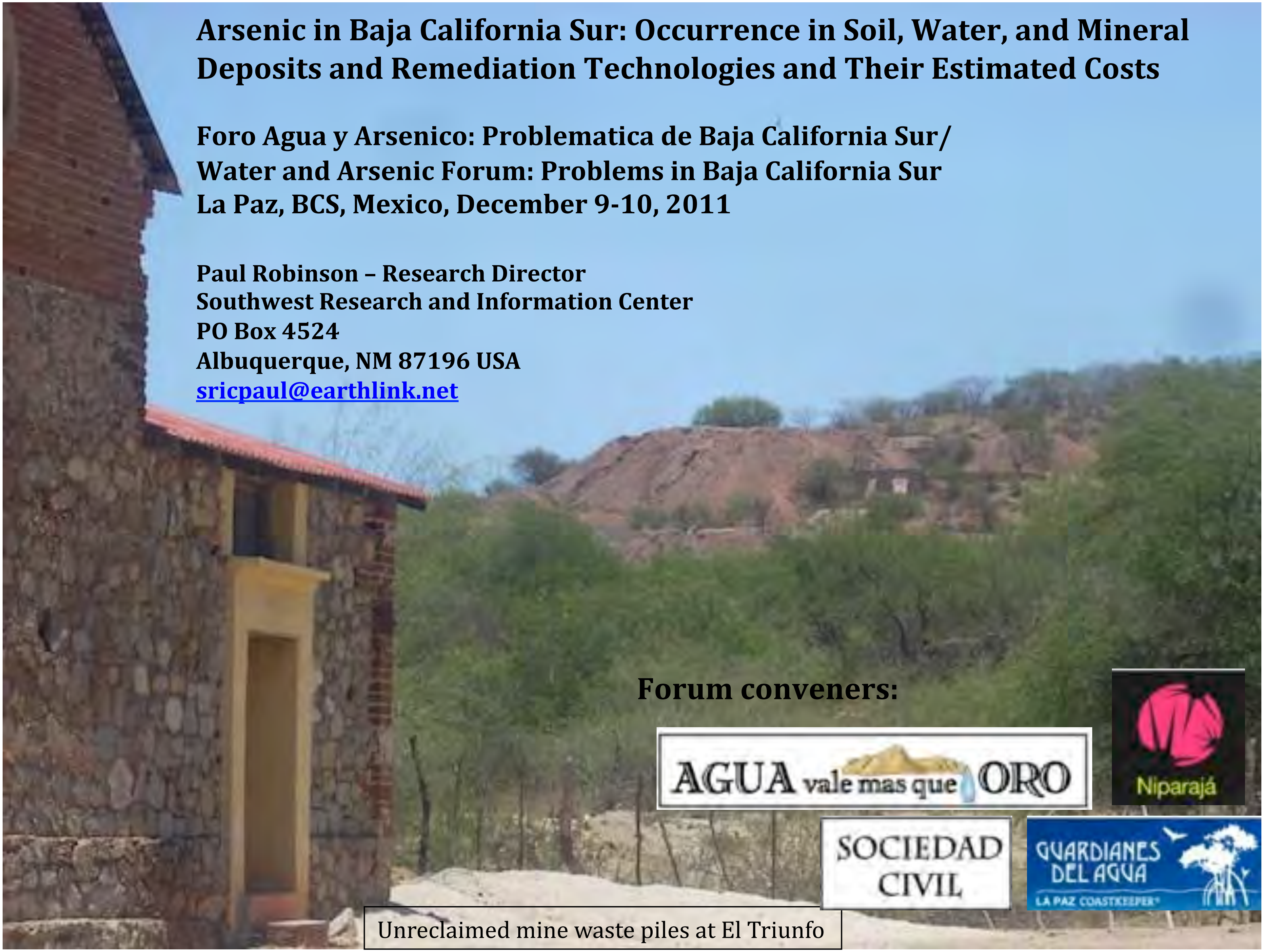

Forum conveners:

AGUA vale mas que ORO

Niparajá

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Unreclaimed mine waste piles at El Triunfo

San Antonio

El Triunfo

Background – "The San Antonio-El Triunfo mining district,, has been worked since the late 1700s. Mine waste material produced during 200 years of mineral extraction area poses a risk of local groundwater pollution and eventually, regional pollution to the Carrizal (west basin) and the Los Planes (east basin) aquifers. There are different types of deposits in the mining area. These are dominated by epithermal veins, in which arsenopyrite is an important component.

"[E]ven though the amount of mine waste is relatively small in comparison to the large scale area, significant As in groundwater derived from the mine waste piles is found locally in the groundwater…. The highest values of total dissolved solids (TDS) and As are in the mineralized area where the mining operations occurred (~1500 ppm TDS and 0.41 ppm As). The lowest concentrations of TDS and As are, in general, away from the mineralized area (~500 ppm TDS and 0.01 ppm As).

A. Carrillo-Chávez, J. I. Drever and M. Martínez, Arsenic content and groundwater geochemistry of the San Antonio-El Triunfo, Carrizal and Los Planes aquifers in southernmost Baja California, Mexico, Environmental Geology, V39N11, October, 2000 http://www.springerlink.com/content/2mblv6p7lldmbm4q/

Arsenic in Water and Soil Contamination in San Antonio–El Triunfo Area

(Water data – mg/l Soil data (bioavailable arsenic) – mg/kg)

For comparison:Arsenic drinking water standard (WHO) – 0.01 mg/l//
background soil 0.46 mg/kg

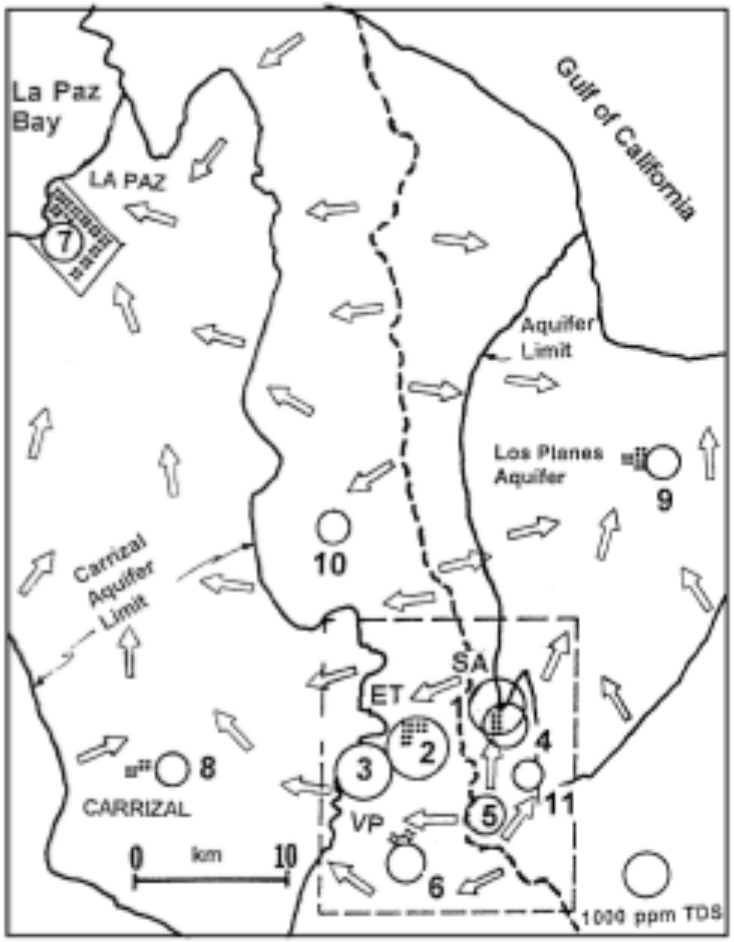
“Soil arsenic contamination in the Cape Region, BCS, Mexico”, A. Naranjo-Pulido, et al, 2002, J.Environ.Biol.23(4), 2002 www.bashanfoundation.org/ortega/ortega**soilarsenic**.pdf

“Mining Activities and Arsenic in a Baja California Sur Watershed”, A. Naranjo-Pulido et al, 2000, USDA Forest Service Proceedings RMRS0P-13, 2000
http://www.treesearch.fs.fed.us/pubs/36036

