NIIP 2-22-92-F-008
94-F-381

Navajo Indian Irrigation Project

Biological Assessment

Prepared For

Bureau of Indian Affairs
Navajo Indian Irrigation Project
Farmington, New Mexico

Prepared
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June 11, 1999

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BIOLOGICAL ASSESSMENT

SCOPE

This biological assessment is prepared in preparation for consultation under Section 7 of the Endangered Species act for Blocks 1-11 of the Navajo Indian Irrigation Project (NIIP) located near Farmington, New Mexico. The assessment deals with new information since the January 12, 1995 Biological Opinion was issued. Issues addressed in previous consultations for which no new information exists are not addressed here.

The full completion of the NIIP is included in this assessment. The previous two biological opinions (October 26, 1991 and January 12, 1995) dealt with only the first 8 blocks of the project, with development restrictions on those blocks. The restrictions were imposed due to uncertainty concerning the water requirements for recovery of razorback sucker and Colorado pikeminnow. A 7-year research program was initiated in 1991 to address, among other issues, the flow requirements for the fish. On October 15, 1998 the San Juan River Basin Recovery Implementation Program (SJRIP) Coordination Committee approved the flow recommendation developed by the Biology Committee. With the results of the flow recommendation, sufficient new information is available to consider the completion of NIIP, including consideration of removal of the acreage restrictions in blocks 1-8.

The 1991 biological opinion authorized a total depletion for the project of 149,420 acre-feet (af), including 16,420 af that were transferred from other Navajo Projects. This biological assessment covers the total depletion for the project of 270,000 af (long term average for equilibrium conditions). With continuation of the transfer of 16,420 af from other Navajo Projects, and removal of the restrictions on development in Blocks 1-8, the increased equilibrium depletion resulting from the completion of the NIIP is 120,580 af.

PROJECT DESCRIPTION

General Description

The Navajo Indian Irrigation Project (NIIP), an element of the Upper Colorado River Storage Project, was authorized on June 13, 1962 (Public Law 87-483, as amended by Public Law 91-416 on September 25, 1970). Its principal purpose is to irrigate 110,630 Navajo-owned acres in northwestern New Mexico, generally south of Farmington. The acreage through Block 8 which will be completed and in full operation by 2002 totals about 76,481 acres. The presently authorized depletion for these first 8 blocks is 149,420 acre-feet (af), requiring 8,000 acres of conservation reserve and additional conservation measures for irrigation of all acreage in the first 8 blocks. Included in the 149,420 af depletion allowance is 16,420 af of depletion transferred from other Navajo nation projects to the NIIP. Full development depletion is estimated at 270,000 af under long term average equilibrium conditions.

NIIP is operated as a tribal enterprise by the Navajo Agricultural Products Industry (NAPI), which also processes and markets most of the crops through agribusinesses located on adjacent non-arable parcels.

Two federal agencies are direct participants. The Bureau of Indian Affairs (BIA) is the lead agency, with prime responsibility for construction and operation. It receives the appropriations to build the project, assists the Tribe in overseeing it and is the accountable agency. Through a cooperative agreement with the BIA, the Bureau of Reclamation is constructing the water, drainage and power-distribution systems. Initially, the Bureau of Land Management (BLM) was involved as it conveyed lands under its jurisdiction to be held by the government in trust for the Tribe.

The 30-mile-square area containing the irrigable lands is on an elevated plain south of the San Juan River between Highway 44 on the east and the Chaco River on the west (Plate l).

Besides the 110,630 acres that will be irrigated, about 1,500 acres are devoted to agribusinesses and another 11,231 acres are taken up by roads, ditches, canals, etc. The balance (93,483) of the total 216,843 acres are grazed by NAPI livestock and used as demonstration areas for range improvement and soil conservation. This over-all area reaches from parts of Township 24N, New Mexico Principal Meridian on the south into T29N on the north, and from parts of R16W east into R11W.

NIIP was originally partly on and partly off the reservation. The lands outside the reservation at the time of authorization have since been transferred into trust for the Navajos and have become part of the reservation.

Set aside for the project was an annual diversion entitlement of 508,000 AF of water, to be brought from Navajo Reservoir through tunnels, siphons, open concrete-lined canals and pipelines (see Plate 1).

Navajo Dam and Reservoir

NIIP receives its water from Navajo Dam and Reservoir. The dam was built between 1958 and 1963. It spans a deeply carved canyon of the San Juan 39 miles east of Farmington, New Mexico. Extending 35 miles upstream and capturing the drainage from 3,190 square miles, the multi-purpose reservoir can hold up to 1,701,300 AF of water. The active capacity is 1,075,625 af, accounting for the inactive capacity below the minimum operating elevation of the NIIP canal (5,085 ft) of 625,675 af. Besides regulating river flow, it creates a source for municipal and industrial water in New Mexico's San Juan Basin. The volume of water stored for NIIP, the Hammond Project and for downstream use allows upstream diversions to be made for the San Juan - Chama Project.

Prior to 1991 the reservoir was operated to maximize storage efficiency and minimize fluctuations in flow downstream of the dam. Under these operating objectives, the average annual variation in the reservoir water level would be about 30 ft with an annual maximum change of about 54 ft. Typically the level rose rapidly in May and June and was drawn down slowly during July and August. Releases were maintained through the winter in wetter years to provide storage space for the next spring runoff. Re-operation of the reservoir began in 1992 under test releases, whereby winter flows were lower and a larger spring release was made to simulate spring runoff flows below the dam.

Included as a part of the 1991 Section 7 Consultation was a requirement to re-operate Navajo Dam for mimicry of a natural hydrograph for the benefit of the native fish community. The flow recommendation completed by the SJRIP Biology Committee (SJRIP, 1998) and approved by the Coordination Committee on October 15, 1998 defined the flow requirements for the fish and described the conditions that must be met to achieve mimicry of a natural hydrograph in the San Juan River. Reservoir operating rules were also recommended that would meet the flow requirements specified. The report acknowledged that other operating scenarios may be possible as long as the specified flow recommendations were met.

The commitment to re-operate Navajo Dam became a part of the NIIP project as a result of the 1991 Biological Opinion. Applying the operating rules outlined in the flow recommendation report allows full development of NIIP while meeting the specified flow requirements. Detailed model results appear later in this report.

Irrigation System

Main Canals. Forming the primary water-conveyance network are the main, gravity main and Amarillo canals. The main canal begins at the left abutment of Navajo Dam (looking downstream) and advances southwest for a little more than 46 miles. The gravity main canal is an extension that heads generally northwest from where the main canal ends. The Amarillo branches to the west off the gravity main after about 10 miles.

The main canal has a capacity of 1,800 cfs from the dam to the Kutz pumping plant at mile-post 28.8 and then is reduced gradually to 1,285 cfs at mile-post 46.3. The main canal includes the following features: a headworks structure with two 9-by-12 foot, fixed wheel gates and two regulating 9-by-12-foot top-seal radial gates; six concrete-lined free-flow tunnels, each 18 ft in diameter and totalling 11.5 miles in length; nine siphons 17.5 ft in diameter with a total length of 7.1 miles and a maximum head of 300 ft; 0.6 miles of unlined canal; 0.1 miles of concrete flume; 0.9 miles of natural channel (Cutter Dam and Reservoir); and 26.1 miles of open concrete-lined canal with a trapezoidal section.

Off the main canal and serving 19,720 acres in Blocks 1 and 4 are four check, three wasteway, 37 cross drainage and 24 turn-out structures, with pump installations with capacities of 1.2 to 81.7 cfs and pump heads of from 90 to 450 ft. Block 5 is served from the main canal via Kutz pumping plant and Coury Lateral.

The gravity main canal is designed for 1,285 cfs at its heading and 225 cfs at the end, and includes 104 miles of concrete-lined free-flow tunnel and 126 miles of concrete-lined trapezoidal canal.

Connecting the canal with the roughly 17,800 acres in Blocks 2 and 6 are four check, three wasteway and 17 cross-drainage structures. Eighteen turn-outs (which can pump 0.5 cfs to 190 cfs, with pump heads from 136 to 372 ft) furnish sprinkler pressure.

The Amarillo canal, with a capacity of 385 cfs at its heading and 175 cfs at the end, is concrete-lined and serves Blocks 3 and 7.

The design features of the three main canals are as follows:

	Mileage	Base Width	Water Depth	Hgt. of Lining
Main Canal	46.3	23-18 ft	11.8-10.9 ft	13.7-12.5 ft
Gravity Main	14.2	18- 7 ft	10.9- 6.0 ft	12.5- 7.0 ft
Amarillo	11.2	8- 5 ft	7.7- 4.4 ft	8.8- 5.2 ft

Operation and maintenance roads parallel each side of the open channels. These are 16 ft wide along the canals on the project and 20 ft wide from the Navajo Dam to the project.

Pumping Plants. Three indoor-type pumping plants, each equipped with four to six electric motor-driven pump units, lift water from the main network to the open laterals.

	Mile-post	Capacity	Dynamic Head	Plant hp
Kutz Plant	28.8 main canal	198 cfs	356 ft	12,000
Gallegos Plant[1]	0.6 gravity main	880 cfs	342 ft	44,200
Moncisco Plant[2]	0.0 Burnham lateral	400 cfs	140 ft	10,600

Off-Stream Storage. One regulating reservoir is required to meet peak irrigation demand during the summer when the total irrigated area exceeds about 97,000 acres. Two alternative sites have been selected and are being investigated for feasibility. The general site locations are shown on Plate 1. Plate 2 shows a close-up of these locations. The active storage requirement for either reservoir is 7,735 af. Sediment storage, evaporative losses and seepage losses are added to this volume to determine the total storage requirement for each site. Since the upstream drainage size is different for the two sites, the sediment storage requirement, design storm and surface area are also different. Either dam would be a zoned earth embankment dam with concrete spillway.

The Gallegos site would have a dam crest elevation between 5,983 and 5,986 ft, depending on the spillway configuration, with the spillway at elevation 5,962 ft. The dam would have a spillway discharge capacity from 29,000 to 44,000 cfs, depending on design, to pass the probable maximum flood (PMF) generated in the drainage above the dam. The total storage capacity, including dead pool and inactive storage, is 14,542 af at spillway crest. Included in this capacity is 3,850 af of storage for sediment, 450 af for evaporation and 270 af for seepage.

The Moncisco site would have a dam crest elevation of 6,040 to 6,045 ft, depending on the spillway configuration, with the spillway at elevation 6,024 ft. The higher dam would contain the entire pmp. The lower dam would pass 12,900 cfs to pass the PMF generated in the drainage above the dam. The total storage capacity, including dead pool and inactive storage, is 11,858 acre-ft at spillway crest. Included in this capacity is 1,603 af of storage for sediment, 450 af for evaporation and 270 af for seepage.

Both sites are pumped storage sites filled by releasing water from the Burnham lateral down Moncisco Wash during off-peak periods. Water is released from either reservoir to the gravity main canal via a short service canal with a capacity of 260 cfs.

Laterals. Open laterals: Together, the Burnham and Coury laterals, transporting 75 to 585 cfs apiece, reach 40.6 miles. They are concrete-lined and trapezoidal, with 1.5:1 side slopes and maintenance roads

[1] Required for Blocks 8 and 9.

[2] Required for Blocks 10 and 11.

16 ft wide. The base widths vary from 5 to 10 ft and water depth from 3.5 to 9.0 ft. The Coury lateral serves Block 5 while the Burnham lateral will serve Blocks 10 and 11. Pumped Lateral: The Gallegos pipeline, supplied by Gallegos pumping plant will initially serve Block 8. When the project expands beyond Block 8, this pipeline will also serve Block 9 directly and feed the Moncisco pumping plant.

