STATE OF NEW MEXICO
WATER QUALITY CONTROL COMMISSION

IN THE MATTER OF	)	
APPEAL OF SUPPLEMENTAL DISCHARGE	)	**Docket Nos.**
PERMIT FOR CLOSURE (DP-1341) FOR	)	**WQCC 03-12(A)**
PHELPS DODGE TYRONE, INC.,	)	**WQCC-03-13(A)**
	)	**(Consolidated)**
Petitioner.	)	
	)	

DIRECT TESTIMONY OF CLINT MARSHALL

I. Introduction

My name is Clint Marshall, and I am a hydrogeologist with the Ground Water Quality Bureau (GWQB) of the New Mexico Environment Department (Department). I am presenting this written testimony on behalf of the Department in the proceeding on the appeal of the Supplemental Discharge Permit for Closure (Closure Permit), DP-1341, for the Phelps Dodge Tyrone, Inc. (Tyrone) open-pit copper mine (Tyrone Mine) located in Grant County, New Mexico. The matter is before the New Mexico Water Quality Control Commission (Commission) on remand from the New Mexico Court of Appeals. My written testimony is marked as **NMED Exhibit 15**.

II. Educational Background and Work Experience

I am presently employed as a hydrogeologist with the Mining Environmental Compliance Section and the Pollution Prevention Section of the Ground Water Quality Bureau of the Department. I have worked for the GWQB for 14 years.

I have a Bachelor of Science degree and a Master of Science degree, both in Geology, from the University of Houston. I also completed summer program in groundwater hydrology at Oklahoma State University.

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Prior to working for NMED, I was employed as an exploration geologist for Marathon Oil Company in Midland, Texas for 4 years. I have previously worked for the United States Environmental Protection Agency (EPA) addressing environmental issues at the Waste Isolation Pilot Project or WIPP site.

As a Hydrogeologist, my responsibilities include overseeing all aspects of discharge permits under the Water Quality Act, including operations, monitoring, reclamation and closure of mine facilities. I conduct inspections, observe fieldwork including site investigations, monitor facilities for compliance, review engineering plans and specifications, and conduct enforcement actions pursuant to discharge permits and abatement plans. I oversee all operational and closure permit issues related to the Tyrone Mine. I am the permit lead for five discharge permits (DP-363, DP-383, DP-396, DP-455 and DP-670) and the Supplemental Discharge Permit for Closure (DP-1341) for the Tyrone Mine. I am also the Team Leader for all mining operational discharge permits in the State of New Mexico.

A copy of my resume is marked as **NMED Exhibit 16**. It is accurate and up-to-date.

III. Summary of Testimony

The purpose of my testimony is to analyze the geological and hydrological settings at the Tyrone Mine. I will also discuss the present quality of ground water at the site and ground water quality prior to discharges at the facility. The final topic I will cover is past and current use of ground water in vicinity of the mine site. In summary, the hydrogeologic setting at the Tyrone Mine is very complex. Numerous faulting and multiple aquifers create a complicated hydrologic system which cannot be fully controlled by pumping the pits at the mine. An additional concern is the fact that the Tyrone Mine is located on the Continental Divide and affects both the Gila-San Francisco and Mimbres ground water basins. If pumping of the pits were to stop, they would fill within 40 to 50 years creating a flow-through hydrologic regime that would allow contamination at the mine to escape into both ground water basins. Tyrone's mining operations have already affected both the regional and alluvial aquifers within and on all four sides of the mine. The number of ground water wells within a four mile radius of the mine has increased five-fold in the last 35 years illustrating the importance of ground water in the vicinity of the Tyrone Mine.