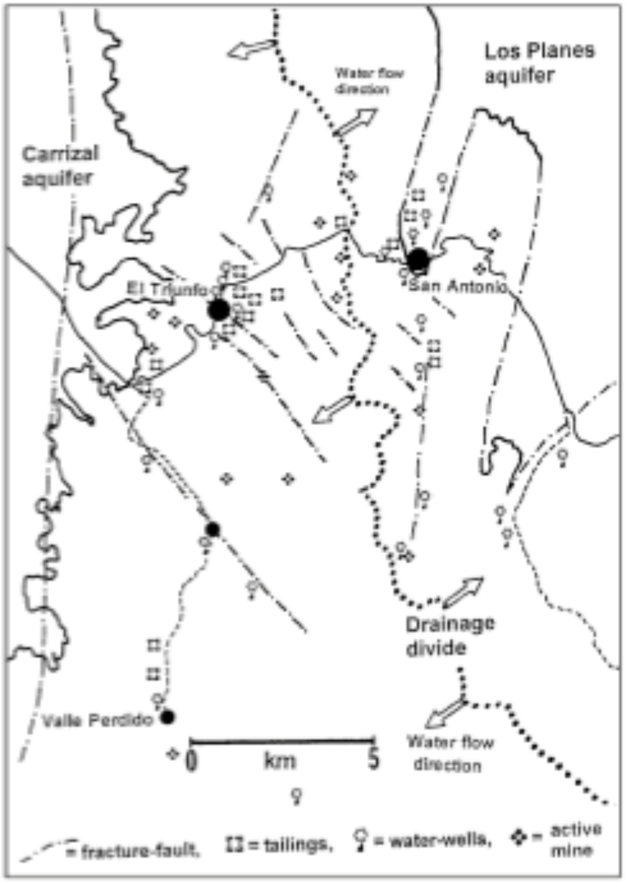
Arsenic flow direction and mobility

"[A] good estimate for the total time for the groundwater to reach the Los Planes area would be in the range of 50 to several hundred years."

"…arsenic concentrations vary seasonally, especially after the heavy summer thunderstorms."



General geohydrological map of the SA-ET area and the Carrizal and the Los Planes alluvial aquifers.
Arrows indicate the general groundwater direction flow. ..Circles with numbers indicate subareas. Diameter of circles indicates the relative amount of TDS. 1 San Antonio spring (SA-spring); 2 El Triunfo (ET); 3 Tule; 4 San Antonio, 5 Testera, 6 Rosario-Valle Perdido, 7 La Paz, 8 Carrizal, 9 Los Planes, 10 Salto, 11 Fundicion. Diameter of circle in the lower right corner is for scale only and indicates 1000 ppm TDS



San Antonio and El Triunfo mineralized area with selected fractures, tailings piles, water wells and active mine sites.

From "Arsenic content and groundwater geochemistry of the San Antonio- El Triunfo, Carrizal and Los Planes aquifers in southernmost Baja California, Mexico", A. Carrillo-Chávez et al, Environmental Geology (39) 11, October 2000
http://www.springerlink.com/content/2mblv6p7lldmbm4q/

How far has Arsenic spread from the old mine workings?

"The anthropogenic influence of those elements is reflected in the arroyo sediments as far as 18 km away from the [Mining District at El Triunfo], whereas the samples closest to the discharge into the Pacific Ocean show a natural to moderate enrichment for As and Zn and low or no enrichment for Hg and Pb."

Study Area– Geologic map with location of sampling site in the main arroyo (Hondo-Las Gallinas–El Carrizal)

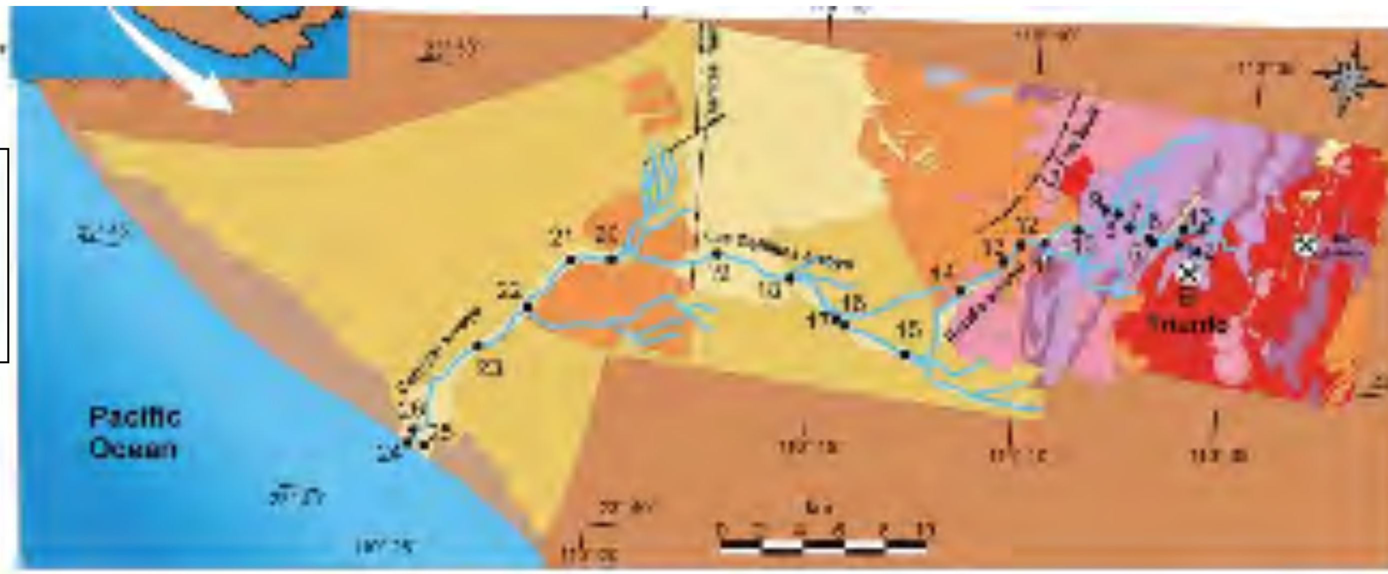


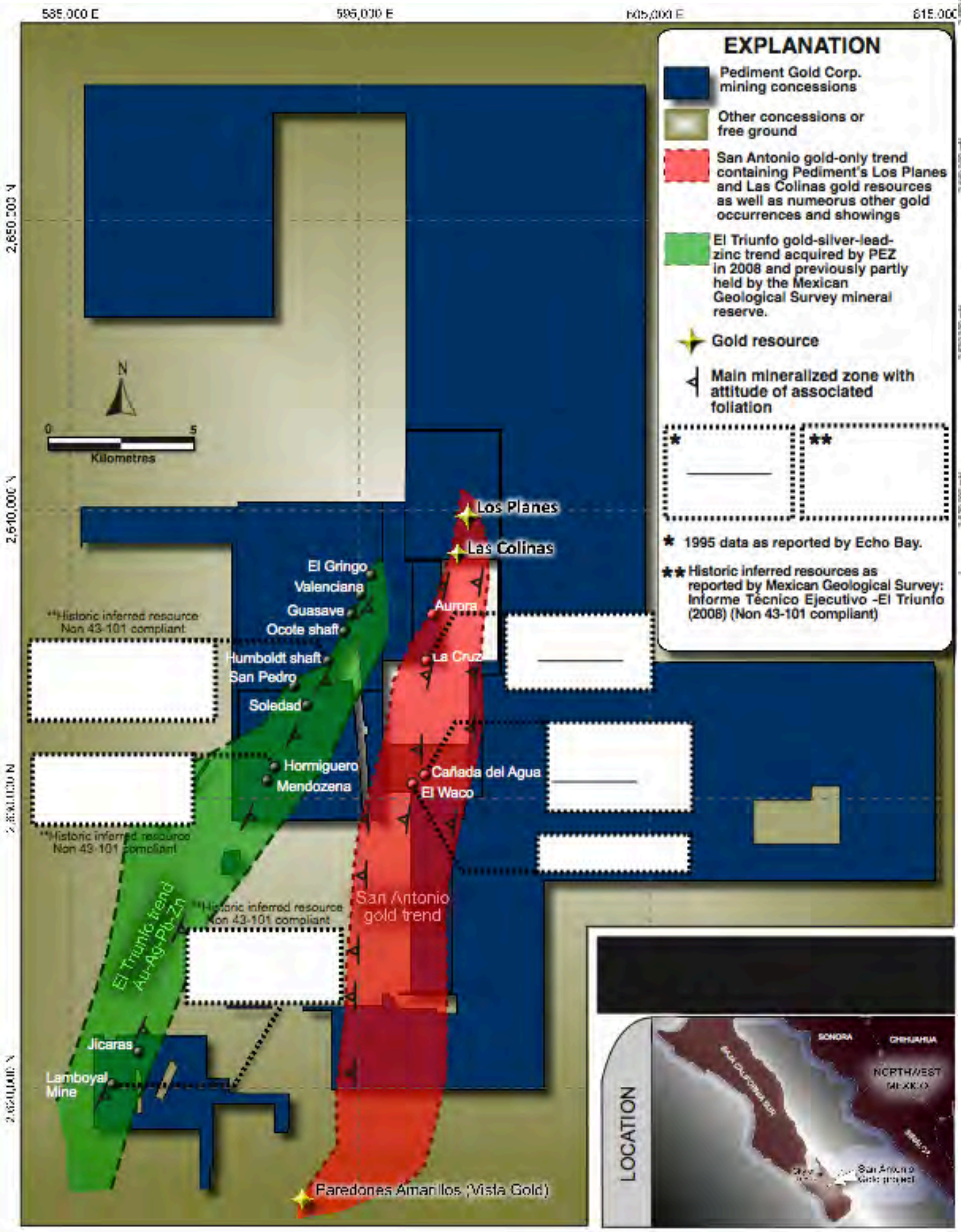
Table showing the range of elements determined [in soil], means and standard deviation(s) of background levels (BLs), normalized enrichment factors (NEFs) in the gold mining district and its main arroyo. Regional contents and other world systems impacted by gold mines(b)

