Other samples from storm runoff events show total suspended sediment concentrations of the magnitude predicted by SEDCAD+. For example, analytical results of samples collected on Chinde Wash in July, 1976, September, 1980, and July, 1984 showed total suspended sediment concentrations of 277,000 mg/l, 183,000 mg/l and 397,420 mg/l, respectively. Flow measurements were not obtained for these samples so it is difficult to compare with SEDCAD+ modeling results.

It is unlikely that monitoring of sediment concentrations on the major arroyos flowing through the permit area will be sufficient to calibrate or validate the SEDCAD+ modeling results. The sediment dynamics are too complex and variable to allow for representative sampling and accurate modeling. Recognizing the pitfalls of interpreting sediment concentration data from the major arroyos, the Navajo Mine has embarked on extensive plot studies of sediment yield to compare pre- and postmining conditions and to demonstrate best technology currently available (CHAPTER 11, Section 11.6.3.3). Despite the inaccuracy and limitations of modeling sediment yields and concentrations using SEDCAD+ or any other event based model, the modeling results are useful for relative comparison of pre- and postmining conditions (CHAPTER 11, Section 11.6.3.3).

7.2.5 Hosteen Wash

Hosteen Wash is an ephemeral stream located in the northern portion of Area II. The drainage area extends from the NIIP (east of the permit area) through the permit area to the Chaco River to the west. EXHIBIT 7-4C shows the watershed area and drainage configuration for the Hosteen Wash watershed. The Hosteen Wash watershed area is about 9.1 square miles. Approximately 3.7 square miles of this drainage is disturbed by mining activity.

Peak flows and sediment yields were predicted for the 6-hr. rainfall event on 2-, 10-, 25-, and 100-yr. frequencies. Predictions were performed for pre-mining conditions for Hosteen Wash. Postmining predictions are reported in CHAPTER 11, Section 11.6.3.3.2.

The peak flows and sediment yields were predicted through the use of the SEDCAD+ computer program (Schwab and Warner, 1987) following the methodology and assumptions described in Section 7.2.3.2. Watershed subdivisions used for Hosteen Wash are provided on the SEDCAD+ Watershed Map (EXHIBIT 7-4C). Input parameters and output results for each subwatershed are provided in APPENDIX 7-A. All input parameters are included in the output results. Sediment yields in Hosteen Wash were predicted to increase from 2,805 tons for the 2-yr., 6-hr precipitation event to 19,646 tons for the 100-yr., 6-hr precipitation event.

7.2.6 Barber Wash

Barber Wash is an ephemeral stream, which flows only in response to runoff from precipitation events. The drainage area extends from just east of the permit boundary through the permit area towards the Chaco River to the west. EXHIBIT 7-4C shows the watershed area and drainage configuration for the Barber Wash watershed. The Barber Wash watershed area is about 5.3 square miles. Approximately 1.4 square miles of this drainage is disturbed by mining activities.

Peak flows and sediment yields were predicted for the 6-hr. rainfall event on 2-, 10-, 25-, and 100-yr. frequencies. Predictions were performed for pre-mining conditions for Barber Wash. Postmining predictions are reported in CHAPTER 11, Section 11.6.3.3.3.

The peak flows and sediment yields were predicted through the use of the SEDCAD+ computer program (Schwab and Warner, 1987) following the methodology and assumptions described in Section 7.2.3.2. Watershed subdivisions used for Barber Wash are provided on the SEDCAD+ Watershed map (EXHIBIT 7-4C). Input parameters and output results for each subwatershed are provided in APPENDIX 7-B.

Sediment yields in Barber Wash were five and six times lower than those predicted for Hosteen. The lower sediment yields occur on Barber Wash because of lower curve numbers and runoff and lower slopes (less badlands area) as well as a slightly smaller drainage area. Sediment yields are predicted to increase from 447 tons for the 2-yr., 6-hr precipitation event to 4,240 tons for the 100-yr., 6-hr precipitation event. Peak suspended solids concentrations exceeded 23,000 mg/l for all events.