Close-Pressure Distribution System: An aggregate of 340 miles of pipeline, 6 to 84 in diameter, are buried three ft deep or more.

Turnouts and Booster Pumping Plants. Outdoor-type booster pumps at about 74 turnouts take water from open canals to the closed-pressure pipelines for sprinkler irrigation. Thirty-five of them have traveling screens and booster pumping plants of four to six units each. The five multiple-unit pumping plants for Block 1 have elevated steel tanks; of the turnouts for Blocks 2 and 3 part are pressure demand and part gravity pressure. The 56 for Blocks 4 through 11 have or will have either elevated tanks or surge tanks. These are rated at 11 to 105 cfs.

Thirty-nine individual pumping plants, each with a single pump, have or will have stationary screens and flow measuring devices. Capacity is from one to 11 cfs.

While the pumping plants for Blocks 1 through 3 run by natural gas, those for Blocks 4 through 11 will be electrically driven.

Approximately 780 individual turnouts set on concrete slabs, above ground, moderate flow and pressure.

A monitoring program is implemented that includes the placement of gaging stations, drilling of observation wells, and periodic determination of flow rates from excessive runoff, normal flows and water level fluctuations. Total dissolved solid (TDS), pesticides and fertilizers in return flows are also sampled.

Drainage. There will be about 67,500 AF of return flow from the project when the project is completed at full acreage level with full implementation of improved irrigation management program presently in development. Of this total, about 13,500 af will be from canal spills or direct runoff . Of the 54,000 af of average annual deep percolation, about 15,700 af will return through natural seeps. The balance of 38,300 af will be collected in pipe drains and conveyed to natural arroyos by surface collector drains.

To date, no subsurface pipe drains have been constructed. As groundwater storage is filled, subsurface drains will be necessary to prevent waterlogging the fields. The first of these drainage systems will be installed for operation in the 1999 irrigation season. Detailed groundwater modeling has been completed to project the timing of construction of additional drains. Monitoring wells have been installed and are monitored for water table elevation on a quarterly basis. In the event that a water table buildup threatens crop production, subsurface drains will be installed, discharging water into open drains or washes, with water ultimately discharged to the river.

The surface drainage system was designed primarily for the runoff from precipitation. Approximately 200 miles of trapezoidal-section surface drains have been or will be constructed. All of these should accommodate a 10-year storm runoff and major structures should accommodate the deluges from 25-year design storms. They also will handle inadvertent irrigation return flow and function as outlets for any required subsurface drains. Runoff is controlled by uphill drain embankments and enters the drains through corrugated metal pipe inlets.

The slopes were designed for a maximum three-foot-per-second velocity during the design-storms and for preventing erosion of the drain section. Rock gabion drop structures meet this requirement. Sediment ponds also are excavated above drain inlets where required, to prevent excessive sedimentation. The collectors modify but do not basically alter natural drainage courses. They do, however, gather and convey water around the irrigated lands. Constructed channels empty onto places in the natural drainages where erosion is substantially stabilized.

The subsurface drainage system will consist of perforated plastic drain pipe buried from 6 to 12 ft below the surface of the ground within farmed areas. The drain pipes will vary in diameter from 4 inches to 42 inches. The spacing between parallel drain pipes will vary from a few hundred feet to over 1,000 ft depending on the soil permeability, drainage volume and naturally available drainage.

Transportation. Around 440 miles of asphalt farm-to-market roads cover a grid of about one mile throughout the cultivated area. (Only the roads through Block 8 are presently constructed). This allows access to each farm unit. Right-of-way widths are 80 ft for 355 miles of secondary roads and 150 to 200 ft for the 85 miles of primary roads. These roads are elevated above the fields, with surface widths of 26 and 34 ft respectively.

Combined Operation and Maintenance Headquarters. Operation and Maintenance (O&M) headquarters, about 10 miles due south of Farmington on State Highway 371, consist of an administrative office building, a garage and warehouse building, a service station and equipment paint shop and limited housing for security and maintenance personnel, and related utilities.

These are shared by O&M personnel and the BIA-NIIP roads department. As growth dictates, additional administrative buildings, shops, laboratories, etc., will be built there.

Land Development

Irrigated Land. For ease of development, egress and water delivery, the 110,630 acres have been arranged in 11 blocks of approximately 10,000 acres each (see Plate 1). Enough canals and drains were completed to allow cultivation of the first block of slightly less than 10,000 acres in 1976. Block 2 began to be irrigated in 1977, and an additional block planned for addition in each of the following nine years. Due to funding problems, the planned schedule was not met. The actual construction schedule to date, plus the projected schedule through Block 11 are presented in Table 1. The actual diversions and computed equilibrium depletions based on crops grown and water applied are shown through 1997. All years after 1997 assume a standard crop mix and average consumptive used conditions. The schedule shows completion in 2018. Actual construction is scheduled for completion in 2012. The irrigated acreage is limited through 2018 to control net downstream impact on the San Juan River until return flow increases from earlier irrigated blocks.

Every block is divided into fields, or water-delivery units, with access roads and individual sprinkler systems. Plate 1 shows the layout of the fields of each block as presently constructed or planned for construction. Although fields vary from 25 to 320 acres, they can be grouped for crops that require more space.

A ground-water monitoring system is installed to monitor water table rise and allow sampling of the water under the project lands. The location of the observation wells are shown on Plate 3.

Demonstration Range. South and east of the farmlands, some of the grazing land is devoted to a demonstration range, established both for the commercial production of livestock and for training Navajos in range management.

Soil Conservation Areas. Parts of the grazing land, along arroyos and where the soil has been severely weathered, is set aside as soil conservation, or erosion control areas. Reseeding and other techniques of vegetative restoration have been employed.

Project Operations. NIIP is operated as a tribal enterprise, Navajo Agricultural Products Industry (NAPI), and is patterned after other successful Navajo commercial enterprises as well as successful corporate farms. It is directed by a 7-member management board consisting of six Navajos and one businessmen or agriculturist from outside the Navajo Nation. NAPI operates under a long-range development and operating plan. The plan considers agronomic, marketing, environmental and economic interactions to develop the operating strategy for the farm.

Irrigation. The legislation authorized an average annual diversion at peak of 508,000 AF of water for the irrigation of 110,630 acres. The use of sprinkle irrigation has reduced the per acre demand. The historic average for 1976 through 1997 is about 3.36 AF/A for the cropped acreage. Historic depletions, including evaporative loss from the sprinklers, crop consumptive irrigation requirement, and consumption by non-crop vegetation has averaged about 2.44 AF/A. The diversion requirement for the full 110,630 acres of cropped land assuming historic crop mix and efficiency with no fallow land or conservation acreage would average about 372,000 AF with an associated depletion of about 270,000 AF. With irrigation efficiency improvement from planned irrigation management changes, the diversion is expected to average about 337,500 AF per year with the same depletion level. It must be understood that these diversion and depletion volumes are average values and are based on projections from a limited amount of measured data. They should not be construed as legally binding figures. Actual amounts could exceed or fall short of these estimates. (A more detailed discussion of water requirements appears in later sections).

The entire project is sprinkle irrigated, predominantly by center-pivot laterals. The systems vary in length, irrigating circular fields ranging in size from about 60 acres to over 200 acres. Early blocks were originally irrigated by sideroll, handmove and solid set laterals, but have mostly been replaced by center pivots to increase efficiency and precision of irrigation and reduce management problems. New blocks will also be predominantly center pivot irrigated, with minor acreages of solid set or trickle irrigation on orchard crops.

Cropping Plan. A summary of the average cropping plan over the last ten years is shown in Table 2. Based on current long range plans, the crop mix is expected to change as shown in the third column of Table 2. This incorporates the potato acreage projected for support of the potato processing plant that is planned for construction in 2000. Although this mix represents the present plan of NAPI, market conditions and facilities availability may alter the mix. (Note the double crop acreage. For water use purposes the water use from this acreage is included in the water requirements for the physical acreage base).

It may be noted that a significant percentage of the acreage is in various conservation programs. These areas are only irrigated sufficiently to maintain vegetative cover and prevent erosion. The average depletion on these conservation acres is about 0.8 AF/A. The acreage varies somewhat year to year, and may be reduced significantly if the payment program for conservation set-aside is reduced. Future planning excludes conservation acreage and plans for full irrigation on 110,630 acres as anticipated in the authorizing legislation.

Table 1. NIIP Development Schedule reflecting the acreage farmed or projected to be farmed in each year through full development.

Year	Block 1 ac	Block 2 ac	Block 3 ac	Block 4 ac	Block 5 ac	Block 6 ac	Block 7 ac	Block 8 ac	Block 9 ac	Block 10 ac	Block 11 ac	Total ac	Diversion af	Depletion af
1976	9,202											9,202	35,067	23,288
1977	9,155	6,320										15,475	37,459	39,276
1978	8,730	8,842	2,465									20,037	49,775	44,007
1979	8,437	8,623	4,617									21,677	75,709	62,309
1980	8,896	9,176	8,558	1,958								28,588	109,552	85,543
1981	8,759	9,350	8,352	8,879								35,340	91,520	81,786
1982	8,162	9,147	8,962	9,334	8,778							44,383	114,822	95,267
1983	8,128	8,987	8,381	9,333	8,755							43,584	128,523	89,594
1984	8,538	8,672	8,135	8,956	8,735							43,036	127,458	87,965
1985	8,389	8,727	8,246	8,896	8,735	623						43,616	131,815	93,422
1986	8,341	8,750	8,182	8,964	8,667	604						43,508	154,790	77,185
1987	8,369	8,749	8,137	8,967	8,666	2,533						45,421	130,528	95,497
1988	8,384	8,749	8,196	8,954	8,666	6,098						49,047	128,868	95,868
1989	8,402	8,769	8,181	8,967	8,666	7,245						50,230	170,656	118,306
1990	8,404	8,813	8,196	8,955	8,545	7,238						50,151	143,330	105,461
1991	7,994	8,952	8,196	9,740	8,949	7,237	8,904					59,972	152,788	102,642
1992	8,872	9,270	8,455	9,885	9,662	8,036	6,216					60,396	146,300	117,708
1993	8,872	9,270	8,455	9,885	9,662	8,036	9,099					63,279	166,500	119,391
1994	8,872	9,270	8,455	9,885	9,662	8,036	9,099					63,279	180,900	126,316
1995	8,872	9,516	8,455	9,894	9,662	8,095	9,387					63,881	181,800	117,718
1996	8,872	9,516	8,455	9,894	9,662	8,095	9,387					63,881	193,100	129,571
1997	8,872	9,516	8,455	9,894	9,662	8,095	9,387					63,881	156,800	113,983
1998	8,872	9,516	8,455	9,894	9,662	8,095	9,387					63,881	182,754	146,203
1999	8,872	9,516	8,455	9,894	9,662	8,095	9,387	3,265				67,146	204,843	163,875
2000	8,872	9,516	8,455	9,894	9,662	8,095	9,387	6,530				70,411	214,804	171,843
2001	8,872	9,516	8,455	9,894	9,662	8,095	9,387	9,795				73,676	224,764	179,811
2002	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060				76,941	234,725	187,780
2003	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	3,704			80,645	246,026	196,821

	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Block	ck 8	Block 9	Block 10	Block 11	Total	Diversion	Depletion
	ac	ac	ac	ac	ac	ac	ac	ac	ac	ac	ac	ac	af	af
2004	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	7,409			84,350	257,327	205,861
2005	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113			88,054	268,627	214,902
2006	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	3,258		91,312	278,566	222,853
2007	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	6,516		94,570	288,504	230,803
2008	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	9,773		97,827	298,443	238,754
2009	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031		101,085	308,381	246,705
2010	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	1,500	102,585	312,957	250,366
2011	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	2,700	103,785	316,618	253,295
2012	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	4,500	105,585	322,109	257,688
2013	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	5,000	106,085	323,635	258,908
2014	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	5,300	106,385	324,550	259,640
2015	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	5,593	106,678	325,443	260,354
2016	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	5,888	106,973	326,343	261,074
2017	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	6,172	107,257	327,210	261,768
2018	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	6,497	107,582	328,203	262,562
2019	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	6,726	107,811	328,899	263,119
2020	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	6,953	108,038	329,593	263,674
2021	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	7,179	108,264	330,283	264,227
2022	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	7,380	108,465	330,896	264,716
2023	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	7,600	108,685	331,567	265,253
2024	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	7,800	108,885	332,177	265,741
2025	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	7,950	109,035	332,634	266,108
2026	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	8,130	109,215	333,184	266,547
2027	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	8,280	109,365	333,641	266,913
2028	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	8,430	109,515	334,099	267,279
2029	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	8,760	109,845	335,106	268,084
2030	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	9,050	110,135	335,990	268,792
2031	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	9,280	110,365	336,692	269,354
2032	8,872	9,516	8,455	9,894	9,662	8,095	9,387	13,060	11,113	13,031	9,545	110,630	337,500	270,000

Table 2. Historic and Projected Future Average Crop Mix Percentages.