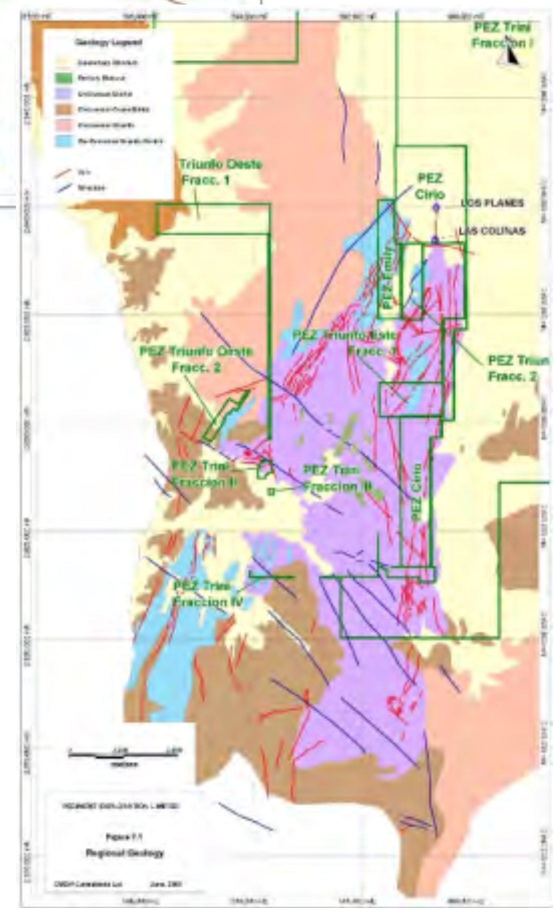
	As (mg kg^{-1})	Hg (ng g^{-1})	Pb (mg kg^{-1})	Zn (mg kg^{-1})	Al (mg g^{-1})	Fe (mg g^{-1})	Li (mg kg^{-1})	Mn (mg kg^{-1})
Range ($n = 26$)[a]	2.8–412	<5 to 217	10.7–1230	14–1950	42.3–92.9	5.5–153	7.3–27.8	97–3390
Background value[b] (mean ± s)	7.9 ± 2.7	10.5 ± 5.3	19.2 ± 9.2	28.9 ± 10.5	78.6 ± 8.1	41.7 ± 16.0	9.9 ± 2.4	900 ± 645
NEF (1–17 stations) UCC[c] (mean ± s)	85 ± 52	2.1 ± 1.5	27 ± 22	12.6 ± 7.7	—	—	—	—
NEF (1–17 stations) BL[b] (mean ± s)	22 ± 13	7.5 ± 5.2	24 ± 19	22 ± 21	—	0.96 ± 0.43	—	—
NEF (18–26 stations) UCC[c] (mean ± s)	5.1 ± 2.3	0.4 ± 0.5	2.5 ± 1.7	0.8 ± 0.3	—	—	—	—
NEF (18–26 stations) BL[b] (mean ± s)	3.2 ± 3.9	1.24 ± 1.67	2.8 ± 2.7	3.0 ± 2.6	—	1.2 ± 2.1	—	—
Tailing[a]	8890	336	92 700	49 600	17.6	173	7.1	1390
Ashes[d] (range)	363 000–505 000	2250–54 900	2170–19 300	565–1380	1.5–3.2	6.9–12.6	<0.5–2	15–137

"Migration of As, Hg, Pb, and Zn in arroyo sediments from a semiarid coastal system influenced by the abandoned gold mining district at El Triunfo, Baja California Sur, Mexico", Ana Judith Marmolejo-Rodrıguez, et al, *J.Environ. Monit.*, 2011, **13**, 2182-2189
http://pubs.rsc.org/en/Content/ArticleLanding/2011/EM/c1em10058

Location of Argonaut Mining Concessions

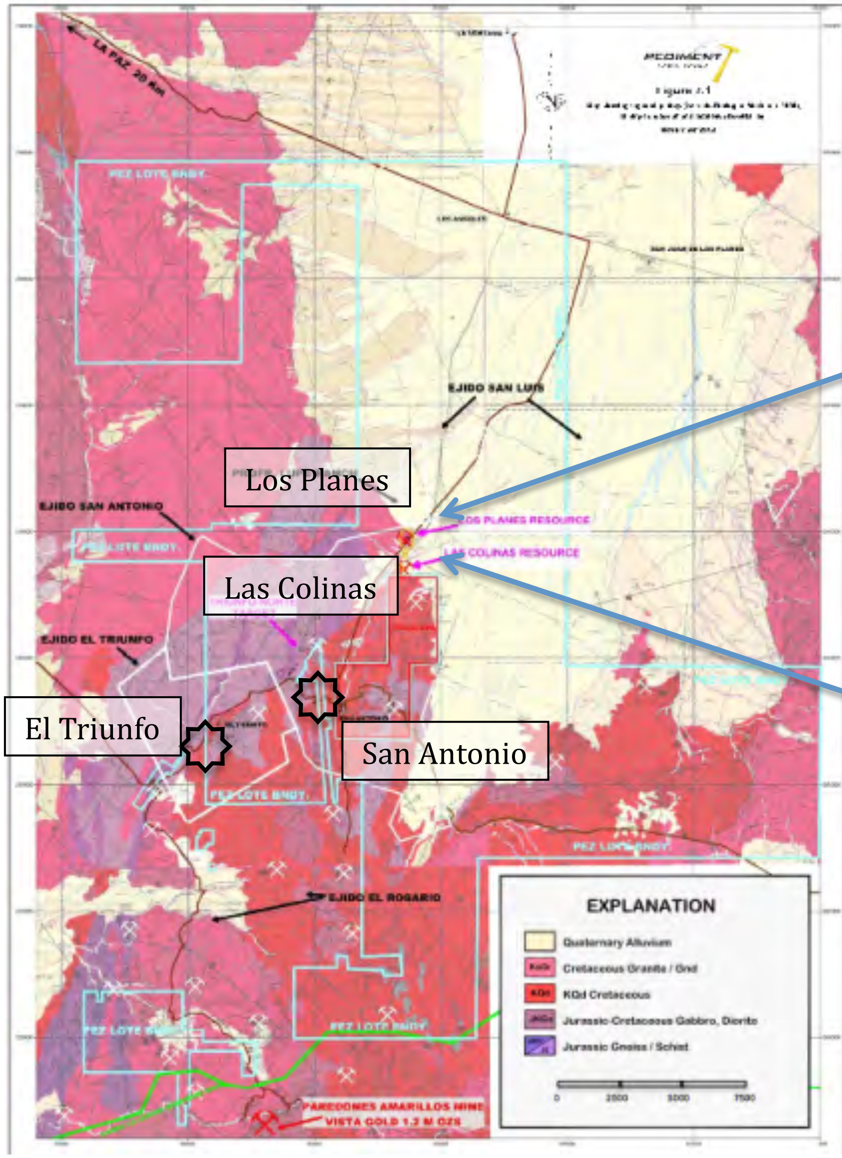
From Argonaut and Pediment Technical Reports