7.2.7 Neck Arroyo

Neck Arroyo is an ephemeral stream that flows only in response to runoff from precipitation events and is located south of the Area III shop complex just north of the Area III mining area (Lowe Pit). The drainage area extends from east of the permit boundary through the permit area towards the Chaco River to the west. EXHIBIT 7-4 shows the watershed area and the drainage configuration for this watershed. The Neck Arroyo watershed area is about 1.88 square miles. Approximately 14 percent of this drainage lies within the permit area.

Peak flows and sediment yields were predicted for the 6-hr. rainfall event on 2-, 10-, 25-, and 100-yr. frequencies. Predictions were performed for pre-mining conditions for Neck Arroyo. Postmining predictions are reported in CHAPTER 11, Section 11.6.3.3.5, even though the relative area affected by life of mine operations is very small.

The peak flows and sediment yields were predicted through the use of the SEDCAD+ computer program (Schwab and Warner, 1987) following the methodology and assumptions described in Section 7.2.3.2. Watershed subdivisions used for Neck Arroyo are provided on the SEDCAD+ Watershed Map (EXHIBIT 7-4). Input parameters and output results for each subwatershed are provided in APPENDIX 7-C.

Sediment yields predicted on Neck Arroyo were about twice the magnitude predicted for Barber Wash even though the Neck drainage area is less than 40 percent than that of Barber Wash drainage area. The higher sediment yields predicted for Neck Arroyo are due to higher curve numbers and runoff and higher slopes (more badlands area). Sediment yields are predicted to increase from 3,748 tons for the 2-yr., 6-hr precipitation event to 34,786 tons for the 100-yr., 6-hr precipitation event. Peak suspended solids concentrations were slightly higher than predicted for other drainages and exceeded 100,000 mg/l for all predicted events.

7.2.7.1 South Barber Drainage

The South Barber Drainage is an ephemeral stream that is a tributary to the Neck Arroyo. EXHIBIT 7-4C shows the watershed area and drainage configuration for the South Barber Drainage. The South Barber Drainage is about 0.82 square miles. Approximately 0.03 square miles (17 acres) of this drainage is disturbed by mining activities.

The Sedcad+ computer program was used to simulate the 2, 10, 25 and the 100 year-6 hour storm events following the methodology and assumptions outlined in Section 7.2.3.2. The watershed subdivisions used to model the South Barber Drainage is presented on Exhibit 7-4C.

The input parameters and output results for each subwatershed are provided in APPENDIX 7-N. The post-mining surface hydrology is presented in Section 11.6.3.3.4.

Results of the SEDCAD+ runs for pre-mining conditions show peak concentrations of suspended solids exceeding 34,000 mg/l for rainfall events of a 2-yr. frequency or larger. Sediment yields increase from 170 tons for a 2-yr., 6-hr rainfall to 1,449 tons for a 100-yr., 24-hr rainfall.

7.2.8 Lowe Arroyo

Lowe Arroyo lies in the middle of Area III and flows from NIIP, east of the permit area, through the permit area to Chaco River to the west. Lowe Arroyo is an ephemeral stream with flows occurring only in direct response to runoff from precipitation events. EXHIBIT 7-4 shows the watershed area and drainage configuration for Lowe Arroyo. Lowe Arroyo has a drainage area of about 11.25 square miles of which approximately 41 percent lies within the permit area.

Peak flows and sediment yields were predicted for the 6-hr. rainfall event on 2-, 10-, 25-, and 100-yr. frequencies. Predictions were performed for pre-mining conditions for Lowe Arroyo. Postmining predictions are reported in CHAPTER 11, Section 11.6.3.3.6.

The peak flows and sediment yields were predicted through the use of the SEDCAD+ computer program following the methodology and assumptions described in Section 7.2.3.2. Watershed subdivisions used for Lowe Arroyo are provided on the SEDCAD+ Watershed Map (EXHIBIT 7-4). Input parameters and output results for each subwatershed are provided in APPENDIX 7-D.