Crop	1988-97 ave. with fallow	1988-97 ave. without fallow	Projected Average
alfalfa	13.6%	17.0%	21.0%
alfalfa establishment (fall)*	1.8%	2.2%	4.2%
beans(dry)	15.6%	19.4%	15.0%
spring grain	0.9%	1.1%	15.0%
winter grain	16.5%	20.5%	12.0%
corn(grain)	19.8%	24.7%	20.0%
potatoes	9.3%	11.6%	15.0%
vine crops	1.0%	1.3%	0.0%
grass crops	1.8%	2.2%	2.0%
other crops	1.8%	2.2%	0.0%
second crops*	3.2%	4.0%	3.0%
conservation	14.7%	0.0%	0.0%
fallow	5.0%	0.0%	0.0%
Total with double crop	105.0%	106.2%	107.2%

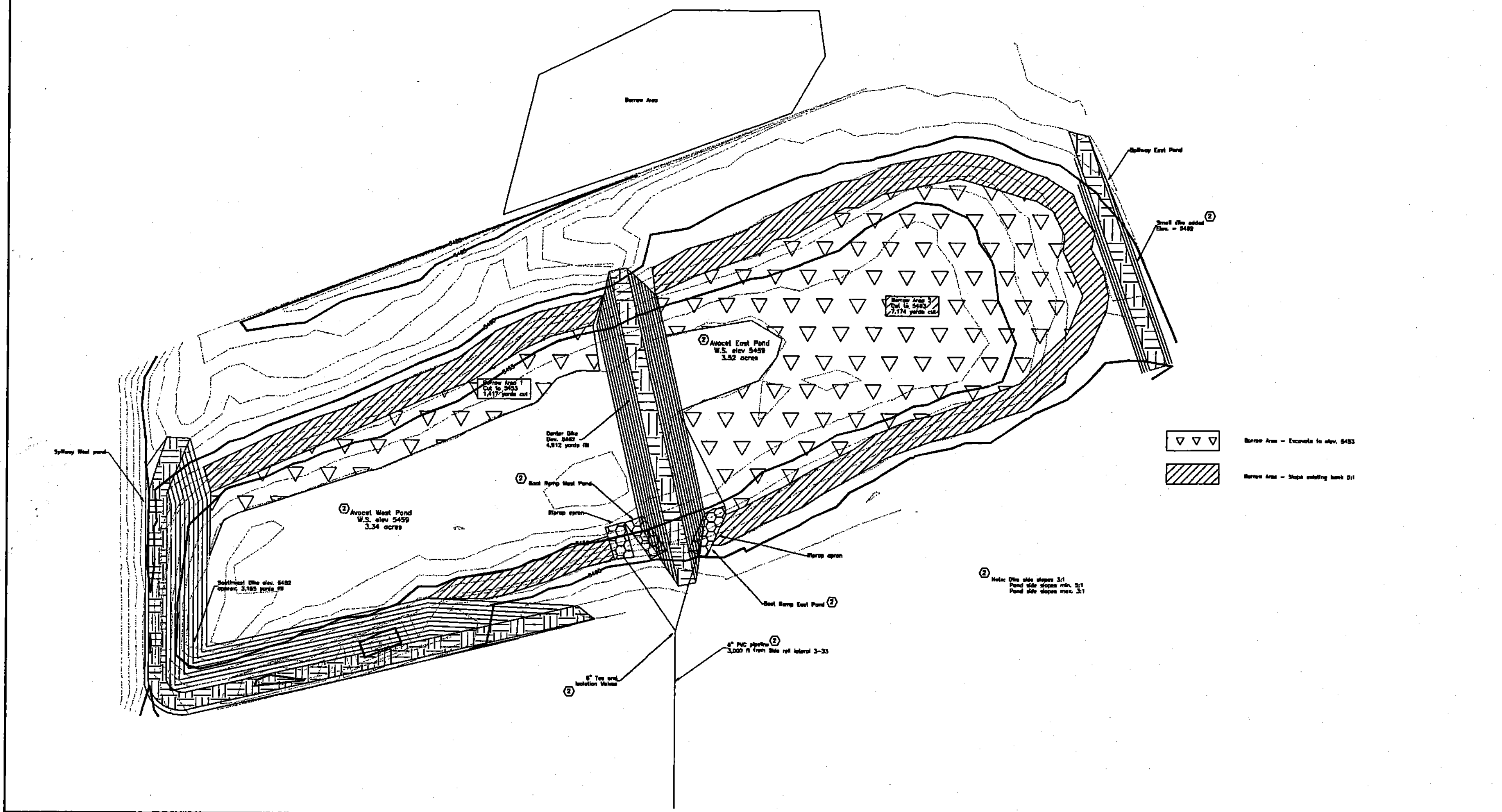
* indicates double cropped acreage, causing the total crop mix to exceed 100%

Other Project Features

As a part of the commitment to conserve populations of endangered fish species under authority of the Endangered Species Act, Section 7, a,1, the features described in this section have been included as a part of the NIIP.

Fish Rearing Ponds. In 1998, three fish rearing ponds were constructed on NIIP lands. The location of the ponds are shown on Plate 1. Ojo pond (Figure 1) was constructed in early spring, 1998 to accommodate up to 10,000 early life stage razorback suckers transferred from the Lower Colorado River. The pond is used for rearing of these young razorback suckers to a size suitable for stocking in the San Juan River as a part of the razorback sucker augmentation plan. The pond has a surface area of about 2.4 acres. It was constructed by raising an existing earthen dam on a tributary of Ojo Amarillo that collects seepage and runoff water from NIIP lands. The shallow areas were deepened, a fish screen was installed and a boat ramp constructed to facilitate fish harvest. The water level can be lowered by about 2.0 ft for harvesting fish by removing flash boards in the outlet structure.

Avocet ponds (Figure 2) were constructed in early summer for future use. The two-cell configuration covers a total area of about 7.5 acres, about equally split between the two cells. Water is supplied from a turnout on the NIIP water supply system. Each cell can be filled independently and each have an emergency overflow. The ponds have a nominal depth of about 6.0 ft. The ponds were filled and tested



This drawing and the ideas and designs incorporated herein are specific to this project and, as an instrument of professional service, are the property of Keller–Bliesner Engineering. They may not be used, in whole or in part, for any purpose without the written authorization of Keller–Bliesner Engineering and the project owner.

REV	Revisions	Date	Design	Draw	Check
2	As built	3/23/98	MI	MI	RDB
1	For construction	3/5/98	RDB	MI	RDB

Status: As built
Designed: RDB/MI
Drawn: MI
Checked: RDB
Approved: RDB
File Name: SJL101.DWG

SCALE 1" = 80'

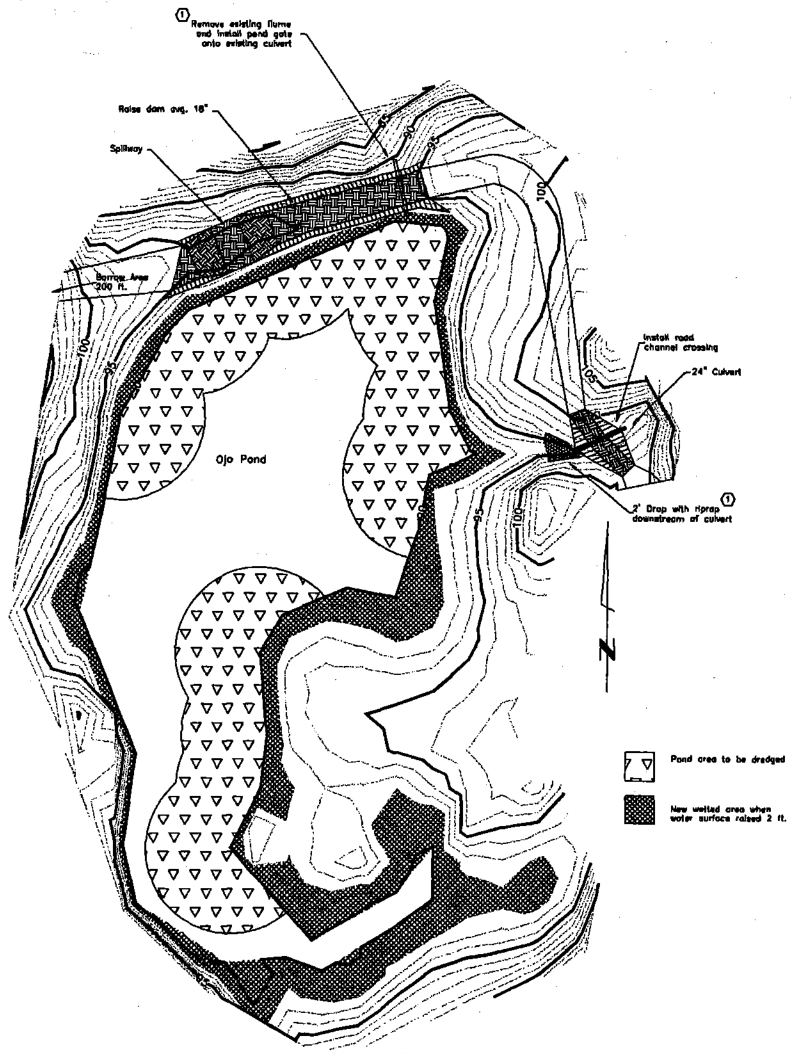
Coordinate System: Local
Datum: Local
Survey Data Source: B.I.A. and Keller–Bliesner

Keller–Bliesner Engineering
Irrigation & Water Resources
78 E. Center
Logan, Utah 84321

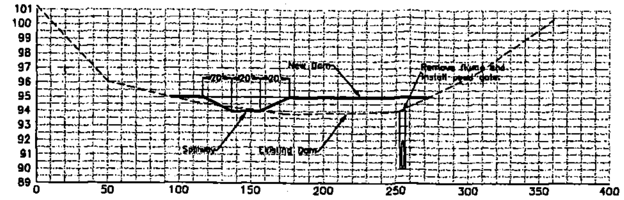
Bureau of Indian Affairs
Navajo Indian Irrigation Project
San Juan Recovery Implementation Program