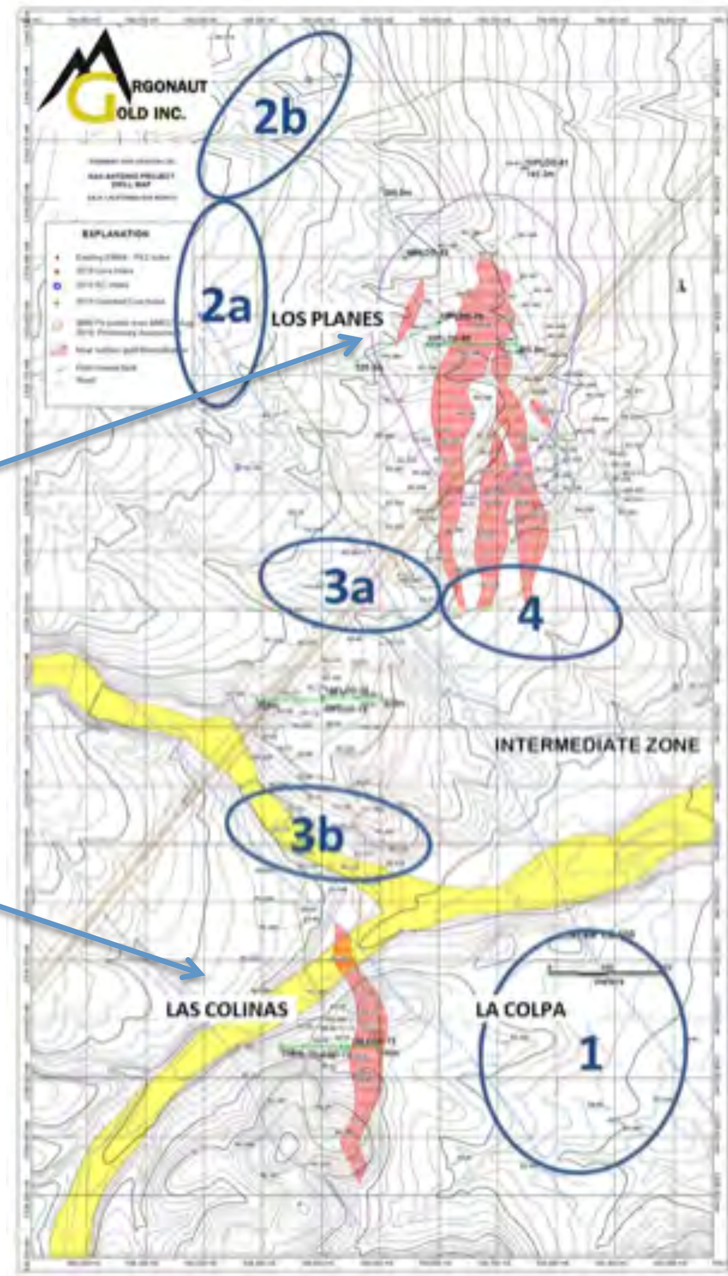




The Argonaut San Antonio Project Mineral Deposits are in the upper portions of the Los Planes Alluvial Aquifer which is currently used for to supply water to the City of La Paz and other users.

Figures from 6-2011 Argonaut San Antonio Project NI 43-101 Technical Report
http://www.argonautgoldinc.com/s/TechnicalReports.asp





What Plans have been published for the San Antonio Project?

"**Planned Open Pit Mining Operations** - "Sufficient mineral resources were estimated in the Los Planes and Las Colinas deposits to support a Preliminary Assessment. AMEC cautions that the Preliminary Assessment is partly based on Inferred Mineral Resources that are considered too speculative geologically to have the economic considerations applied to them that would enable them to be categorized as Mineral Reserves, and there is no certainty that the Preliminary Assessment based on these Mineral Resources will be realized."

"AMEC developed a conventional open pit mine plan for San Antonio and established a practical mining schedule for an 11,000 t/d gold heap leach project."

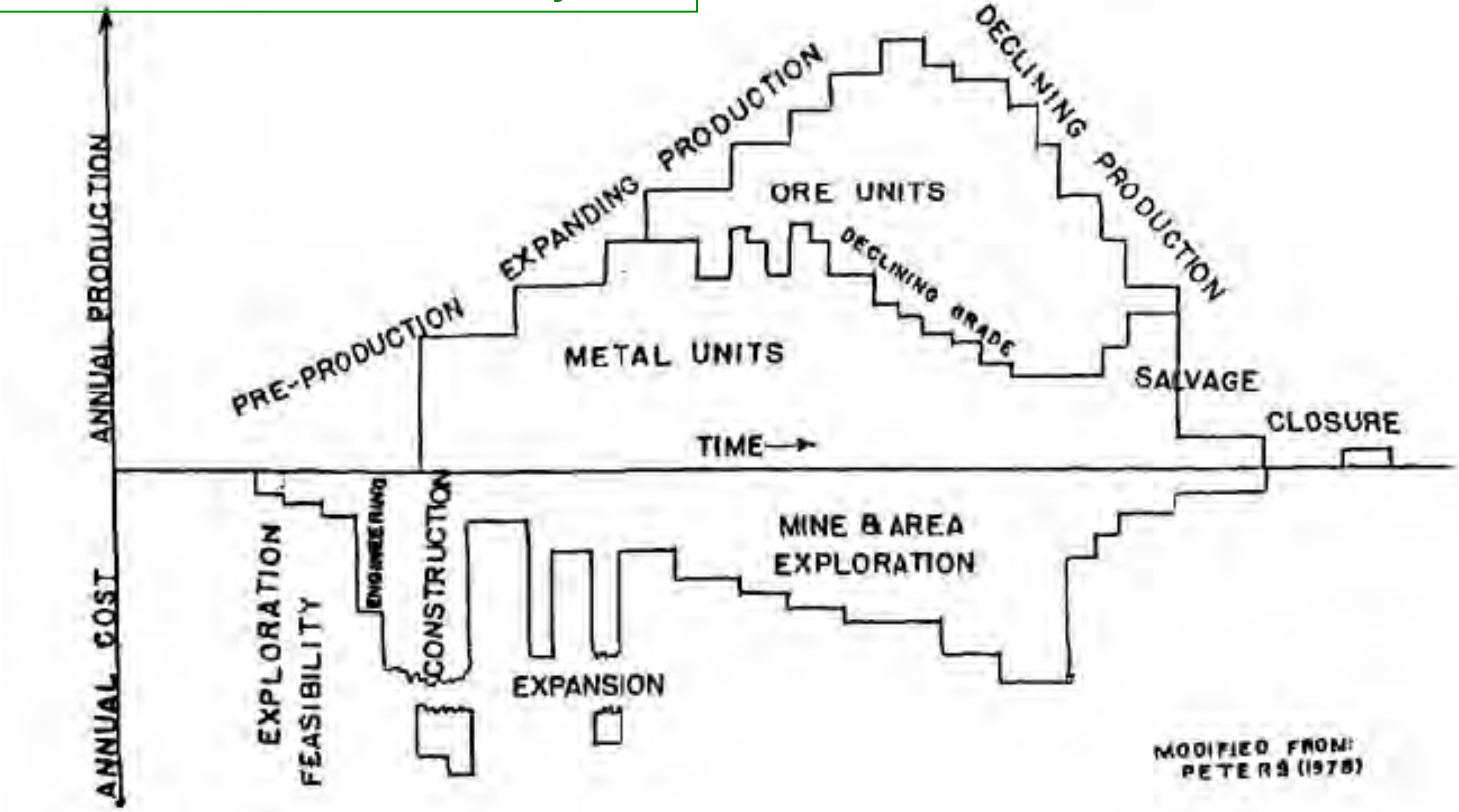
"Of the mineralization considered in the schedule, <3% is classified as Inferred Mineral Resources."

"**Processing Plant** - "The preliminary design … consists of the following key elements:

- **A permanent leach facility with mineralization stacked in 6 m lifts**. The heap is designed as a permanent single-use facility, and will require topography suitable to contain the storage capacity requirements that will provide a positive flow of solution to an external solution collection area and ensure side slope grades that allow construction of stable liner systems and stable geotechnical conditions;
- **A maximum mineralization height over liner of 36 m**;
- **A composite liner system to contain process solutions within the facility**;
- **Upstream and hillside diversion channels to collect and route surface water runoff around the facility**. Non-impacted surface water flows will be routed through engineered surface water channels and discharged down-gradient of the facility;
- **PLS [pregnant leach solution] pond, barren pond and contingency (storm) pond to provide operational flexibility, contingency capacity for upset conditions, and to allow environmental monitoring**. The contingency pond will be located adjacent to the PLS pond, and connected to it by a lined spillway….
- **Integrated leak collection and recovery system (LCRS) layer and sump** for the PLS pond."

8-2010 Pediment San Antonio Project NI 43-101 Tech. Rpt. on Preliminary Assessment
http://www.argonautgoldinc.com/s/TechnicalReports.asp

Mine Life Cycle and Mine Financial Life Cycle



The sequence of activities in the life of a mine can be called the "mining life cycle". In this figure, above the "Time" line, a bar graph that shows a "typical" rise and fall of ore production and onset of closure activities in the mining cycle. Below the "Time" line, the bar graph shows the rise and fall of capital and operating costs during the mining cycle.