IV. Hydrogeologic Setting

The Tyrone Mine Facility is set in the Basin and Range physiographic province. The mine site straddles the Continental Divide between the Big Burro Mountains and Little Burro Mountains. It is located on the northeastern slopes of the southern end of the Big Burro Mountains, a northwest-southeast trending range approximately 22 miles long and 4 to 12 miles wide. The Little Burro Mountains are situated northeast of the Big Burro Mountains and are separated from the Big Burro Mountains by the mine and the Mangas Valley. The topography in the vicinity of the Tyrone Mine reflects the relatively gentle northeastern slopes of the Big Burro Mountains. Burro Peak, on the Continental Divide, rises to an elevation of 8,035 feet above mean sea level. The trace of the Continental Divide is to the northeast through the Tyrone Mine, crossing the Mangas Valley at an elevation of 5,825 feet above mean sea level.

A. Geology

The Tyrone Mine Facility is located within a porphyry copper deposit generally confined to a triangular area at the southeast end of the Big Burro Mountains. The mine is bounded by the Burro Chief and West Main fault systems on the west, the Sprouse-Copeland Fault on the east, the San Salvador fault system on the south, and the Mangas Fault to the north. A geologic map of the site is marked as **NMED Exhibit 17.** The Sprouse-Copeland Fault strikes in a northerly direction near the eastern boundary of the Mining Area. It is nearly vertical, with displacement on the order of hundreds of feet. This fault has juxtaposed the Gila Conglomerate, downthrown to the east, and the Precambrian Burro Mountain granite. Another major fault, the Mangas Fault, strikes northwest-southeast along the Mangas Valley forming a prominent scarp on the Little Burro Mountains. Along the fault trace, Gila Conglomerate and bolson fill deposits of the southern downthrown block have been juxtaposed against the older rocks of the Little Burro Mountains. In general, the Central Mining Area contains numerous smaller faults and in places the bedrock is highly fractured.

The Big Burro Mountains are dominantly composed of the Precambrian Big Burro Granite. This batholith was subsequently intruded by the Tyrone stock nearly 56 million years ago. The Tyrone laccoliths are composed of Tertiary quartz monzonite formed during four stages of porphyry intrusion. Cretaceous rocks are limited to the Little Burro Mountains and consist of predominantly sedimentary units including the Beartooth Quartzite and the Colorado Formation. Cretaceous and Tertiary volcanic rocks, primarily andesites and rhyolites, overlie the Cretaceous sedimentary units. The youngest rocks in the area are of late Tertiary and Quaternary age and consist mostly of sands, gravels and conglomerates. The Gila Conglomerate, the oldest of the younger sedimentary rocks, is a semi-consolidated unit that was deposited as bolson fill and fan sediments derived from late Tertiary and earlier uplifts. The youngest sedimentary units are located along present-day drainages and consist of unconsolidated valley fill that was deposited unconformably on Gila Conglomerate.

B. Climate

The climate in the Tyrone Mine area is semiarid, with annual evaporation exceeding annual precipitation. The average annual precipitation is approximately 16 inches, while the average annual evaporation from lakes and reservoirs is estimated to be approximately 64 inches. Most of the precipitation in the area falls during July through October in the form of rain during short, intense thunderstorms. A limited snow pack forms at higher elevations in the winter and yields some runoff in the spring. However, the greatest precipitation can be expected during summer months when convective activity is at its maximum. Average daily maximum temperatures for the period from 1982 through 1998 ranged from about 49°F in December and January to about 86°F in June and July.

C. Surface Water Hydrology

The Tyrone Mine Facility area contains portions of two ephemeral watercourses, Mangas Wash and Oak Grove Draw and five tributary watersheds, Wind Canyon, Red Rock Canyon, Niagara Gulch, Deadman Canyon and Brick Kiln Gulch. Mangas Wash extends northwestward from the northern boundary of the Mining Area through the Mangas Valley Tailings Area. Oak Grove Draw flows east along the southern perimeter of the Mining Area. Brick Kiln Gulch extends from the No. 1B Leach Ore Stockpile and merges with Oak Grove Draw one mile east of the mine site. Deadman Canyon, a tributary to Mangas Wash, flows north along the western perimeter of the Mining Area. The canyon contains several springs which produce surface flows over short distances. Several smaller watersheds drain into Mangas Wash from the northeast and southwest. Tailings impoundments or leach stockpiles are located adjacent to most of these drainages.