Figure 2. Avocet Fish Pond

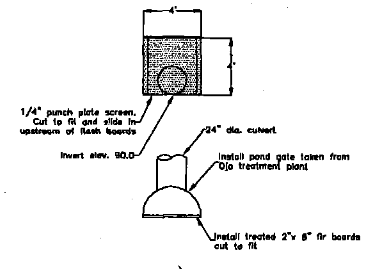
Job No. 208–100
Date: 3/2/98
Sheet 1 of 2
DRAWING NO. L101
REV 2



Ojo Pond Layout



① Dam Plan and Profile View
Vertical Scale x 10



Pond Gate Details
Scale 1" = 4'

REV	Revisions	Date	Design	Draw	Check
1	As Built	4/2/98	MI	MI	RDB

Status: As built
Designed: RDB/MI
Drawn: MI
Checked: RDB
Approved: RDB
File Name: SJL100.DWG

SCALE 1" = 40'
Coordinate System: Local
Datum: Local
Survey Data Source: B.I.A. and Keller-Bliesner

Keller-Bliesner Engineering
Irrigation & Water Resources

Bureau of Indian Affairs
Navajo Indian Irrigation Project
San Juan Recovery Implementation Program

Figure 1. Ojo Amarillo Fish Pond

Job No. 208-100
Date: 12/10/98
Sheet 1 of 1
DRAWING NO. L100
REV ①

during the summery of 1998 with satisfactory results. Water quality parameters were well within specification for rearing larval razorback suckers. When needed, each cell has the capacity of at least 10,000 fish. Water levels will be maintained by releases from the NIIP water supply system with water requirements a part of the depletion allocation for NIIP.

Cudei Diversion Dam Removal. The Cudei diversion dam is located about 6 miles downstream of Shiprock on the San Juan River. The quarry rock dam spans the entire width of the river as it diverts water to the Navajo-owned Cudei irrigation project. This is the lowermost diversion dam on the San Juan River.

Findings of SJRIP research indicate that expansion of range of Colorado pikeminnow in the San Juan River is likely important to the recovery of the species and identified five diversion dams as being impediments to this range expansion (Masslich and Holden, 1996). While there have been isolated sightings of Colorado pikeminnow above the diversion, most of the wild fish captures have been below.

To allow expansion of range, plans are underway to remove this diversion dam and supply the Cudei project from the Hogback main canal via an 21-inch diameter inverted siphon crossing the river as shown in Figure 3. The river crossing will be accomplished by routing the river on alternate sides of the island and installing the pipeline in an open cut trench across the de-watered portion of the river.

Upon completion of the siphon crossing, the existing diversion dam would be removed to allow free migration past this point. Construction is anticipated for fall/winter of 1999/2000 or 2000/2001, depending on funding availability. This project will eliminate a barrier to upstream passage and entrainment of down-migrating fish.

Hogback Diversion Dam and Fish Passage. The Hogback diversion dam on the San Juan River about 10 miles east of Shiprock diverts water for the Navajo owned Hogback irrigation project. The historic quarry rock diversion dam has failed and the diversion is maintained by bulldozing up a dike across the river during low flow and routing most of the water through the canal intake and sluiceway. During storm events the dike is breached and must be re-built. The present operation impedes fish passage upstream past the site.

The Bureau of Reclamation is presently designing a low gradient riprap dam with steel sheet pile cutoff wall to replace the existing temporary dike arrangement. The conceptual layout is shown in Figure 4. A low-flow fish passage channel will be incorporated into the structure adjacent to the sluiceway, as shown. At high flow, the entire structure will be passable by most fish species. The fish passage is constructed to allow passage of down-migrating fish, including larval drift, through the fish passage channel.

During construction, water will be routed through the canal and sluiceway to allow construction of the dam in dry conditions. The existing dike will be repaired and used for water control during construction. Construction is anticipated for the fall/winter of 1999/2000, depending on funding availability.

With the completion of these two projects, the potential range of the endangered fish species will be expanded by about 22 miles to the Four Corners Generating Station weir, representing a 15% expansion in range.

DESCRIPTION OF THE ENVIRONMENT

Physiography

Topographically, the Navajo Indian Irrigation Project typifies the mesas and high plateaus of the semi-arid Intermountain West. Gently rolling, smooth slopes rim the narrow to somewhat broad valley that will be farmed. The natural drainage pattern is well defined, with slopes of one to four percent, and averaging two to two and one-half percent. The semi-desert soils have been formed from sandstones and shales and deposited by wind and water.

Topography

The project is located in the San Juan Basin. On the parcels to be irrigated, on what once was called the Chaco Plateau (Gregory, 1916), elevations rise from 5,400 ft above mean sea level on the west to 6,480 ft on the east. Surface drainage generally moves north-northwest because of the Continental Divide thrusting up diagonally across northwestern New Mexico. The project area is bounded on the north by the San Juan River valley, on the west by Chaco wash and is dissected south to north by Gallegos Canyon.

Geology

Rocks of all the ages from Archaean to recent alluvial deposits are found on or close by the project, which will have no impact on the geology. Plate 4 shows contact geology.

The surface of the project area is overlain (with the few exceptions of occasional sand dunes and isolated wind-eroded pockets) with an eolian deposit of fine silty sand or sand silt. This layer varies in thickness from 8 to 40 ft. The minimum thickness of 8 ft was one of the criteria for irrigable lands. Beneath this is a layer of alluvial deposit composed predominantly of clean sand of fine to medium grain, varying in thickness between 8 and 30 ft and averaging 20 ft.

<u>Quaternary</u>. Alluvial deposits of silty, sandy, gravelly materials blanket much of the highlands. They are present, too, in gravel terraces along the river and as channel fill in most drainages. Drilling indicates that they are from a few to more than 70 ft thick. In places, they are covered from a few feet to 30 ft with eolian deposits of fine silty sand. Southwest of Farmington, these eolian accumulations become well-developed, relatively stable sand dunes.

<u>Tertiary</u>. The Nacimiento formation, 500 to 1,000 ft of varicolored shale and arkosic sandstone, with some conglomerate and rare coal beds, is overlain by the San Jose formation of the quaternary (Peterson, 1965).

<u>Upper Cretaceous</u>. The Ojo Alamo Sandstone is a lenticular, crossbedded, fine to coarse-grained arkosic and conglomeratic sandstone and conglomerate. It contains thin lenses of clay shale and silicified logs and is about 200 ft thick. An erosional unconformity separates it from the underlying Kirtland shale, and the Ojo Alamo intertongues with the overlying Nacimiento (Baltz, 1966).

The Ojo Alamo directly overlays the Kirtland formation. Gray to brownish-gray clay and silty shale with a subordinate content of light gray and tan, soft sandstone make up the Kirtland shale, which is gradational with the Fruitland formation below. It generally is considered an aquiclude and is unlikely to be affected by the proposed operation. Plate 4 shows the differentiation of the Kirtland formation described by O'Sullivan and Beikman (O'Sullivan, 1966) into the Upper Kirtland, Farmington sandstone member, and Lower Kirtland formation. Field investigations by Morrison-Maierle (Morrison, 1975) indicated that the sand lenses of the Farmington Sandstone Member may be present throughout the upper Kirtland and are often in contact with the overlying Ojo Alamo sandstone. This conclusion is supported by Fassett and Hinds (Fassett, 1971) based on interpretation of subsurface data throughout the San Juan Basin.

The Fruitland formation interbeds gray, brown and black shales with thin to massive-bedded, cross-bedded, lenticular brown and gray sandstone. It is this coal-bearing formation that is being strip-mined. Although some of the sandstones portend a minor local potential for ground water yield, they are considered a poor prospect due to of the discontinuity of individual beds. The beds, about 250 ft thick in the area of operation, are completely gradational with the overlying formation and intertongued with the underlying Pictured Cliffs sandstone. (Beaumont, 1955),(U.S. Geological Survey, 1955)

Soils

The soils largely are deep and sandy alluvial and eolian deposits, underlain by sandstone and shale. Of those subject to irrigation, sandy loams and loamy sands predominate; loams and sandy clay loams appear widely in patches.

Soil associations and land classification for irrigation were mapped in San Juan County by the New Mexico Agricultural Experiment Station (Maker, 1973). Two such associations are significant in the project area: The Shiprock-Sheppard-Nageesi and the Persayo-Farb.

The soils of the Shiprock-Sheppard-Nageesi association, which were used principally for the grazing of livestock prior to project development, generally support a moderately dense cover of vegetation. Under good management moderate yields of forage are obtained. Native vegetation included galleta, blue grama, Indian ricegrass, sand dropseed, poverty three-awns, snakeweed, big sagebrush, common winterfat, and long-leaf ephedra.

The Shiprock soils usually occur on the nearly level to gently sloping in part of the area occupied by the soils of this association. They have a thin surface layer of light brown or light reddish-brown noncalcareous fine sandy loam. Their subsoil is a brown to reddish-brown noncalcareous heavy fine sandy loam. This horizon typically extends to a depth of 15 to 20 in. The substratum is a reddish-brown to reddish-yellow calcareous sandy loam or loamy fine sand. A few fine streaks and small soft masses of lime are usually present in the upper part of the substratum.

The Sheppard soils, in this association, occupy the gently rolling or dune-like areas. The ridges and dunes are oriented in the direction of the prevailing winds, or in a southwest to northeast direction. They have surface layers of loose, weakly calcareous pale brown or light reddish-brown loamy fine sand. This is underlain by a moderately calcareous sand, fine sand, or loamy sand to a depth of five feet or more.

Nageesi soils usually occur on the gentle slopes in close association with the Shiprock soils. Nageesi soils are characterized by the calcareous surface soils and pinkish-white lime zones at shallow to moderate depths. They usually have moderately thick surface layers of light brown or reddish-yellow sandy loam. The lower part is typically more limy than the upper part. This layer grades through a pale brown sandy loam to very limy pinkish-white loam at depths ranging from 10 to 20 in.

Kinnear soils, which are also moderately extensive in this association, commonly occur in small depressional areas as well as on the adjacent side slopes. They are usually gently sloping and undulating, but may range from nearly level to strongly sloping. The surface layer is a typically brown, slightly calcareous, fine sandy loam or very fine sandy loam about eight in thick. This is underlain to a depth of 30 to 48 in by reddish-yellow clay loam, loam, or very fine sandy loam that contains soft masses and threads of segregated lime. The substratum to a depth of five or more feet is typically a loamy sand, but may range in texture from a sand to a fine sandy loamy or very fine sandy loam.

Also in this association are soils identified as Typic Camborthids, shallow and moderately deep soils underlain by interbedded sandstone and shale, and small areas of miscellaneous land types. The Typic Camborthids resemble the Shiprock soils, but have coarser textured substrata. They are typically underlain by sand at a depth ranging from about 20 to 24 in. The shallow soils, which have brown or light brown fine sandy loam or light loam surface layers are underlain by shale or shale interbedded with sandstone at depths of 6 to 20 in. The moderately deep soils are similar except that the interbedded shale and sandstone occur below a depth of 20 in and usually within a depth of 60 in. The miscellaneous land types include small areas dominated by outcrops of shale and sandstone, gullied land and alluvial land.

The soils of the Persayo-Farb provide only limited grazing as they support a sparse cover of native grasses and shrubs. The principal grasses include galleta, Indian ricegrass, and blue grama. Pinon, juniper, serviceberry, bitterbrush, saltbrush, shadscale, and snakeweed represent the more common shrubs and woody species. Due to the sparse vegetative cover and low intake rate of many of the soils, runoff is high and erosion hazard moderate to severe.