The types of environmental and social impacts, the types of public policy decisions and the economical and financial aspects of mines vary widely for the different phases of mining activity.

How much old mine waste and Arsenic are in the San Antonio-El Triunfo area?

"There are between 800,000 and 1 million tons of mine waste materials scattered in the 350–400 km2 area of the SA-ET region. These materials have been classified by Carrillo as: (1) oxidized tailings, (2) low-grade mineral ore, (3) cyanide heap-leached material, and (4) by- products of old, mineral processing plants (smelters), mostly arsenic trioxide ("arsenolite", As2O3). The ruins of at least three old mineral-processing plants whose chambers are partially filled with arsenolite remain in the area and contain [about] 600 tons of arsenolite. The arsenic content in all the mine waste material ranges from >1 to 30 wt%."

A. Carrillo-Chávez, J. I. Drever and M. Martínez, Arsenic content and groundwater geochemistry of the San Antonio-El Triunfo, Carrizal and Los Planes aquifers in southernmost Baja California, Mexico, Environmental Geology, V39N11, October, 2000 http://www.springerlink.com/content/2mblv6p7lldmbm4q/

Who is responsible for the environmental effects of the the old mine wastes?

According to Agronaut Gold, they have signed a *"*San Antonio Ejido Assignment of Dumps Agreement - The San Antonio ejido concluded an agreement with Pitalla on December 9, 2009, under which Pitalla has assigned all Pitalla's rights to dump material that fall within Pediment Gold-owned concessions, and are within San Antonio ejido land. The dumps are related to previous mining activity.

*"**The San Antonio ejido will bear all environmental responsibilities inherent to the removal or disposition of the dumps**." (emphasis added)*

- 6-2011 Argonaut, San Antonio Project NI 43-101 Technical Report p. 4-14 http://www.argonautgoldinc.com/s/TechnicalReports.asp

What is the concentration of Arsenic in the San Antonio Mineral Deposits?

Table 3.2
San Antonio Project
ICP Multi-Element Scan on Head Sample

Element	Symbol	Units	Oxide Composite	Mix Composite	Sulfide Composite
Aluminum	Al	%	9.15	9.06	7.9
Arsenic	As	ppm	930	142	3436
Barium	Ba	ppm	986	952	1575
Calcium	Ca	%	1.68	1.42	1.46
Cadmium	Cd	ppm	14	2	45
Cobalt	Co	ppm	22	20	24
Chromium	Cr	ppm	154	65	126
Copper	Cu	ppm	154	167	237
Iron	Fe	%	7.19	7.08	7.52
Mercury	Hg	ppm	<0.001	<0.001	<0.001
Magnesium	Mg	%	1.52	1.47	1.38
Titanium	Ti	ppm	4115	4054	4667
Vanadium	V	ppm	163	144	166
Zinc	Zn	ppm	109	75	58

The ICP multi-element scan results indicate the following:

- The arsenic assays ranged from 142 to 3436 parts per million. The sulfide composite revealed the highest amount of arsenic when compared to the oxide and mix composites.

San Antonio Project Column Leach Testing…METCON August 2009
http://www.argonautgoldinc.com/s/MetallurgicalReports.asp

How much Arsenic is likely to be in the San Antonio Project Mineral Deposits?

San Antonio Project (Mineral Resource from Pediment 43-101 Tech Rpt. 6/2011)	Tons	Gold (Au) (average g/t 1 gram/ton = I part per million (ppm)	Gold (**kilograms**)	Arsenic (As) (average ppm from composite samples in 8/2010 METCON Rpt.)	Arsenic (**tons**; kilograms x 1000 based on average from composites)
Las Colinas Deposit – (deposit only, waste rock volume not identified)					
Oxide/Transition					
Measured Resource	248,000	0.76	187	930 (0.093%)	23.1
Indicated Resource	970,000	0.71	689	930	90.2
Sulphide					
Measured Resource	360,000	0.72	260	3,436 (0.34%)	1,236.9
Indicated Resource	5,447,000	0.84	4,569	3,436	18,715.9
Los Planes Deposit - (deposit only, waste rock volume not identified)					
Oxide/Transition					
Measured Resource	6,297,000	0.92	5,804	930	5,856.2
Indicated Resource	8,689,000	0.90	7,830	930	8,080.7
Sulphide					
Measured Resource	3,935,000	1.30	5,111	3,436	13,520.7
Indicated Resource	22,098,000	1.03	22,794	3,436	75,928.7

Old Mine Waste at	800,000 (estimate)	if 10,000 (1%)	800
San Antonio/El Triunfo	800,000 (estimate)	if 30,000 (3%)	2,400
Old Processing Waste	(arsenolite volume at old processing sites estimated at 600 tons)		

From A. Carrillo-Chávez, J. I. Drever and M. Martínez, Arsenic content and groundwater geochemistry of the San Antonio-El Triunfo, Carrizal and Los Planes aquifers in southernmost Baja California, Mexico, Environmental Geology, V39N11, October, 2000 http://www.springerlink.com/content/2mblv6p7lldmbm4q/

Arsenic contamination is not the only potential risk to water quality from the San Antonio Project deposits.

Significant Sulphide Mineral Content Indicates Significant Potential for Acid Generation

"Los Planes - Typically, the cataclasite contains a zone where sulphides increase with abundance to as much as 20%. Pyrite appears more commonly throughout the system; however the more intense development of mineralization is accompanied by an increase of arsenopyrite and pyrite in addition to pyrrhotite. Sulphides are present in brittle structures including cracks, faults, joints and micro-fractures. Pyrite lines the walls of many fractures and joints as observed from drill core and outcrop. Quartz veining is also common.

"Las Colinas - The Las Colinas deposit consists of gold and arsenic occurring with disseminated and veinlet sulphides associated with cataclasite and locally extending into the wall rocks….

"The gold mineralization is interpreted to consist of two stages, the first being disseminated gold-arsenic deposition during mylonitization, and a second stage gold-silver-bismuth mineralization hosted by crosscutting, high-angle, northeast-trending structures. The primary alteration assemblage consists of sericite, 2-5% sulphides including pyrite, arsenopyrite, pyrrhotite, and minor quartz and K-feldspar.

Argonaut, San Antonio Project NI 43-101 Technical Report June 2011 p. 9-1 (79 of 166)
http://www.argonautgoldinc.com/s/TechnicalReports.asp

Heavy metal contamination is not the only risk to the Los Planes aquifer. The Las Planes aquifer already suffers from both overdrafting - water recharge less than water extraction - and saline intrusion.

M2.8 Overdrafted aquifers by Hydrological-Administrative Region, 2008

SOURCE: CONAGUA. Deputy Director General's Office for Technical Affairs. Groundwater Department.

M2.9 Aquifers with saltwater intrusion and/or suffering from the phenomenon of soil salinization and brackish groundwater, 2008

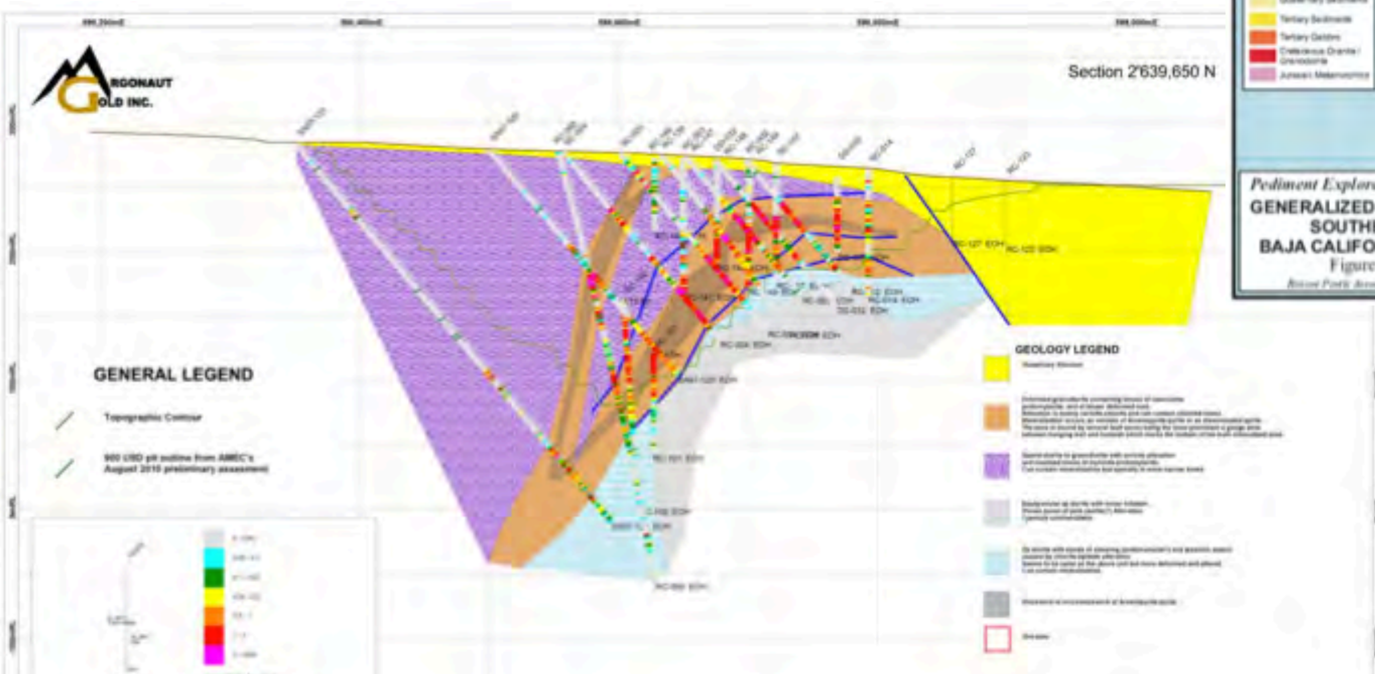
SOURCE: CONAGUA. Deputy Director General's Office for Planning. Produced based on: CONAGUA. Deputy Director General's Office for Technical Affairs. Groundwater Department.