D. Ground Water Hydrology

The Tyrone Mine is located within a complex hydrogeologic system. It straddles the Continental Divide between two ground water basins. There are also two separate aquifer systems that behave independently of one another. The site contains a multitude of faults and fractures that affect the flow of ground water in the aquifers in unpredictable ways. The mining activities at Tyrone have artificially affected this hydrogeologic system in ways that are still poorly understood. All of these factors added together comprise a great deal of uncertainty in predicting where ground water contamination might spread, regardless of artificial controls proposed by Tyrone.

1. Basins

The Continental Divide tracks southwest-northeast through the center of the Tyrone Mining Facility. Regionally, ground water is recharged along the divide and moves either toward the northwest, into the Gila-San Francisco ground water basin; or toward the southeast, into the Mimbres ground water basin. The pumping of the Main and Gettysburg Pits at the Tyrone Mine has artificially lowered ground water levels and induced ground water flow toward the open pits at the mine. Because the Tyrone Mine is located on the Continental Divide, ground water in both basins has been degraded from its operations.

2. Aquifer Systems

Two separate aquifer systems, the regional aquifer and the alluvial aquifer, exist in the area within and surrounding the Tyrone Mine. The regional aquifer is the primary source of water for domestic and agricultural use in the region. This aquifer extends across the Continental Divide and exists on both sides of it. In the vicinity of the mine, the water within the regional system resides in either the Gila Conglomerate or in the fractured igneous rocks of the Burro Mountain Granite and Tertiary quartz monzonite. In the Mangas Valley northwest of the mine, regional ground water occurs within the Tertiary Gila Conglomerate over much of the area and in Quaternary alluvium along the major axis of the Mangas Valley. The depth to ground water ranges from approximately 40 feet to nearly 90 feet below ground surface. Ground water flow is generally northeasterly, following Mangas Wash.

In the Central Mining Area, the regional ground water occurs primarily within fractured igneous rocks consisting primarily of Tertiary quartz monzonite, Burro Mountain Granite, and at some locations within the Gila Conglomerate. Strongly influenced by fractures, the bedrock units have highly variable saturated hydraulic conductivity. The depth to ground water ranges from approximately one foot at the bottom of the Main and Gettysburg Pits to more than 500 feet east of the mine. Fractured zones within the igneous formations can produce significant amounts of water. The Main Pit at the mine currently produces 1,300 to 1,400 gallons per minute. Local faulting substantially affects ground water levels in the regional aquifer in some areas. Depth to water increases by several hundred feet as one moves eastward across the Sprouse-Copeland Fault and as one crosses the Mangas Fault from north to south. The presence of numerous fault systems within the mine site limits Tyrone's ability to fully capture and control contaminated groundwater beneath leach stockpiles. Portions of faults in some areas have been shown to channel contaminants at the surface into regional ground water. Some of these faults also create barriers in horizontal ground water flow, which prohibit Tyrone's ability to contain contamination with artificially produced cones of depression in the water table.

The Central Mining Area is underlain and surrounded on all sides by a second aquifer system consisting of shallow alluvial aquifers. In the past, this aquifer has supplied domestic water, however presently it is mostly used for livestock. This aquifer system is located at the base of the alluvium-filled channels that have been eroded into the igneous bedrock or the Gila Conglomerate. These channels generally follow ephemeral stream drainages at the Tyrone Mine Facility. Depth to ground water in the shallow aquifer generally ranges from 10 to 50 feet below ground surface. Pumping of the pits within the Tyrone Mine that affects the regional ground water table does not affect ground water flow in these shallow aquifers.

3. Ground Water Flow

Significant recharge of the regional aquifer occurs in the Big Burro Mountains located on the southwest border of the Tyrone Mine. Ground water moves generally northeastward into the mine area parallel with the Continental Divide. The flow then diverges either northward into the Gila-San Francisco ground water basin or eastward into the Mimbres ground water basin. Some of the ground water also moves into the mine site and emerges in the Main and Gettysburg Pits that are presently being pumped down for mining operations.