Persayo soils, the most extensive in the association, are developing on upland slopes and ridges in a thin layer of calcareous material weathered from the underlying shale. They have a thin surface layer of pale yellow or light yellowish-brown granular silty clay loam. This is underlain by a light yellowish-brown or pale yellow silty clay loam subsoil that typically contains a moderate amount of partly weathered small fragments. Concretions of calcium carbonate and crystals of calcium sulfate are also common throughout the subsoil and substratum. The depth of shale ranges from about 6 to 18 in.

Farb soils, which are shallow over sandstone, are also relatively extensive in this mapping unit. They have a surface layer of pale brown to yellowish-brown, calcareous sandy loam. This is underlain by sandy loam or loamy fine sand that often contains a few angular fragments of sandstone gravels and cobbles. Sandstone bedrock is typically encountered at depths ranging from about 10 to 18 in.

In addition to the two principal soils, miscellaneous land types and soils of minor extent comprise approximately 30 percent of the association. The land types include Sandstone Rock Land and Badland. These occupy the very steep slopes and breaks and are characterized by outcrops of bedrock. Soils of the Shiprock series and an associated deep loamy sand soil are also important in this unit. The Shiprock soils have a surface layer of fine sandy loam over a thin sandy clay loam subsoil. This is underlain by loamy fine sand or sandy loam. Alluvial soils in the narrow valley bottoms and swales contiguous to intermittent drainages also comprise a small acreage in this unit. These soils are deep and generally medium to moderately fine-textured.

ENDANGERED SPECIES LIST
FEDERALLY LISTED SPECIES

A number of species of vegetation, fish and wildlife found or potentially found in the vicinity of the NIIP have been listed by the Federal Government as threatened, endangered, candidate 2 or species of concern. Threatened or endangered species are listed as such under Section 7 of the Endangered Species Act. Candidates are species which the USFWS has sufficient information on their biological status and potential threats to propose them as endangered or threatened, but have yet to be formally listed. Species of concern are suspected by USFWS to have vulnerable population status, but require further study to determine their conservation status.

Those species identified by U.S. Fish and Wildlife Service (USFWS 1997) as occurring in San Juan County, New Mexico are as follows:

WILDLIFE:

Black-footed ferret	*Mustela nigripes*	Endangered
Big free-tailed bat	*Nyctinomops macrotis*	Species of Concern
Fringed myotis	*Myotis thysanodes*	Species of Concern
Long-eared myotis	*Myotis evotis*	Species of Concern
Long-legged myotis	*Myotis volans*	Species of Concern
Occult little brown bat	*Myotis lucifugus occultus*	Species of Concern
Pale Townsend's big eared bat	*Plecotus townsendii pallescens*	Species of Concern
Small footed myotis	*Myotis ciliolabrum*	Species of Concern
Spotted bat	*Euderma maculatum*	Species of Concern
Yuma myotis	*Myotis yumanensis*	Species of Concern
American peregrine falcon	*Falco peregrinus anatum*	Endangered
Arctic peregrine falcon	*Falco peregrinus tundrius*	Threatened
Baird's sparrow	*Ammodramus baidrii*	Species of Concern
Bald eagle	*Haliaeetus leucocephalus*	Threatened
Black tern	*Chlidonias niger*	Species of Concern
Brown pelican	*Pelecanus occidentalis*	Endangered
Ferruginous hawk	*Buteo regalis*	Species of Concern
Loggerhead shrike	*Lanium ludovicianus*	Species of Concern
Mexican spotted owl	*Strix occidentalis lucida*	Threatened
Mountain plover	*Charadrium montanus*	Candidate Species
Northern goshawk	*Accipiter gentilis*	Species of Concern
Southwestern willow flycatcher	*Empidonas traillii extimus*	Endangered
Western burrowing owl	*Athene cunicularia hypugea*	Species of Concern
White-faced ibis	*Plegadis chihi*	Species of Concern

VEGETATION:

Arizona leatherflower	*Clematis hirsutissima var. Arizonica*	Candidate Species
Beautiful gilia	*Gilia fomosa*	Species of Concern
Bisti fleabane	*Erigeron bistinensis*	Species of Concern
Brack's fishhook cactus	*Sclerocactus cloveriae var. Brackii*	Species of Concern
Goodding's onion	*Allium goodingii*	Candidate species
Knowlton cactus	*Pediocactus knowltonii*	Endangered
Mancos milk-vetch	*Astragalus humillimus*	Endangered
Mesa Verde cactus	*Sclerocactus mesae-verdae*	Threatened
Parish's alkali grass	*Puccinellia parishii*	Proposed Endangered
Sant Fe cholla	*Opuntia viridiflor*	Species of Concern

FISH:

Colorado pikeminnow	*Ptychocheilus lucius*	Endangered
Razorback sucker	*Xyrauchen texanus*	Endangered
Roundtail chub	*Gila robusta*	Species of Concern

Listed Species - Wildlife

Black-footed ferret (*Mustela nigripes*) - This species is listed as endangered by the USFWS. While the former range of this species included the project area, black-footed ferrets are generally considered to be extirpated from New Mexico. This species is associated with large colonies of prairie dogs, particularly towns over 200 active burrows, and there is a small possibility that a colony of ferrets could still inhabit such a colony in New Mexico. The project area does not contain any prairie dog colonies and thus does not contain suitable conditions for the presence of black-footed ferrets. The project area is also not adjacent to lands containing prairie dog colonies.

Big free-tailed bat (*Nyctinomops macrotis*) - This species is listed as a species of concern by USFWS. The project site does not provide suitable habitat for roosting of this species. The site may provide possible very low quality foraging opportunities for this species, but is not adjacent to suitable roosting habitat and use is likely to be very infrequent.

Fringed myotis (*Myotis thysanodes*) - This bat species is listed as a species of concern by USFWS. This species is often associated with oak and pinyon pine woodlands, but may be found from desert scrub to fir forests. Foraging is often conducted over water courses. The site does not provide suitable habitat for roosting of this species. The project site may provide possible very low quality foraging opportunities for this species, but is not adjacent to suitable roosting habitat and use is likely to be very infrequent.

Long-eared myotis (*Myotis evotis*) - This bat species is listed as a species of concern by USFWS. This species is typically associated with conifer forests, commonly pinyon-juniper stands. The project site does not provide suitable habitat for roosting of this species. The site may provide possible very low quality foraging opportunities for this species, but is not adjacent to suitable roosting habitat and use is likely to be very infrequent.

Long-legged myotis (*Myotis volans*) - This bat species is listed as a species of concern by USFWS. This species is typically associated with conifer forests, but they may inhabit watercourses and desert areas. The project site does not provide suitable habitat for roosting of this species. The project site may provide possible very low quality foraging opportunities for this species, but is not adjacent to suitable roosting habitat and use is likely to be very infrequent.

Occult little brown bat (*Myotis lucifugus occultus*) - This subspecies is listed as a subspecies of concern by USFWS. This bat uses a variety of habitats for foraging and a variety of structures for roosting. The project site does not provide suitable habitat for roosting of this subspecies. The site may provide possible very low quality foraging opportunities for this subspecies, but is not adjacent to suitable roosting habitat and use is likely to be very infrequent.

Pale Townsend's big-eared bat (*Plecotus townsendii pallescens*) - This subspecies is listed as a subspecies of concern by USFWS. This bat uses a variety of habitats including scrublands, and pine, juniper and deciduous forests. The project site does not provide suitable habitat for roosting or hibernation by this subspecies. The site may provide possible very low quality foraging opportunities for this subspecies, but is not adjacent to suitable roosting habitat and use is likely to be very infrequent.

Small-footed myotis (*Myotis ciliolabrum*) - This bat species is listed as a species of concern by USFWS. This species is often associated with rocky canyon areas, but may also be found in forests and along water courses. The project site does not provide suitable habitat for roosting of this species. The project site may provide possible very low quality foraging opportunities for this species, but is not adjacent to suitable roosting habitat and use is likely to be very infrequent.

Spotted bat (*Euderma maculatum*) - This species is listed as a species of concern by USFWS. This species is often associated with rocky canyon areas, but may also be found in forests and caves. The project site does not provide suitable habitat for roosting of this species. The project site may provide possible very low quality foraging opportunities for this species, but is not adjacent to suitable roosting habitat and use is likely to be very infrequent.

Yuma myotis (*Myotis yumanensis*) - This bat species is listed as a species of concern by USFWS. This species is typically associated with deserts and dry grasslands. The project site does not provide suitable habitat for roosting of this species. The project site may provide possible very low quality foraging opportunities for this species, but is not adjacent to suitable roosting habitat and use is likely to be very infrequent.

Peregrine falcon (*Falco peregrinus*) - Two subspecies of this species occur in New Mexico: American peregrine falcon (*F. p. anatum*) which is listed as endangered by the USFWS, and arctic peregrine falcon (*F. p. tundrius*) which is listed as threatened by the USFWS. A portion of the American peregrine falcon population nests within the southwestern portion of the United States in suitable habitat, while the arctic peregrine falcon nests north of the continental United States and some individuals migrate through portions of New Mexico. Peregrines are often associated with high cliffs and water, but may nest some distance from water. The project area does not provide nesting or foraging habitat for peregrine falcons. Any use of the project area would be very incidental and associated with movements between areas of suitable habitat.

Baird's sparrow (*Ammodramus bairdii*) - This species is listed as a species of concern by the USFWS. Baird's sparrow is a bird of grasslands, but uses weedy fields during migration. Baird's sparrow is a rare migrant through this portion of New Mexico. The project area provides low quality habitat for this species during migration, but because of the low numbers passing through the area, use of the project area would be accidental.

Bald eagle (*Haliaeetus leucocephalus*) - Bald eagle is listed as threatened by the USFWS. Bald eagles winter in small numbers along the San Juan River. The project area does not contain suitable habitat or forage species for bald eagle and use of the project area would be limited to infrequent flyovers.

Black tern (*Chlidonias niger*) - This species is listed as a species of concern by the USFWS. Black terns are birds of open fresh water and nest in associated marsh areas. The project area does not contain suitable habitat for this species, and no use of the site would be expected.

Brown pelican (*Pelecanus occidentalis*) - This species is listed as endangered by the USFWS. This species has occurred accidentally in the region, but the project area contains no suitable habitat.

Ferruginous hawk (*Buteo regalis*) - This species is listed as a species of concern by the USFWS, and inhabits open grasslands and scrublands. This species occurs in low numbers in the region, and likely nests. The project area does not contain suitable nesting habitat for this species and low quality foraging habitat. Use of the project area would be minimal due to the present low quality of the forage base.

Loggerhead shrike (*Lanius ludovicianus*) - This species is listed as a species of concern by the USFWS. Loggerhead shrike is a permanent resident of the region that includes the project area, and prefers open country with scattered shrubs. The project area likely provided suitable habitat for this species prior to the development of agriculture, but presently the habitat value to this species is very low. The quality of adjacent lands is similarly low. Use of the project area by this species would be infrequent, and nesting is very unlikely.

Mexican Spotted owl (*Strix occidentalis*) - This subspecies is listed as threatened by the USFWS. The Mexican spotted owl typically is found in canyon habitats, particularly where there are large conifers. The project area does not contain suitable habitat for this species, and is not adjacent to such habitat.

Mountain plover (*Charadrius montanus*) - This species is listed as a species of concern by the USFWS. Mountain plover breed in the northeastern quarter of New Mexico, but would only be a rare visitor to the northwest portion of the state. The project area contains low quality habitat for this species after tilling of the soil. However, any use of the project area would be very infrequent and for very brief periods.