7.2.9.4 Comparison of Channel Cross-Sections

Exhibit 7-6 shows channel cross sections from monitoring stations in Cottonwood Arroyo before and after the large flow events that occurred in July and August 1999. The cross-sections, taken in early June 1999 and again in January 2000, show the extreme amount of channel transformation due to large flow events, particularly at station CNS-1. At station CNS-1, the north bank (cut-bank) of the channel moved approximately 80 feet horizontally (See Exhibit 7-6, CNS-1 cross-sections 2 and 2A) over a six-month time frame. In addition to the loss of sediment on the cut-bank, some sediment is temporarily stored as evidenced by the formation of sand bars on the opposite bank and the sediment deposition on the flood plain for these out of bank flows.

The amount of horizontal and vertical change depicted in the cross-sections reinforces the dynamics of sediment movement within this ephemeral sand bed channel that is subjected to short duration high intensity flows.

7.2.9.5 Sediment and Hydrologic Predictions Compared with Surface Water Data

Predictions for the 6-hr. rainfall event on 2-, 10-, 25, and 100-yr. frequencies for pre-mining peak flows and sediment yields are listed on Table 7-6 (see APPENDIX 7-H for detailed results). Postmining predictions are reported in CHAPTER 11, Section 11.6.3.3.

Sediment yields in Cottonwood Arroyo were higher than from the other drainages. The higher sediment yields predicted for Cottonwood Arroyo are due to the larger drainage area, nearly twice the size of Chinde Wash, the next largest drainage. Sediment yields in Cottonwood Arroyo were predicted to increase from 10,054 tons for the 2-yr., 6-hr precipitation event to 70,850 tons for the 100-yr., 6-hr precipitation event (see Table 7-6).

Peak suspended solids concentrations in Cottonwood Arroyo were similar to those predicted for Lowe Arroyo and lower than predicted for other drainages. Peak suspended sediment concentrations in Cottonwood Arroyo exceed 30,000 mg/l for all events.

Comparison of predicted sediment concentrations with measured sediment samples from storm runoff events on Cottonwood Arroyo shows total suspended sediment concentrations of the magnitude predicted by SEDCAD 4.0 for events of a magnitude similar to that predicted for a 10-yr., 6-hr storm or less. Table 7-6 lists the SEDCAD predictions for different design events. The results suggest that the SEDCAD 4.0 predictions for peak sediment concentration in Cottonwood Arroyo are reasonable compared to observed conditions.

The storm events of August 21, 1998 and August 3, 1999 may have been equivalent to a 25 year, 6 hour event or larger in portions of the watershed. Although the SEDCAD predictions for peak discharge, runoff volume and sediment yields are greater, the results compare reasonably to actual data for large flow events.

7.2.10 Pinabete Arroyo

Pinabete Arroyo flows east to west along through the BNCC lease area south of the existing permit area to the Chaco River. Pinabete Arroyo is a large ephemeral stream that flows only in direct response to precipitation events. The Pinabete Arroyo has a drainage basin of approximately 59.1 square miles of which approximately 2.9 percent lies within the permit area.

For the pre- mine, the hydrology modeling was done only on the subwatersheds or the tributaries to the Pinabete Arroyo that are projected to be disturbed by mining and reclamation support activities, not on the entire drainage basin. This should be appropriate since the stream channel will not be disturbed and only a small portion of the drainage basin (approximately 0.002 percent) will be disturbed by mining and reclamation support activities.

The peak flows and sediment yields were predicted using the SEDCAD+ computer program following the methodology and assumptions outlined in Section 7.2.3.2. The computer model was used to simulate the 2, 10, 25 and 100 year-6 hour storm events, the results are presented in Appendix 7-O. The watershed subdivisions used to model the hydrology are presented on Exhibit 7-4. The post-mining predictions and hydrologic impacts are reported in CHAPTER 11, Section 11.6.3.12.