Ground water, direct precipitation and storm run-off flowing into Tyrone's Main and Gettysburg Pits exceeds local evaporation rates. Modeling conducted by Tyrone's consultants **(AR 1341 D-19)** shows that if pumping of the pits at the Tyrone Mine were discontinued, a ground water flow-through system would begin to occur within 40 to 50 years. Relatively clean ground water entering the southwest side of the mine site from the Big Burro Mountains is of good quality. However, as the ground water moves into the Central Mining Area it becomes contaminated by leaching operations and acid rock drainage migrating downward through unleached waste rock piles and formally leached leach stockpiles. Under a flow-through scenario after the pits fill up, the contaminated water in the mine would then move northwestward into the Gila-San Francisco ground water basin, and eastward into the Mimbres ground water basin. This "flow-through" scenario is depicted on the map marked as **NMED Exhibit 18**.

V. <u>Ground Water Quality</u>

A. Pre-Mining Ground Water Quality

Prior to open pit mining, ground water quality in the vicinity of the Tyrone Mine was of good to excellent quality. Tyrone conducted water sampling in of many wells in the area in 1981 as part of the discharge permit, DP-166. Analyses showed concentrations of total dissolved solids (TDS) of regional ground water moving northeastward from the Big Burro Mountains to the mine site had concentrations of total dissolved solids (TDS) of approximately 200 to 300 milligrams per liter (mg/l) and sulfate concentrations of 20 to 100 mg/l. **(AR 166 A-12)** TDS concentrations in the alluvial aquifer is approximately 210 to 380 mg/l and the sulfate concentrations range from 30 to 100 mg/l. **(AR 166 C-36)** Presently, ground water moving into the mine area from the southwest off the Big Burro Mountains is of similarly good quality.

B. Current Ground Water Quality

Over the years, mining operations at the Tyrone Mine have discharged contaminants into ground water, contaminating ground water quality so that WQCC ground water standards have been exceeded. Let me begin with a brief review of the process that causes acid rock drainage. The Tyrone Mine Facility's Leach Ore Stockpiles, Waste Rock Piles, Open Pits, and Tailing Impoundments all contain mineral sulfides which, when oxidized, generate acidic solutions. These acidic solutions react with in situ minerals, which produces acid rock drainage and associated metals and sulfate contamination. The Leach Ore Stockpiles also contain acidic leach solutions and residual acidity, including metals, from the leaching process that forms acidic leachate. This leachate from acid rock drainage and from the leaching process has moved directly or indirectly into surface and ground water.

Both the regional and the shallow alluvial aquifers have been contaminated from leaching operations and seepage from the tailings deposition. Ground water quality in the central mining area is depicted in the map marked as **NMED Exhibit 19**. I described the ground water at the Tyrone Mine in quite a bit more detail during the October 2003 hearing before the Commission. (See Transcript, WQCC, Tyrone Appeal, vol. 5, Oct. 31, 2003, beginning at page 1236.)

Ground water in the Mangas Valley Tailings Area has been historically impacted by extensive mining operations, and continues to be contaminated by discharges from passive and active operations. Tyrone is presently in the process of closing these tailing impoundments. Ground water within the Mangas Valley has been degraded by seepage from the tailing impoundments located along the perimeter of the valley. Leachate from these impoundments has moved directly or indirectly into ground water within the valley. Ground water beneath the Tailing Impoundments exceeds Commission ground water quality standards for total dissolved solids (TDS) and sulfate. Sulfate is an indicator parameter, which signals that leachate is reaching ground water. Sulfate is a precursor to other more toxic contaminants such as metals. Currently, sulfate and total dissolved solids either exceed the Commission standards or are trending upward toward the standards in various monitoring wells downgradient of the Nos. 1, 1X, 2 and 3X Tailing Impoundments and in ground water adjacent to the No. 1 Tailing Impoundment.

Tyrone's primary mining facilities in the Central Mining Area are located in the southern part of the mine site in and around several open pits. This area includes several active leach stockpiles, as well as waste rock piles, which have caused extensive ground water contamination within the facility. Ground water has also been degraded along the perimeters of the mine site on the north, west, south and east sides. Ground water contamination has been discovered moving many miles offsite, and contaminated leachate continues to move unabated into the regional aquifer.