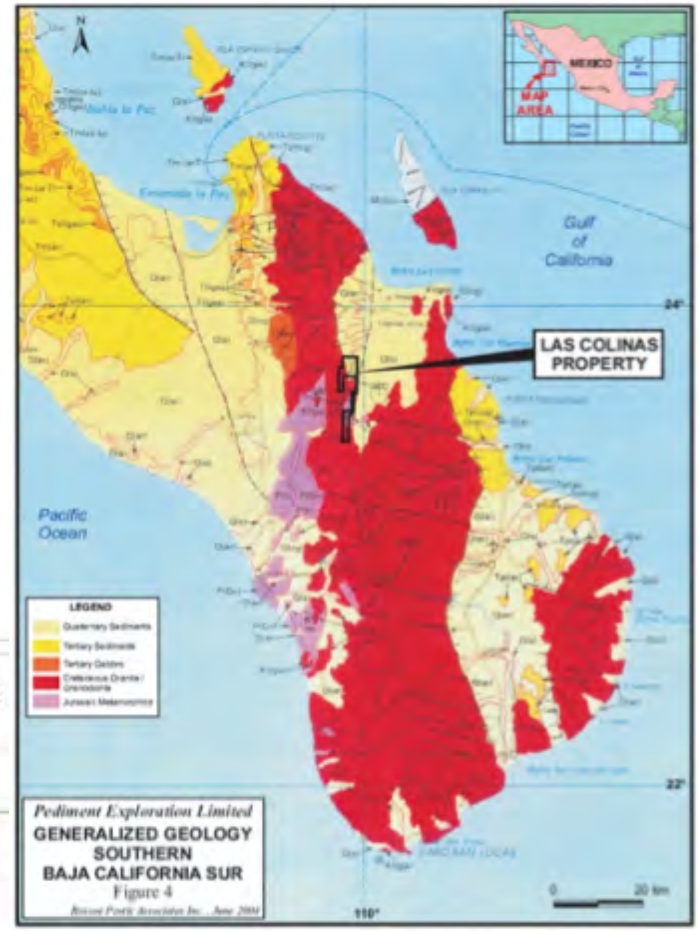
"Aquifers with saltwater intrusion and/or suffering from the phenomenon of soil salinization and brackish groundwater For 2008, saltwater intrusion had been encountered in 16 aquifers nationwide, located in the states of Baja California, Baja California Sur, Sonora and Veracruz de Ignacio de la Llave. The [affected aquifers in Baja California Sur] are ……Santo Domingo, **Los Planes**, La Paz and Mulegé. "

Statistics on Water in Mexico - 2010, June 2010
www.conagua.gob.mx/english07/.../EAM2010Ingles_**Baja**.pdf

The Los Planes deposit unlies the upper portion of the Los Planes Aquifer. The deposit has been drilled to a depth of 300 meters below surface.

Potential water resources impacts of mine and processing operations including mine dewatering, wind blown deposition from waste rock, blasting and heap leach pile, and releases of seepage to groundwater are not addressed in Company Technical Report to date.





Figures from 6-2011 Argonaut San Antonio Project NI 43-101 Technical Report
http://www.argonautgoldinc.com/s/TechnicalReports.asp

"Possible Treatments for Arsenic Removal in Latin American Waters for Human Consumption" (p. 1 of 4)

Marta I. Litter et al, Environmental Pollution, Vol. 158, Issue 5, May 2010, Pages 1105-1118 (Litter 2010)
http://www.sciencedirect.com/science/article/pii/S0269749110000564

"Considering the toxic effects of arsenic, the World Health Organization recommends a maximum concentration of 10 mg/L of arsenic in drinking water. Latin American populations present severe health problems due to consumption of waters with high arsenic contents.

"The physicochemical properties of surface and groundwaters are different from those of other more studied regions of the planet, and the problem is still publicly unknown. Methods for arsenic removal suitable to be applied in Latin American waters are here summarized and commented.

"Conventional technologies (oxidation, coagulation– coprecipitation, adsorption, reverse osmosis, use of ion exchangers) are described, but emphasis is made in emergent decentralized economical methods as the use of inexpensive natural adsorbents, solar light technologies or biological treatments, as essential to palliate the situation in poor, isolated and dispersed populations of Latin American regions."

“**Possible Treatments for Arsenic Removal in Latin American Waters for Human Consumption**” (Litter, 2010, 2 of 4)

“To evaluate arsenic contents in waters and soils or to select a removal technology, it is essential to have suitable methodologies for quantitative measurement of low arsenic concentrations, mainly due to the low detection and levels that must be attained….

“From a technical point of view, the physicochemical and microbiological characteristics of the waters and the available materials in the region will determine the most convenient technology for removal of arsenic in each site. The selection of the method depends greatly on arsenic speciation, chemical composition of the water, reduction potential, hardness, presence of silica, sulfate, phosphate, iron and other chemical species, volumes to be treated and degree of sophistication that may be applied.

“All technologies rely on a few basic chemical processes that can be applied alone, simultaneously or in sequence: oxidation/reduction, coagulation–filtration, precipitation, adsorption and ion exchange, solid/liquid separation, physical exclusion, membrane technologies, biological methods, etc.

“The most common technologies include processes that can be used alone or in combination, such as oxidation, coprecipitation and adsorption onto coagulated flocs, lime treatment, adsorption onto suitable surfaces, use of ion exchange resins and membrane technologies. Most of them are confident and well understood technologies for arsenic removal in large and medium scale treatment plants for centralized services.”

“**Possible Treatments for Arsenic Removal in Latin American Waters for Human Consumption**” (Litter, 2010, 3 of 4)

ADVANTAGES AND DISADVANTAGES OF CONVENTIONAL TECHNOLOGIES FOR ARSENIC REMOVAL		
TECHNOLOGY	ADVANTAGES	DISADVANTAGES
Oxidation and reduction Solid obtained can be removed through sedimentation and filtration.	Simple. Small installation costs. Easily applied to large water volumes. Arsenite can be directly oxidized by a number of chemicals and/or UV light.	Some oxidants produce toxic and carcinogenic by-products. Needs further removal treatment.
Precipitation	Solid obtained can be removed through sedimentation and filtration.	Solids rather unstable and inadequate for direct disposal as they will produce As-containing liquid residues.
Coagulation/filtration	Simple. Easily applied to large water volumes. Effective when As(V) is the only pollutant. Low capital and operative costs. Alum allows F removal.	Low removal efficiency. pH needs adjustment. Disposal of the arsenic-contaminated coagulation sludge may be a concern. Low removal efficiency. Filtration needed. As(III) must be previously oxidized.
Lime softening	pH > 10.5 provides efficient As removal. Efficient to treat water with high hardness.	Low efficiency. High coagulant dose. High pH in the effluent. May require secondary treatment.
Adsorption (activated alumina, iron oxides/hydroxides, TiO2, cerium oxide, metals)	Simple. Not other chemicals required. Highly selective towards As(V). Effective with water with high TDS. Useful at community or household levels.	Moderate efficiency. Regeneration needed. Interferences: Se, F], Cl and SO4(-2). Application of point-of-use treatment devices needs regeneration and replacement.
Reverse osmosis and nanofiltration	Useful at community or household levels. Minimal membrane operation and maintenance. Highly effective towards As, effective in treating water with high TDS	Only low As levels can be treated. Poor As(III) removal. For high water volumes, multiple membrane units required. Low water recovery rates (10–20%). High electrical consumption. High capital and operation costs. Membrane fouling. Many interferences. 20–25% water rejection. Other ions can be removed
Electrodialysis, electrodialysis with reversion of polarity of the electrodes	Efficiency similar to reverse osmosis, effective in treating water with high TDS. Minimize scaling by periodically reversing the flows of dilute and concentrate and polarity of the electrodes.	Very high costs.
Ion exchange	Effective removal. Not pH and influent concentration dependent.	As (III) is not removed. Sulfate, TDS, Se, F and NO 3 interfere. SS and precipitated iron cause clogging. May require pretreatment.