Table 7-7
Summary of Surface Water Monitoring Data - Average Values

Parameter	NB-1	NB-2	CD-1	CD-2	CD-1A	CD-2A	CN-1	CS-1	CNS-1
Start Date	6/5/1986	7/21/1986	7/21/1986	4/17/1986	9/14/1996	8/6/1997	7/18/1990	7/18/1990	7/18/1990
End Date	5/22/1997	5/22/1997	5/23/1997	5/23/1997	9/21/2010	3/24/2010	9/2/1999	9/5/1999	8/3/1999
pH (S.U.)	8.14	8.1	7.7	7.7	8.23	8.26	7.8	8.4	8.16
Max # of Observations	96	123	289	168	85	51	96	92	104
Total Dissolved Solids (mg/l)	2271.5	2300.77	1301	1536	1139	1654	972	1047.8	1098.6
Total Suspended Solids (mg/l)	9172.02	<10270.51	5945	10290	169	78	131005	115803.9	95334.6
Total Settleable Solids (mg/l)	203.08	<229.3	69	96	0.3	0.2	327	247.3	<134.6
Conductivity (µ mhos/cm)	2912.63	3066.67	1696	2207	1650	2233	1151.4	1041.3	861.32
Arsenic(mg/L)	0.002	<0.002	0.002	0.002	0.003	NA	0.024	<0.0021	<0.0023
Boron (mg/l)	0.37	<0.39	0.19	0.21	0.37	0.26	0.17	<0.189	<0.17
Calcium (mg/l)	115.55	98.72	91.25	89.55	72	153	47.6	33.5	8.5
Cadmium (mg/L)	0.002	<0.0016	0.002	0.002	<0.0005	NA	<0.002	<0.002	<0.0019
Chloride (mg/l)	181.65	<168.53	44	217	55	80	<19.6	17.14	<14.07
Fluoride (mg/l)	1.28	<1.17	1.05		1.95	1.25	ND	ND	ND
Iron (mg/l)	0.38	<0.78	0.44	0.57	0.12	0.15	<2.48	<4.84	<4.11
Total Iron (mg/l)	73.42	<94.95	29.83	31.26	3.11	1.55	632.8	419.7	444.7
Lead	0.008	<0.0089	0.009	0.008	0.003		0.028	<0.03	<0.015
Magnesium (mg/l)	29.42	27.74	21.29	19.58	18	27	6.6	4.8	<4.68
Manganese (mg/l)		<0.23				0.03	<0.286	<0.52	<0.34
Total Manganese (mg/l)	1.29	<1.36	0.12	0.17	0.03	0.03	<12.5	8.88	<8.92
Mercury		ND	NA	NA	NA	NA		ND	ND
Nitrate as N (mg/L	9.4	8.9	11.67	15.25	4.20		<11.5	<18.91	<15.59
Potassium (mg/l)	6.7	7.3	5.5	6.8	2.3	6.8	6.5	5.98	5.4
Selenium (mg/l)	0.02	<0.016	0.004	0.003	0.009	0.010	<0.0035	<0.0026	<0.0025
Sulfate (mg/l)	1187	1139	729	697	519	891	451	317.3	292
Sodium (mg/l)	578	596	289	388	292	375	221	180.08	171
Bicarbonate as $CaCO_3$(mg/l)	167	186	153	255	290	255	169	170	152
Carbonate s $CaCO_3$(mg/l)	78.21	<56.75	0	9	13	9	<9.5	82	<65.93

*CD-1A & CD-2A are the remaining active sample points (3/04).
Dissolved unless stated otherwise

The pre-mine sediment yields from the tributaries are predicted to increase from 3 tons for the 2 yr- 6 hr precipitation event to 669 tons for the 100 yr- 6 hr precipitation event. Peak suspended solids concentrations are predicted to exceed 6,000 mg/l for all storm events.

7.3 SURFACE WATER QUALITY

Historically, seven surface water monitoring stations were established on ephemeral drainages that pass through the Navajo Mine. All of the monitoring stations except station CS-1 have been impacted by return flow irrigation activities derived from the Navajo Agricultural Products Industries (NAPI) project located to the east of the mine. CS-1 has been influenced by direct releases from unused waters in the NAPI canals. Average surface water quality data collected at the seven stations between 1986 2010 is summarized in TABLE 7-7. A geochemical analysis of historic surface water monitoring data is presented in APPENDIX 7-E.