Portions of the regional ground water within the central part of the facility have been severely degraded by mining operations. Ground water quality in many areas exceed Commission standards by over 10 times for TDS, sulfate, nickel, cobalt and copper; and by 1000 times for aluminum, cadmium, iron, manganese and zinc. On the north side of the mine, leaching operations at the No. 3A Leach Stockpile have resulted in extensive ground water contamination of the alluvial and regional aquifers underlying the head of Mangas Wash. Since August 1990, an extensive ground water investigation and remediation system has been implemented, including the installation of several hundred monitoring wells in both the shallow and the regional aquifers. On the west side of the mine, seepage of acid rock drainage from the No. 2 and No. 2A Leach Stockpiles as well as from historic operations has caused contamination of surface and ground water within Deadman Canyon. On the south side of the mine, seepage from the No. 1C Waste Rock Pile has contaminated the alluvial and regional aquifers within and along Oak Grove Draw. This stockpile, and several others at the Tyrone Mine, has never been leached, yet years of rainfall on the sulfide minerals it contains has resulted in extensive contamination of ground water.

Some of the most extensive and complex ground water contamination at the Tyrone Mining Facility is located on the east side of the mine. In May 1996 while installing a regional monitoring well east of the No. 1A Leach Stockpile, Tyrone discovered pregnant leach solution approximately 20 feet below ground surface. An extensive subsurface investigation revealed a plume of highly contaminated ground water in the alluvial aquifer extending 3.5 miles from the mine perimeter. Regional ground water on the east side has also been degraded from leaching operations. Ground water standards have been exceeded in wells farther and farther from the mine perimeter as contamination continues to spread eastward unabated. Some of the contaminated regional wells such as MB-29 and MB-33 are located directly below the contaminated shallow alluvial aquifers indicating a likely connection between the two aquifers. Therefore, in addition to ground water being contaminated in the alluvial aquifer, these alluvial systems also act as contaminant pathways that carry contamination off the site and outside the influence of pit pumping.

VI. Past and Current Ground Water Use

Ground water in the vicinity of the Tyrone Mine has been an important resource for domestic, municipal and agricultural purposes. A report entitled *Water Resources and General Geology of Grant County, New Mexico* by F. D. Trauger, marked as **NMED Exhibit 20** (AR 1341-E75), provides an inventory of wells for Grant County in 1972. **NMED Exhibit 21** is a map that shows the wells that existed in the area around Silver City and the Tyrone Mine at that time. On the map is a red line that circumscribes the area within a four mile radius around the mine perimeter, and the caption on the map gives the number of wells within this area. I used a four-mile radius because it encompasses the greatest extent of contamination that has migrated from the Tyrone Mine in the past, and it is also consistent with EPA guidance used by federal and State Superfund programs. Within this area, Trauger reported approximately 84 wells for domestic, industrial and agricultural use in 1972. Please note that some of the wells contained in the Trauger report may not exist today or may not be included in current well databases managed by the Office of the State Engineer. The point of this map is to provide a "snapshot" of ground water use in this area in the early 1970's.

NMED Exhibit 22 is another map that shows the number of well permits for domestic, municipal and agricultural use for the same area in 2006 as provided in the Office of the State

Engineer's WATERS well database. This database does not include wells that existed prior to the Gila-San Francisco and Mimbres basins being declared. This database may also include some wells were which were permitted by the Office of the State Engineer, but which may not have been drilled. Nevertheless, in 2006 the number of wells within a four-mile radius of the mine totaled 349. Comparison of the two maps shows a four-fold increase in the number of wells around the Tyrone Mine in the last 35 years, and demonstrates the growing dependence of ground water in the vicinity of the Tyrone Mine.