"**Possible Treatments for Arsenic Removal in Latin American Waters for Human Consumption**" (Litter, 2010, 4 of 4)

ADVANTAGES AND DISADVANTAGES OF EMERGENT TECHNOLOGIES FOR ARSENIC REMOVAL		
TECHNOLOGIES	ADVANTAGES	DISADVANTAGES
In-situ remediation (PRBs)	Low operational costs. Low-cost local materials can be used.	High impact of microbiological and geochemical processes at long term. Corrosion of materials. Permeability diminished by precipitation of sulfides, oxides, hydroxides and carbonates.
Zerovalent iron	Widely available local iron materials at low-cost. As(III) and As(V) can be treated.	Produces toxic solid wastes.
Zerovalent iron nanoparticles	Higher contact surface results in a lower amount of iron. As(III) and As(V) can be treated.	Complicate synthesis of material.
Geological materials as natural adsorbents	Feasible process in developing countries	Possible growth of microorganisms. Becomes clogged, if excessive iron.
Biological methods: bioadsorption, ex-situ bioleaching, phytofiltration, phytoremediation	Environmental compatibility and possible cost-effectiveness.	Much research still needed.
Photochemical oxidative technologies: Fe salts/solar light, SORAS, TiO2 Heterogeneous Photocatalysis, ZVI, NZVI	Friendly and non-expensive technologies for poor and isolated populations. Based on the use of solar light and low-cost materials. Simultaneous oxidation of As and removal of natural organic pollutants, toxic metals and microbiological contamination can be achieved in most of the cases.	External addition of iron to the waters before or after treatment is needed in LA.
Reductive TiO2 Heterogeneous Photocatalysis	Provides immobilized As(0) on TiO2.	Addition of organic donors and acid pH is required. Much research is still needed.

Cost of arsenic treatment or alternate supply,
Not including cost remediation of contaminated arsenic sources

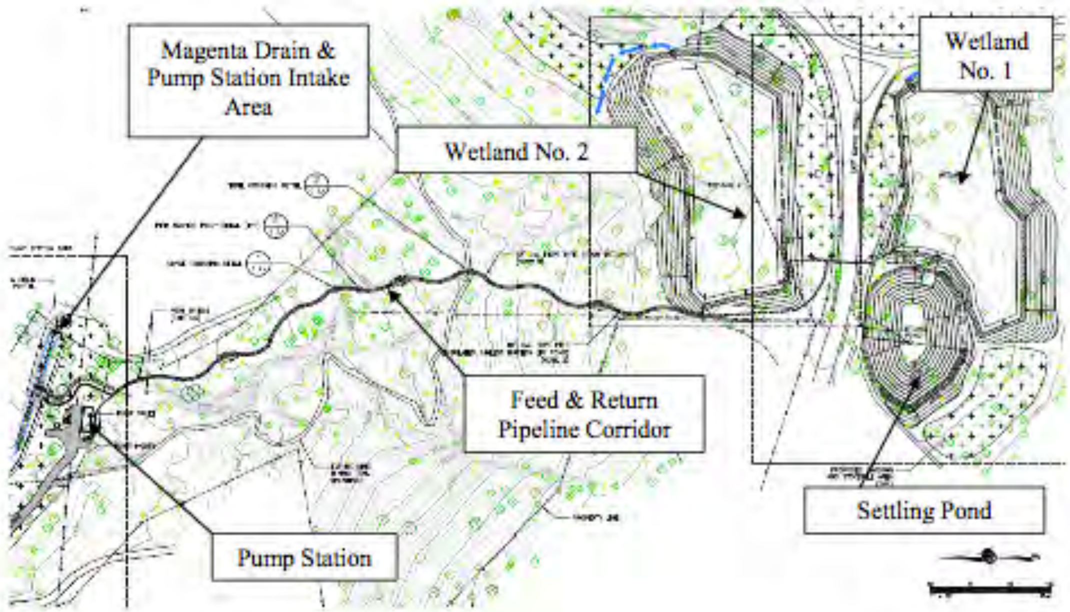
Cost of Water Supply Options for Arsenic Mitigation					
Technology	**Tech life (years)**	**Annualized capital recovery(US$)**	**Operation and maintenance cost/year $US)**	**Water output (m3)**	**Unit cost (US$/m3) [potential]**
Alternative water supply:					
Rainwater harvesting	15	30	5	16.4	2.134
Deep tubewell	20	120	4	820 - 4,500	0.151 [0.028]
Pond sand filter	15	117	15	820 - 2,000	0.161 [0.066]
Dug or ring well	25	102	3	410 - 1,456	0.256 [0.072]
Conventional treatment	20	2,008	3,000	16,400	0.305
Piped water	20	5,872	800	16,400 - 73,000	0.375 [0.084]
Arsenic treatment (households) based on:					
Coagulation-filtration	3	3	25	16.4	1.70
Iron-coated sand/ brick dust	6	0.9	11	16.4	0.73
Iron filings	5	3	1	16.4	0.24
Synthetic media	5	1.2	29	16.4	1.84
Activated alumina	4	3.2	36	16.4	2.39
Arsenic treatment (community) based on:					
Coagulation-filtration	10	44	250	246	1.21
Granulated ferric hydroxide/oxide	10-15	500-600	450-500	820-900	1.20
Activated alumina	10-15	30-125	500-520	164-200	3.20
Ion exchange	10	50	35	25	3.40
Reverse osmosis	10	440	780	328	3.72

Arsenic Contamination in South and Southeast Asia: Toward a More Effective Operational Response - Arsenic Mitigation Technologies in South and East Asia Vol II Technical Report Paper 3, Water and Sanitation Program, World Bank, 2004, p.201
http://siteresources.worldbank.org/INTSAREGTOPWATRES/Resources/ArsenicVolII_PaperIII.pdf

Arsenic removal from mine water in California: An example of remediation

The Empire Mine - www.empiremine.org - is the site of the oldest, largest, and richest gold (Au) mine in California. From 1850 to its closing in 1956, it produced about 170,000 kg (5.8 million ounces) of Au…. There are about 592 km (367 miles) of underground mine workings. Most of the underground mine workings are flooded, comprising one massive mine pool with an identified underground "spill point" that contributes in maintaining a relatively constant mine pool surface elevation.

The Magneta Drain is a drainage adit that is connected to the mine workings and it discharges net neutral pH mining influenced water (MIW) with dissolved concentrations of Fe, As, and Mn. Trace amounts of secondary contaminants including Al, Sb, Ba, Cd, Cr, Co, Cu, Pb, Hg, Ni, Th, V, and Zn have also been detected in water samples. Observations suggest that the flow in the Magenta Drain is directly influenced by local rainfall, which infiltrates into the mine pool proper and into mine workings down gradient of the underground spill point, producing a fairly quick flow response to surface water events.