The Navajo Nation Environmental Protection Agency (NNEPA) has designated uses, Fish Consumption (FC), Secondary Human Contact (ScHC), Aquatic and Wildlife Habitat (A&WHbt), and Livestock Watering (LW), for all Waters of the Navajo Nation (NNEPA WQP, 2008), which includes the drainages within the Navajo mine permit area. There are no other higher levels of designated use for surface water resources within the Navajo Mine permit area. During mining and reclamation activities, BNCC will conduct surface water monitoring (Section 7.4), will demonstrate compliance with applicable surface water quality standards prior to bond release.

7.4 SURFACE WATER MONITORING PLAN

Navajo Mine's surface water monitoring program was established to monitor surface water quality at locations where major watercourses enter and leave the permit area and/or lease area. The monitoring program provides the basis for assessment of the impact of mining on the surface water resource. While the chance of surface water impact resulting from mining remains remote, the following monitoring program has been developed to collect water quality information for use in the possible identification of impacts to the prevailing hydrologic regime.

7.4.1 Surface Water Monitoring Locations

The Chinde watershed was selected since it is the most representative watershed of the seven ephemeral arroyos which traverse the permit area. In addition, the drainage experiences direct discharges and irrigation return flows from NAPI. The irrigation season occurs generally from

Surface water monitoring was discontinued in Cottonwood Arroyo following extensive data collection that adequately characterized baseline conditions. The expansion of mining into Area IV North will involve the construction of a crossing with culverts in the Cottonwood Arroyo. Navajo Mine will not discharge into Cottonwood Arroyo during the Area IV North development and there will be minimal mine related impacts. The only effect from mining to Cottonwood Arroyo is the Lowe diversion, which diverts an undisturbed portion of the Lowe watershed into Cottonwood Arroyo (See Section 11.6.3.3.6). Because the Lowe Diversion increases the Cottonwood watershed by only 4%, any water quality effects will likely be so small as to be immeasurable. Monitoring will resume within the Cottonwood Arroyo watershed if conditions change as the result of major NAPI impacts.

7.4.2 Monitoring Equipment

The existing Chinde Wash monitoring stations CD-1 and CD-2 have been relocated to take advantage of stable cross sections afforded by culvert crossings at BIA Highway 3005 (upstream station CD-1A) and at the BHP railroad embankment (downstream station CD-2A). FIGURE 7-2 shows the locations of the Chinde monitoring stations. Station CD-1A is located outside the mine lease and right of access permission was granted from the Navajo Nation to place the monitoring location within the road right-of-way. Station CD-2A is located within the Navajo Mine permit boundary.

TABLE 7-10

SURFACE WATER QUALITY PARAMETERS

(All Surface Water Stations)

pH Total Dissolved Solids (TDS) Total Suspended Solids (TSS) Conductivity Settleable Solids Total Sediment
Aluminum Arsenic Boron Cadmium Calcium Chloride Fluoride Iron Iron (Total) Lead Magnesium Manganese Manganese (Total) Mercury[1] Nitrate Potassium Selenium Sulfate Sodium Bicarbonate Carbonate
Cation/Anion Balance
[1] Monitoring for mercury to be conducted for three (3) years after OSM's record of decision on the Area IV North Mine Plan Revision (submitted to OSM on 15 February 20111, OSM No. NM-0003-F-R03). After which time, BNCC and OSM will reevaluate if continued monitoring is required.

7.4.6 Data

The analytical data received from the laboratory is entered into an in-house database program. The data is used to determine and assess long-term trends for the parameters monitored and will be used to monitor and assess potential impacts to the hydrologic regime.

The Probable Hydrologic Consequences (PHC) predicts an overall reduction in sediment yields from the reclaimed areas as compared to the premine conditions. The Chinde main channel data collected will be used in conjunction with computer modeling results for the Bond Release Application to support the PHC.

7.4.7 Reporting

Surface water monitoring results will be submitted on a quarterly basis to OSM. BNCC will provide all water quality information to OSMRE in an electronic format on a quarterly basis. In addition, a detailed review of monitoring results will be submitted to OSM twice during the permit term. See CHAPTER 11, SECTION 11.6.6 for additional information.

7.5 REFERENCES

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