NMED Exhibit 23 is a map that shows wells used for domestic and agricultural purposes that have been drilled within or near the Tyrone Mine. Some of the most prolific wells in the area are located at the old Tyrone Townsite at the head of Mangas Wash. The original supply well for the town pumped up to 3 million gallons per month. Two wells later drilled by Tyrone, Fortuna Wells #1 and #2, are located near the original well and have supplied the Tyrone Mine with potable water for at least 35 years. Of particular interest is the site of a test hole that the Town of Silver City drilled in Section 10 just north of the mine in 1944.

Other wells near the Tyrone Mine include two wells on the south side used for domestic and stock purposes. One of the wells, Well O, supplied domestic water to the Oak Grove Ranch near the southeast corner of the mine until 1979. The well is located approximately 200 feet south of the No. 1C Waste Rock Pile in Oak Grove Draw. On the west side of the Tyrone Mine, the shop at the former USNR Mine was supplied with domestic water from a good producing well drilled to a depth of 175 feet in Deadman Canyon. The WATERS database records three other domestic wells farther south in Deadman Canyon. One of these wells was associated with a trailer home that resided in the canyon for several years before Tyrone bought the property.

There are also a number of public water systems, including mutual domestic water systems, in the vicinity of the Tyrone Mine. Public water systems are regulated under the State's safe drinking water regulations. **NMED Exhibit 24** is a list of all public water systems in Grant County. PD Tyrone LLC Water System is the public water system that presently serves the Tyrone Mine site using the Fortuna Wells, mentioned above. That system presently serves 450 people. The Burro Mountain Homestead water system, serving 79 people, is located approximately 2 ½ miles from the Tyrone Mine.

The alluvial aquifer has also provided water for domestic and livestock purposes in the vicinity of the Tyrone Mine. To the west of the mine, Trauger documents a well dug in the alluvium of California Gulch that produced domestic water for an entire mining camp at what is now called the Little Rock Mine. Trauger also documents several wells south of the mine that produced water from the alluvial aquifer mainly for livestock.

Interest in the ground water around the Tyrone Mine continues today, despite the presence of active mining operations. In April of this year I met with a citizen of Silver City who was inquiring about the ground water quality on the northwest side of the mine. He stated he was interested in drilling a domestic well to supply a small mobile home park on property that he and his partner owned. The property is located a few hundred feet from the front gate of the Tyrone Mine.

Past as well as present use of ground water within and adjacent to the Tyrone Mine demonstrates the importance of this resource in this area. In my opinion, as a hydrogeologist and as a regulator, the Tyrone Mine is a place of withdrawal of ground water for present or reasonably foreseeable future use.

The Tyrone Main Pit serves, in effect, as a large well (effectively the second largest well in New Mexico). Tyrone presently extracts water from the Main Pit to use for industrial purposes. After the mine closes, and for at least the next 100 years after that, Tyrone is required to continue to extract the water from the Main Pit and treat it to remove contaminants. Putting aside for the moment the Department's skepticism that this pump and treat requirement can or will be maintained for 100 years, the treated water from the pit can then be used as a water supply for domestic or agricultural use in the region. In fact, Tyrone and Phelps Dodge Corporation have indicated their intent to use this water for drinking water purposes after the mine closes. Tyrone and Phelps Dodge Corporation have proposed the water be used for the municipalities of Silver City, Deming, Hatch and Las Cruces, as Craig Roepke from the New Mexico Interstate Stream Commission will discuss later.

Moreover, the use of ground water in the vicinity of the Tyrone Mine has increased substantially in the past few decades. After Tyrone ceases operations and closes the mine, potential users of ground water will encroach ever closer to the mine and perhaps within the mine itself. There are locations around and within the mine that individuals or developers might install a well for domestic or agricultural purposes. In addition, there are hundreds of wells on the Tyrone Mine, that are currently used for monitoring or remediation, which could foreseeably be converted to agricultural or domestic use in the future.

Thank you. This concludes my direct testimony.

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Santa Fe, New Mexico

AKNOWLEDGEMENT

Subscribed and sworn to before me this 9th day of July, 2007 by Clinton L Marshall.

Melissa Y. Mascarenas

Notary Public

My commission expires:

April 3, 2011