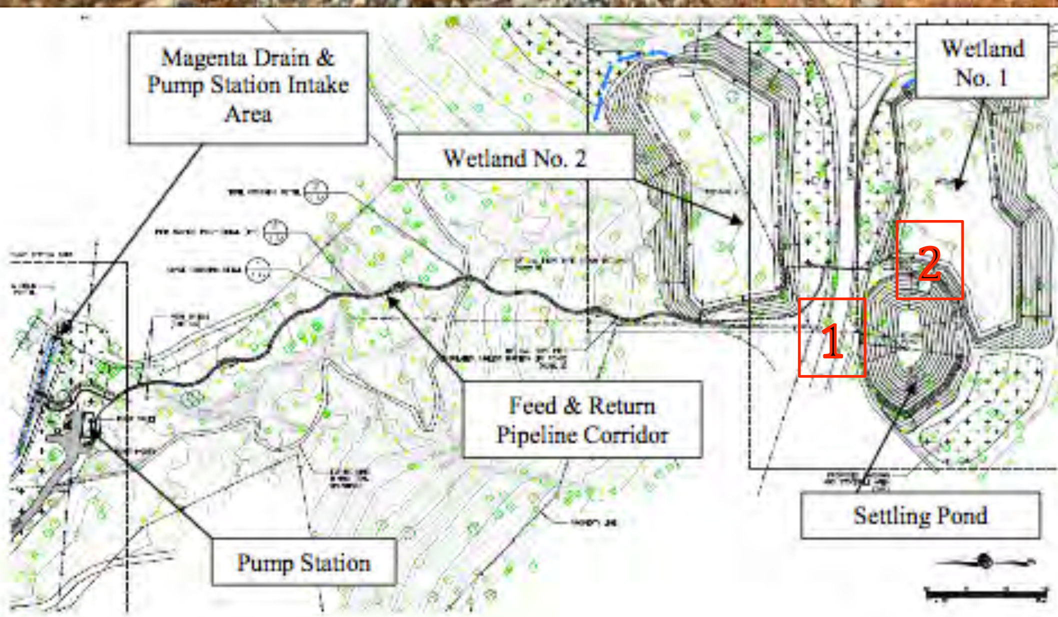
"The goal of this project is to cost-effectively meet some very stringent discharge criteria using passive treatment methods. To the authors' knowledge, a PTS of similar scope and effluent goals has never been constructed. However, the individual processes of iron hydroxide settling, As adsorption, manganese oxide adsorption to limestone, and secondary contaminant adsorption to manganese oxide are well documented in the literature. These collective mechanisms were all likely responsible for the success of the wetland bench study in meeting the required effluent standards. It is likely that they will function equally well, if not better, at the design flows anticipated at the Magenta Drain PTS.

The Magenta Drain Passive Treatment System PTS is composed of:
- a water collection structure and pump station
- overland and partially buried conveyance piping
- passive treatment components (settling pond and a multi-celled free water surface wetland) and
- associated infrastructure (vehicle access and utilities)

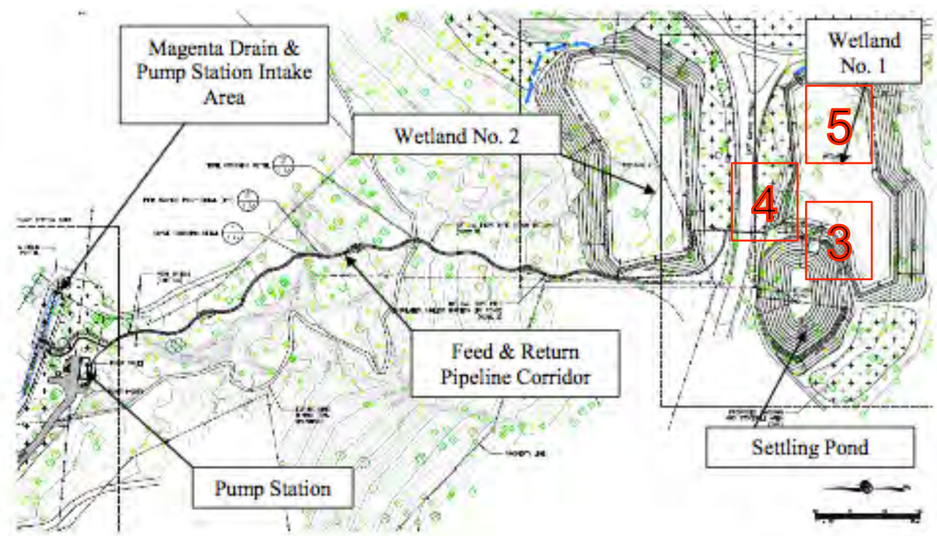
- From "**PROCESS SELECTION & DESIGN OF A PASSIVE TREATMENT SYSTEM FOR THE EMPIRE MINE STATE HISTORIC PARK, CALIFORNIA**", James Gusek , Lee Josselyn, William Agster, Steve Lofholm, and Daniel Millsap, 2011 National Meeting of the American Society of Mining and Reclamation, Bismarck, ND, June, 2011 – dmillsaps@parks.ca.gov

1 - Settling Pond

2 - Outfall from Settling Pond to Wetland No.1

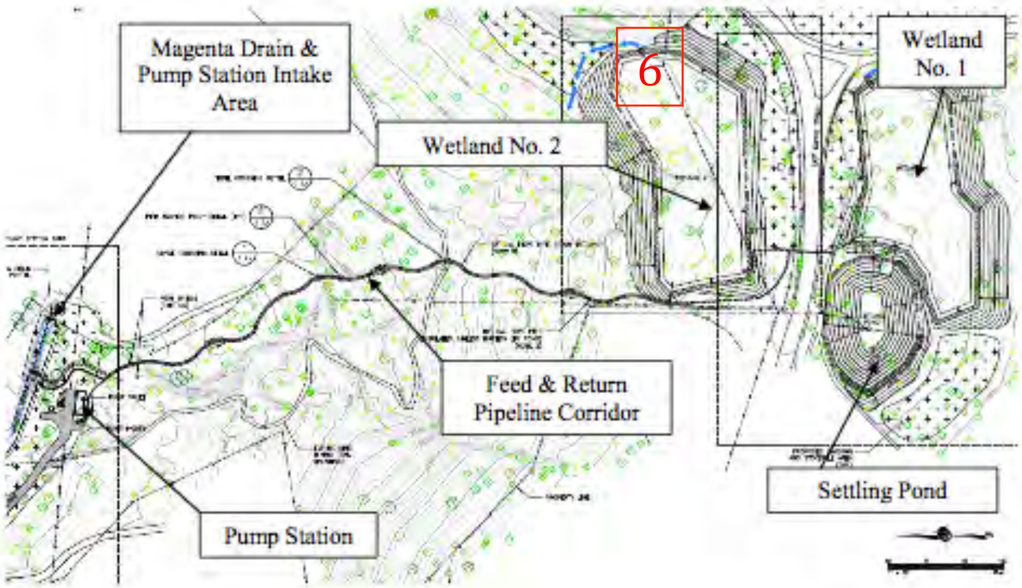


3 – Outfall to Wetland No. 1



4 – Aquatic plants and drain in Wetland No. 1

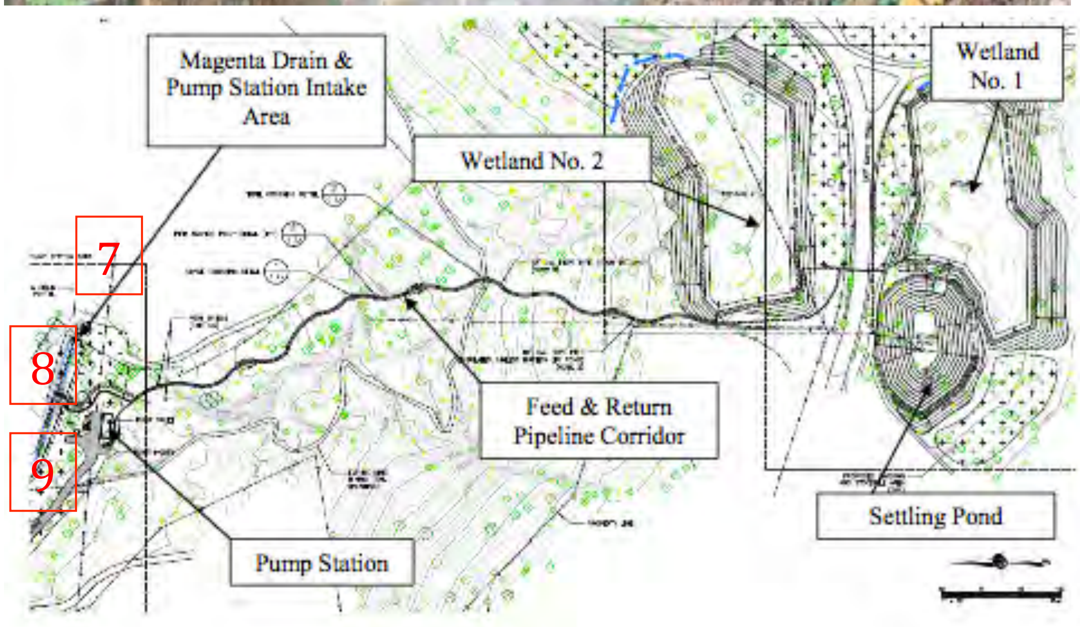
5 –Baffles insure long flow path in Wetland No. 1



6 – Wetland No. 2


7 – Sealed mine drain where contaminated water is collected and piped to treatment system


8 – Outfall of treated water


Magenta Drain & Pump Station Intake Area
Wetland No. 1
Wetland No. 2
7
8
9
Feed & Return Pipeline Corridor
Settling Pond
Pump Station


9 – Treated water enters stream where contaminated water used to flow

Thank you very much for your time and attention