Northern goshawk (*Accipiter gentilis*) - The goshawk as a species of the northern and mountain forests, and is listed as a species of concern by the USFWS. The project area does not contain suitable habitat for this species and use of project area would be limited to very infrequent flyovers.

Southwestern willow flycatcher (*Empidonax traillii extimus*) - This subspecies is listed as endangered by the USFWS. The range of this subspecies includes the San Juan River basin, but designated critical habitat does not include this drainage, nor was critical habitat proposed for the drainage (USFWS 1993). The southwestern willow flycatcher is a riparian obligate neotropical migrant and typically nests in willow/cottonwood associations vegetation communities of similar structure associated with standing or flowing water (Verner 1997). The decline of this subspecies has been linked to a variety of factors including: large-scale habitat destruction, invasion of exotic vegetation species, brood parasitism by brown-headed cowbirds (*Molothrus ater*), and direct mortality through nest destruction by grazing livestock (Verner 1997).

Within the San Juan River drainage, populations of breeding southwestern willow flycatcher appear to have been quite small for many years. Woodbury (1961) lists the willow flycatcher as a summer resident based on a single observation of a singing and feeding individual along the Piedra River in early July,

1960. Schmitt (1976) lists the species as Occasional at Kirtland, but overlooked and/or misidentified and thought to breed. Behle (1985) shows the location of collection for two specimens of this species in the San Juan River drainage in southeastern Utah. A survey conducted in 1997 along the San Juan River from Navajo Dam to Lake Powell located only one nesting pair (Ecosphere, Inc., Farmington, NM, unpublished data). This nest, located in the floodplain along the San Juan River near the mouth of Malpais Arroyo, was the first documented southwestern willow flycatcher nest along the mainstem San Juan River (Tim Reeves, Ecosphere, Inc., Farmington, NM, Pers. Comm.). This survey also found several willow flycatchers during the migratory period within the main San Juan River corridor, but could not determine whether these birds were of the southwestern subspecies (Ecosphere, Inc., Farmington, NM, unpublished data). These birds may be using the riparian corridor as a temporary stopover to replace resources spent during migration. Similar use of larger rivers as important refueling sites for willow flycatchers as they migrate between breeding grounds and wintering grounds has been described along the middle Rio Grande River (Yong and Finch 1997).

Southwestern willow flycatchers are not necessarily restricted to willow/cottonwood complexes along larger rivers, and may also utilize suitable willow habitat away from these large rivers. Within the project area, however, there is no suitable willow habitat, nor has there historically been such habitat. This subspecies is not expected to use the project area.

Reoperation of Navajo dam will affect habitat in the San Juan River flood plain. More frequent flooding of riparian areas may enhance feeding areas for the fly catcher. However, these flooded areas likely will not persist long enough to support nesting birds, but provide areas suitable for transient individuals. The only nesting area found receives a water supply from irrigation return flow from the Hogback project. Re-operation of Navajo dam will likely not affect this area.

Western burrowing owl (*Athene cunicularia hypugea*) - This subspecies is listed as a subspecies of concern by the USFWS. Burrowing owls are birds of open flat ground with low grass or bare soil. They are often associated with prairie dog colonies, but also utilize airports, golf courses, vacant lots, industrial parks and other open areas. The project area does not contain suitable habitat for this species during the breeding season due to crop production, and has limited foraging opportunities. Use of the project area would be limited to infrequent foraging if birds were residents on lands nearby.

White-faced ibis (*Plegadis chihi*) - This species is listed as a species of concern by the USFWS. The while-faced ibis is a casual migrant through the area, and there are no nesting colonies within this portion of New Mexico. This species typically nests in dense marsh habitats, and forages in shallow water including flooded cultivated lands. The project area does not contain suitable habitat for this species because of the lack of standing water from irrigation.

Listed Species - Vegetation

Gilia formosa, *Erigeron bistiensis*, *Sclerocactus cloveriae*, *Astragalus humillimus* and *Sclerocactus mesa-verdae* are all found in Great Basin Desert Scrub habitat. *Pediocactus knowltonii* is found in Great Basin Conifer Woodland habitat, and *Clematis hirsutissima* is found in Rocky Mountain Montane Conifer Forest habitat (BLM, 1995). *Allium gooddingii* grows in deep shade at higher elevations. It has been found at only two sites on the Navajo Nation (Roth, Navajo Fish and Wildlife Dept, pers comm). *Puccinellia parishii* occurs in alkali seep areas and in areas where grazing has eliminated competitive species (Roth, pers comm). It has recently been found to the east of the project, between Shiprock NM and Kayenta, AZ (Roth, pers comm). According to Bob Sevinsky of New Mexico Energy, Minerals and Natural Resources Dept., this grass could possibly grow in conditions produced by recent seeps on NIIP lands, but it would not have had the time or opportunity to become established in these areas. *Opuntia viridiflora* is endemic to the town of Santa Fe and found strictly in north central New Mexico (Sevinsky, pers comm.).

Listed Species - Fish

In 1991 Section 7 consultations were completed for the Animas LaPlata Project (ALP) and NIIP. As a part of the reasonable and prudent alternatives for these projects addressing impacts on endangered razorback sucker and Colorado pikeminnow, the San Juan River Basin Recovery Implementation Program was required. The plan was formulated during 1992. A 7-year research program began in 1991, associated with the Recovery Implementation Program that is documenting the status of the endangered and other native and non-native fish in the San Juan Basin, identifying limiting factors to the recovery of the species and developing specific recovery recommendations, including a flow recommendation for the needs of the fish.

Four annual reports (1992-1995) summarizing research results have been produced. The 1996 report in summary form only. Draft flow recommendations are completed and the flow recommendation report details the research results in terms of flow for the two species as well as the native fish community. A 5-year augmentation plan has been prepared for the razorback sucker and a similar plan is proposed for Colorado Pikeminnow. Extensive research has been conducted to identify limiting factors in the areas of native/non-native interaction, contaminants, fish health and habitat. During this research period, Navajo dam has been operated to mimic a natural hydrograph and provide test flows to determine biological response to the flows. These actions are expected to have a positive effect on the endangered species and the native fish community in general.

Colorado Pikeminnow (*Ptychocheilus lucius*) - This species is listed as endangered by the USFWS. On March 21, 1994, the final rule designating critical habitat was published. The extent of the critical habitat is the San Juan River and its 100 year flood plain from Neskahai Canyon in Lake Powell to the confluence of the San Juan and Animas rivers. The 7-year research studies indicate that while numbers are low for this species, a reproducing population exists in the San Juan River. Limiting factors to the recovery of the species are being identified as a part of the studies. Early indications are that recovery potential exists. Due to the small population and limited range, an augmentation plan is being developed for this species, in conjunction with other actions that are expected to lead to the recovery of this species.

Razorback Sucker (*Xyrauchen texanus*) - This species is listed as endangered by the USFWS. On March 21, 1994, the final rule designating critical habitat was published. The extent of the critical habitat is the San Juan River and its 100 year flood plain from Neskahai Canyon in Lake Powell to the Hogback diversion dam. The historical presence of this species in the San Juan is based primarily on anecdotal information and limited capture. No documented captures above Bluff, Utah have been made and the last capture in the river was in 1988 (Platania 1990). However, an experimental stocking program conducted as a part of the 7-year research program has demonstrated that the habitat is suitable for juvenile and adult razorbacks and that augmentation has potential (Ryden, 1997). Accordingly, a 5-year augmentation plan has been developed and is being implemented (Ryden 1997).

Roundtail Chub (Gila robusta). This species is listed as a species of concern by the USFWS. Historic collections of this species have demonstrated presence but never abundance, although early sampling was not sufficiently comprehensive to arrive at conclusions as to the early abundance of this species in the San Juan River. Intensive sampling during the 7-year research period has documented the existence of this species in the San Juan River, capturing YOY, juvenile, and adult individuals, but in low numbers with most captures downstream of the confluence with the Mancos River (San Juan Biology Committee, 1994, 1995, 1996). Surveys of tributaries in the San Juan Basin by Miller (1994) showed the presence of roundtail chub in the Florida, LaPlata and Mancos rivers with the greatest abundance in the upper Mancos river where this species accounted for 36% of the captures in the entire river and 67% above Johnson Canyon during the March 1994 sampling.

HYDROLOGY

Project Operation

Navajo Indian Irrigation Project has been in operation since 1976 with Blocks 1-7 completed and in operation by 1998. Understanding the operation of the project and its effect on the hydrology of the San Juan River is critical to the understanding of the biological affects of the project. Fortunately, excellent records on water use have been collected over the period of operation, allowing accurate assessments of water demands.

Historic Water Use. The historic water use of the Navajo Indian Irrigation Project is taken from the annual operation and maintenance reports published by NAPI from 1976 to 1997. The data are broken into categories dealing with various aspects of the project including: (1) releases from Navajo Dam, (2) amount of water metered at each field, (3) recorded waste or operational spills, (4) recorded dilution releases to reduce selenium concentration in Gallegos canyon and Ojo Amarillo (RIP release) and (5) contract water delivered through the canal system.

NAPI also published crop mix data for the same time period. Based on these crop data, the consumptive irrigation requirement (CIR) was calculated for years 1976-1997. Note that the CIR was computed for a simulated crop mix prior to 1982 based on the actual data available for 1982-1990, since actual crop data were not available prior to 1982. In the CIR calculations, climatic data, temperature and precipitation, collected at the New Mexico State University Science Center located in Block 2, were used. The Hargreaves-Samani method (Jensen, 1990) for calculation crop consumptive use and the SCS method (U.S. Dept of Agriculture, 1976) of computing effective precipitation were used to find monthly CIR values. The metered water deliveries to the conservation set-aside lands were broken out separately. It was assumed that the entire deliveries to set-aside lands, which were always under-irrigated, represented a total depletion. Hence, these lands were excluded from the CIR calculations. In Appendix Table A-1, diversion, delivery and CIR data are presented by month for 1976 through 1997. Table 3 summarizes the annual data for the same period.

The releases from Navajo Reservoir, the total irrigation water metered at the fields and the recorded waste or operational spills beginning in 1976 are plotted in Figure 5. The releases from Navajo Reservoir represent project diversions. The total metered water is the farm delivery. The difference between Navajo release and total metered represents the conveyance losses, part of which are the recorded waste. As depicted in Figure 5, the water use is rising as the blocks come on line. For example, the water use from years 1976 through 1987 increased steadily as Blocks 1 through 6 became operational. Although from 1988 through 1990 the irrigated acreage has not changed, crop water use has varied due to weather changes. In 1989 growing season water use increased markedly due to the dry, hot summer. The irrigated acreage increased during 1990-1995 as Block 7 came on line. Of course the metered water has always been less than the releases from Navajo Reservoir. The difference is partially the recorded waste and the remainder due to system leakage and evaporation.

The original project design was for side-roll sprinkle irrigation, but beginning in 1981, the existing fields were mostly converted to center-pivot irrigation. Some fields in Block 1 through Block 6 are still irrigated using side-roll sprinklers. Subsequent blocks are planned for all center-pivot irrigation.

Table 3. Annual Water Use, 1976-1997.

Year	Navajo Release	Cutter Release	Total Metered	Recorded Waste	Other / Contract	Crop CIR	Cons. CIR
1976	35,067		31,249	375	0	17,293	0
1977	37,525		34,836	2	366	27,219	0
1978	49,775		47,071	42	393	30,814	0
1979	75,709		74,469	195	307	48,027	0
1980	109,552		99,895	889	0	69,157	0
1981	91,520		84,614	2,759	0	63,713	0
1982	114,828		112,994	154	0	74,356	0
1983	128,523		101,911	1,102	0	68,786	1,005
1984	127,458		110,054	1,316	0	66,365	982
1985	131,815		110,156	3,514	0	71,674	1,061
1986	124,790		100,793	7,186	0	54,204	4,123
1987	130,528	127,236	106,934	5,358	0	69,477	5,376
1988	128,868	117,838	109,964	4,978	0	67,402	7,272
1989	170,656	164,784	156,197	3,177	0	87,312	5,067
1990	142,988	133,487	127,152	2,827	0	77,475	4,963
1991	152,788	137,909	133,688	3,077	294	77,764	1,203
1992	146,300	137,579	120,972	11,879	8	89,259	6,045
1993	166,500		140,452	14,817	44	93,901	1,137
1994	180,900		154,639	12,860	138	95,481	5,064
1995	181,800		148,581	23,803	5	88,098	4,454
1996	193,100		160,949	17,243	98	101,419	1,750
1997	156,800		130,496	15,696	12	87,781	2,846

The historic water diversion for the period most representative of future conditions, 1988-1997, equals about 3.36 AF/A on a net cropped acre basis (any double cropping is counted in the total). The crop CIR for the same period is about 1.84 AF/A for an overall efficiency of about 55%. A detailed water balance for the project will be considered in more detail in the next section.

Project Water Balance. The annual water balances were calculated from the published NAPI water use data, the crop CIR, and loss estimates due to evaporation and phreatophyte use. Using these data, the loss due to sprinkler evaporation (10% of water metered at the field), the conveyance loss - evaporation and seepage (free-water surface of canal times 3 ft/yr plus difference between Navajo releases and total metered water at fields) and the phreatophyte-wet soil loss (planimetered area times 3 ft/yr) - were determined. The total return flow was then calculated by subtracting all consumptive losses from the total Navajo release. The total return flow was further divided into recorded spills and return flow from irrigation. Using these data for each year, the results were plotted as an annual time series which is shown in Figure 6.

As depicted in the Figure 6, the main components of the water balance, in order of decreasing magnitude, are: crop CIR, deep percolation, conveyance losses, sprinkler evaporation, phreatophyte consumption and spills.

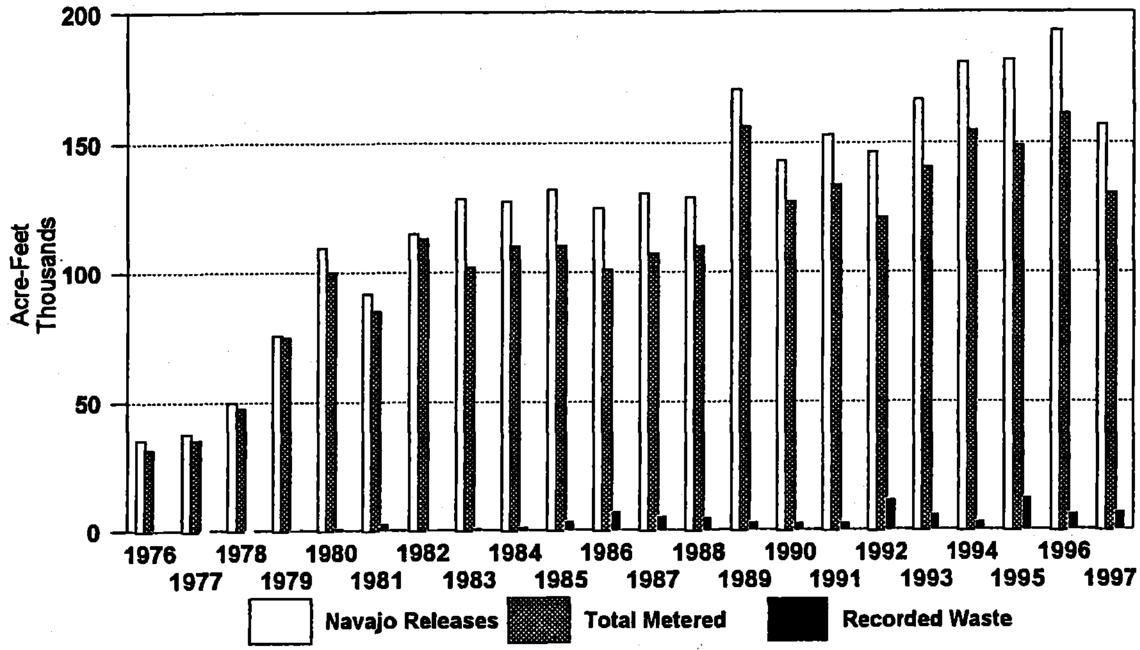


Figure 5. Diversion, Farm Delivery and Recorded Spills for NIIP, 1976-1997.

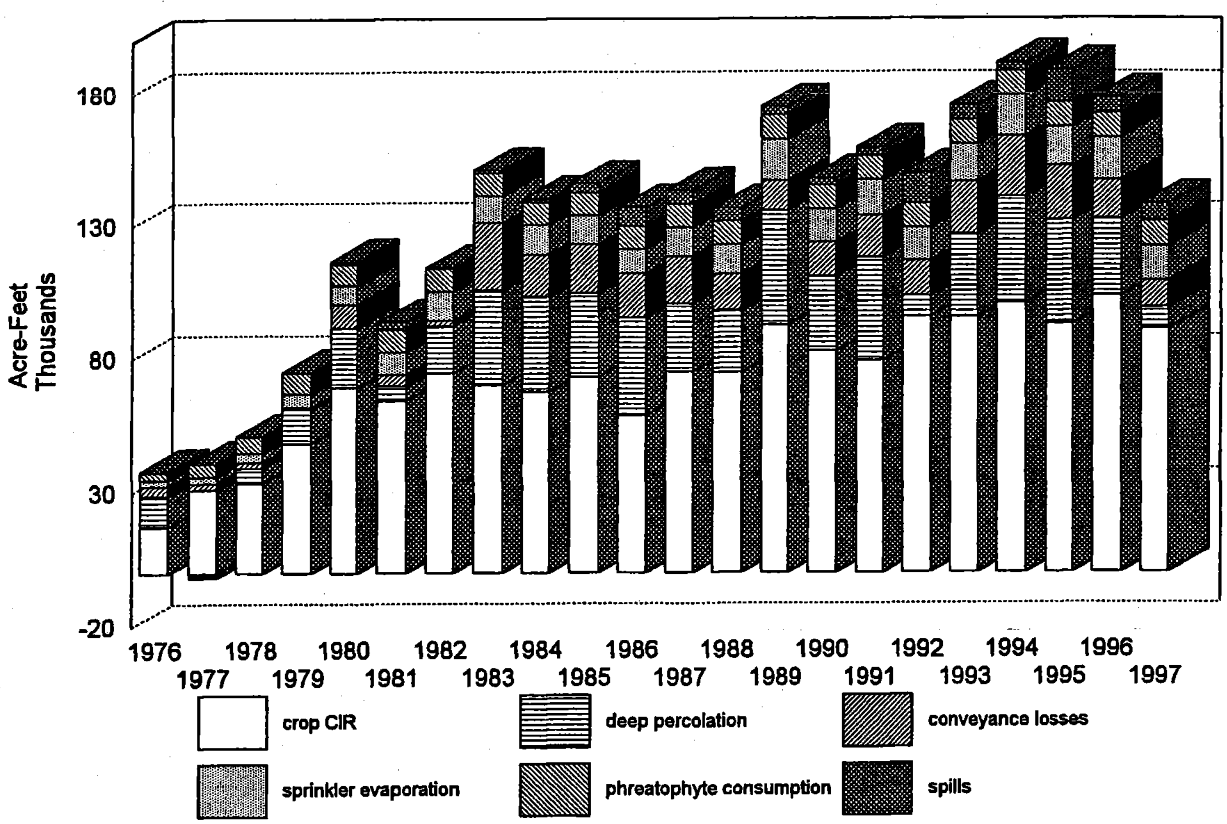


Figure 6. NIIP Water Balance, 1976-1997.

Since the different components of the balance are varying annually due to increasing acreage and weather changes, each component of the balance was averaged for the period 1988-1997, the most recent 10 years. The breakout of each component of water use is summarized in Figure 7.

The combined crop and conservation depletions for the period constituted 55.9% of the total diversion. The next largest portion was deep percolation, 22.4%. Sprinkler evaporation, which was estimated to be 10 percent of field metered flow, amounted to 8.5% of the diversion. Non-crop depletion - phreatophyte evapotranspiration and runoff channel evaporation - consisted of 5.7%. The operational spill was 3.7% and the releases for dilution (recovery implementation or RIP release) was 3.1% and the canal evaporation was 0.7%. The total diversion averaged 162,100 AF, of which 114,700 AF or 70.8% was depleted.

Projected Water Use. The project efficiency has been increasing with time. As more acreage is irrigated, the conveyance losses as a portion of the total water delivered are reduced. At full development, the availability of the Gallegos reservoir to absorb changes in system demand will further improve operating efficiency. The center pivot systems are now being automated to allow central control and an irrigation management program is being developed to more closely match irrigation delivery to actual crop demand. With these changes instituted, the project water balance at full development (110,630 acres) is expected to follow the pattern shown in Figure 8. To accomplish this improvement, irrigation efficiency will be improved by 8% to an overall efficiency of about 64%. It was assumed that the acreage is fully cropped with no conservation lands. Based on an average NIIP diversion of 3.05 AF/A, the total diversion will be 337,500 AF. Of that amount 270,000 AF will be depleted (based on 2.44 AF/A) and the balance, 67,500 AF, will be returned to the San Juan River system (totals rounded to nearest 100 AF).

Irrigation Return Flow Analysis

The water balance discussed above is based on equilibrium conditions with no water going to or coming from groundwater storage under the project. In reality, there is a large potential water storage reservoir in the unsaturated soils between the top of bedrock and the project land surface. With the highly efficient center pivot sprinkler systems most of the excess applied water percolates below the soil surface and will eventually enter the San Juan River through one of the arroyos within and surrounding the project lands.

Measurement of discharge out the major drainage channels of the project, Gallegos Canyon and Ojo Amarillo, indicate that the average annual base flow from these channels is about 6.0 cfs or about 4,300 AF per year. Estimating the flow in smaller washes that are not measured brings the total outflow to about 10 cfs or 7,200 AF per year. Based on the water balance for the last 10 years, the average annual loss to deep percolation was 47,400 AF. With only about 15% of the water discharging out the washes, 85% of the deep percolation was either going into groundwater storage or leaking through the bedrock.

To better understand the fate of the deep percolation losses three dimensional groundwater models were developed for the irrigated lands that drain to Gallegos Canyon, Ojo Amarillo and small washes in the vicinity (Peralta, 1997, 1998). The models (separate models were developed for the Gallegos and Amarillo drainages) were calibrated to water level rise measured in the observation wells shown on Plate 3 through 1996. The models demonstrated that leakage through the bedrock is minor and that the deep percolation can be accounted for in change in groundwater storage. If further demonstrated that artificial, subsurface drainage was going to be required eventually over substantial portions of the project.

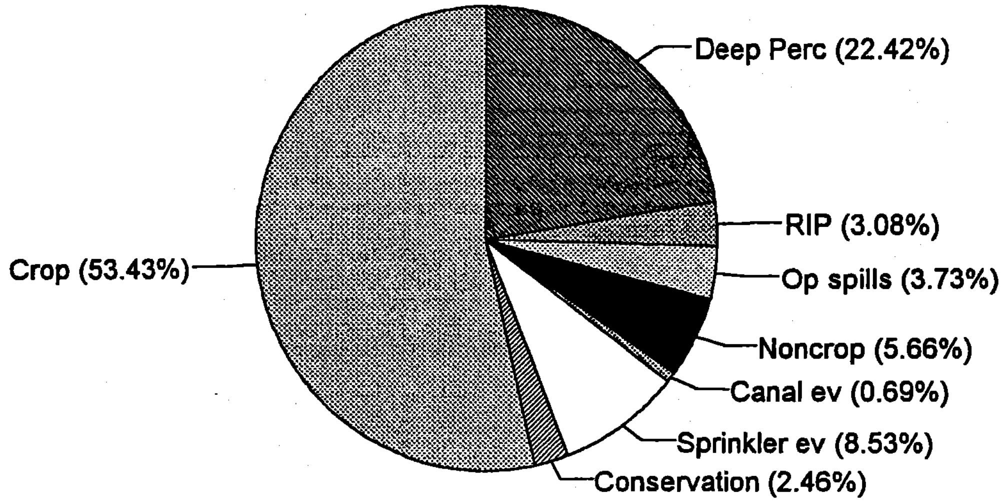


Figure 7. Components of NIIP average water balance for the period 1988-1997.

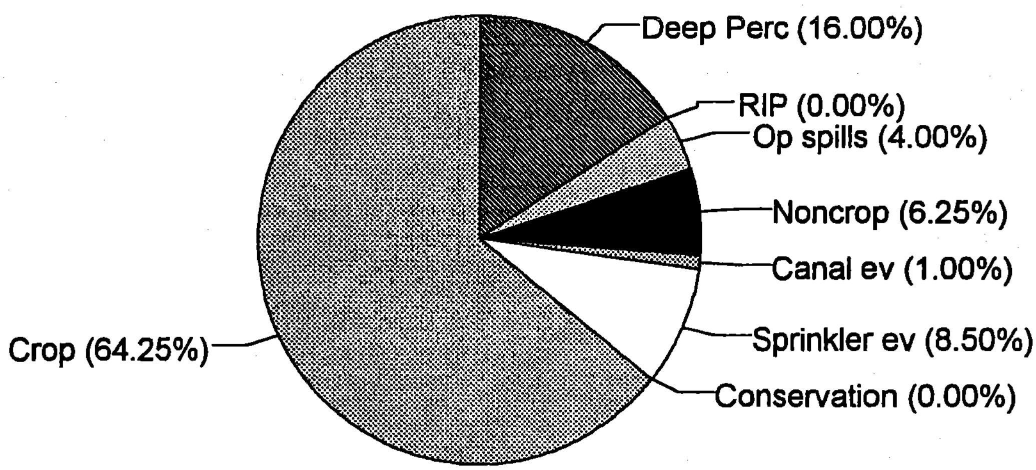


Figure 8. Components of NIIP average water balance projected at full project development.

Two future development scenarios were examined: one assuming present irrigation efficiency and one assuming a 50% reduction in deep percolation loss, representing the best practically attainable efficiency. For this return flow analysis, a condition midway between these two conditions was assumed, based on planned management improvements.

Blocks 10 and 11 were not modeled and data are insufficient to model these blocks. In this case, the results of the Gallegos model were adjusted to reflect the later start date and the difference in project size to project the return flow timing of these two blocks.

The models were operated over a period sufficient to reach equilibrium. It was assumed that artificial drains would be installed when the water level was within 5.0 ft of the ground surface. Utilizing the results of these two models and the development plan shown in Table 1, a projection of the return flow pattern with time was completed. The resulting return flow pattern and net effect to the San Juan River is shown in Figure 9. Under equilibrium conditions, 29% of the deep percolation will discharge through natural seeps and washes. The remaining 71% will discharge from subsurface drains. The maximum impact to the San Juan River of 280,600 af occurs in 2014 and remains at that level until2032 when the project is completed. 99% of equilibrium conditions are reached by 2054.

Resulting Effects on the San Juan River Hydrology

The recently completed flow recommendation report for the San Juan River completed by the SJRIP Biology Committee describes the modeling process used to assess impacts of water development on the ability of the system to meet the flow recommendations. The models described in that report were used to assess the impact of NIIP development as described here.

Environmental Baseline. In the process of developing the flow recommendation and assessing availability of water for future development, the states of Colorado and New Mexico identified acreage that they believed should have been included in the environmental baseline at the time of the Section 7 consultations for the Animas-LaPlata project (ALP) and NIIP. These adjustments were applied in the modeling reported in the flow recommendation report for the level of development titled "depletion base". While the values used in this category have not been agreed to by the various affected parties, they represent a level of development that is greater than previously considered in the baseline and are assumed to be conservative in terms of assessing the ability to develop future water.

The depletion base listed in the flow recommendation report under-represented the ALP project depletions allowed in the Section 7 consultation for that project. The ALP depletion has been modified from 55,610 af listed in the flow recommendation report, to 57,100 af as represented in the Section 7 consultation.

Since the modeling was completed for the flow recommendation report, the Jicarilla Apache Tribe has completed there water rights negotiation and have received a historic depletion allocation of 2,195 af. Their historic use was represented in the model for the flow recommendation report as 449 af. The additional 1,746 af has been added to depletions in the San Juan River reach above Carracas.

An inter-service Section 7 Consultation has also been completed for an additional 3,000 af of minor depletions in the system. This has also been added to the depletion base to develop the environmental baseline for this consultation.

While it is likely that some reduction in this baseline will be achieved under careful evaluation, all modeling has been completed assuming that the completion of NIIP is incremental to the level of development represented by this baseline as shown in Table 4.

Table 4. San Juan River Environmental Baseline Depletion for this consultation.

Depletion Category		Average Depletions KAF/YR	Average Totals KAF/YR
New Mexico Depletions			
San Juan-Chama[1]		107.5	
Navajo Indian Irrigation Project - Blocks 1-8[2]		149.4	
Navajo Reservoir Evaporation[3]		28.3	
Hammond Canal		10.2	
Utah International		39.0	
Existing Private and Tribal Rights with the following breakdown:		113.8	
Upstream of Navajo Dam - private	0.8		
Upstream of Navajo Dam - Jicarilla Apache Tribe	2.2		
San Juan between Archuleta and Farmington (Citizen's & Misc.)	9.1		
Bloomfield industrial diversion	2.5		
Animas River irrigation not including Farmer's Mutual	36.7		
Farmer's Mutual Ditch	9.6		
LaPlata River	9.6		
Fruitland (Navajo)	7.9		
Jewitt Valley	3.1		
Municipal and industrial uses	9.0		
Hogback and Cudei projects (Navajo)[4]	13.0		
Westwater Canyon	0.1		
Scattered Rural Domestic Uses[5]	1.4		
Scattered Stockponds & Livestock Uses[5]	2.2		
Fish and Wildlife uses[5]	1.4		
Chaco River[5]	4.6		
Whiskey Creek[5]	0.6		
M&I Contracts from Navajo Dam - San Juan Power Plant		16.2	
Minor Depletions (NM portion of 3,000 af approved by SJRIP in '92)		1.5	
Total New Mexico Depletions - Excluding ALP			**465.9**
Colorado Depletions (Colorado portion minor depletions equaling 1,500 af included in following categories)			
Upstream of Navajo Dam including the following[6]:		97.0	
Upper San Juan	10.9		
Navajo-Blanco	7.9		
Piedra	8.5		
Pine River	69.7		
Downstream of Navajo Dam including the following[6]:		88.1	
Florida	28.6		
Animas and La Plata Rivers	39.6		
Mancos	19.9		
Total Colorado Depletions - Excluding ALP			**185.1**
Animas LaPlata Project (Colorado and New Mexico)			**57.1**
Utah Depletions [6]			**10.9**
Arizona Depletions[5]			**12.4**
Minor Depletions from 1999 USFWS inter-service consultation			3.0
Total San Juan River Basin Depletions			**734.4**
Return Flow from Dolores River Imports			-15.2
Net Depletions Measured at Bluff, Utah			**719.2**

[1] 1989 San Juan Chama Project Yield Analysis reports 109,532 af/yr average for 1935-1987. Numbers shown are for 1929 - 1993.
[2] Includes 16,420 af/yr transferred from Hogback and Hogback extension.
[3] Increased by 2,300 af/yr due to re-operation of Navajo Dam for fish releases.
[4] 16,420 af/yr transferred to NIIP, including 10,000 af from Hogback extension.
[5] Offstream depletion accounted for in calculated natural gains to the river.
[6] 1,705 af/yr San Juan R. depletion, 9,224 af/yr off-stream depl. accounted for in calculated natural gains.

PLANT STUDIES

A study was initiated prior to the 1991 consultation in order to determine the present and future potential for impacts of the Navajo Indian Irrigation Project (NIIP) in San Juan County, New Mexico to threatened and endangered plant species in the vicinity of the project. That process is documented in the 1991 Biological Assessment. No further surveys have been completed.

IMPACTS TO SPECIES

Plants

See 1991 biological opinion. No new information exists that would affect plants within the project area.

Blackfooted Ferret

See 1991 biological opinion. No new information exists that would affect the conclusions concerning blackfooted ferret.

Bald Eagle

See 1991 biological opinion. No new information exists that would affect the conclusions concerning Bald Eagle.

Peregrine Falcon

See 1991 biological opinion. No new information exists that would affect the conclusions concerning peregrine falcon.

Brown Pelican

No habitat exists within the disturbed area of the project and no other impacts are expected beyond those listed for Bald Eagle concerning prey base from the San Juan River and associated contaminant concerns.

Southwest Willow Fly Catcher

The habitat for nesting willow fly catchers identified in studies in the San Juan Basin are typically supported by an external water source, usually irrigation return flow. Other sightings have occurred in willow complexes adjacent to the San Juan area that typically flood during high flow. Re-operation of Navajo dam will increase the frequency of flooding of these areas and may enhance habitat during the runoff period. No adverse effects are anticipated.

Colorado Pikeminnow and Razorback Sucker

As noted in Section **ENDANGERED SPECIES** of this report, the Colorado pikeminnow and razorback sucker are present in the San Juan River within the area of influence of NIIP. The NIIP project will impact both water quality and quantity in the San Juan River.

The Section **Hydrology** discusses the impact of the NIIP project completion on the ability of the system to meet the flow requirements of the fish as specified in the Flow Recommendation Report prepared by the San Juan River Basin Recovery Implementation Program (SJRIP). The conclusion of this Section is that the flow recommendations can be met with full development of NIIP by reoperating Navajo Dam as indicated in the project description. Therefore, there is not likely to be an adverse effect in terms of water depletion.

The discussion in the Section **Water Quality Analysis** addresses the issues of contaminants. The Section concludes that the project will increase arsenic, copper, selenium and zinc levels in the San Juan River. Forecast levels during base flow conditions are projected for elements of concern.

It was concluded that levels of arsenic and zinc will be below levels of concern for the two endangered fish species.

Conclusions concerning copper are less certain. The present copper levels in the river are within the published range of concern for aquatic species. However, research found that the most sensitive species tested in the San Juan River was flannelmouth sucker, the most abundant native species in the river. Since the existing level of copper is 2.3 times that suggested as a level of concern from the study and there is no apparent negative effect on the flannelmouth sucker, the two endangered species are not likely to suffer ill effects from the 1.2 ppb potential increase in copper levels at base flow.

While selenium is indicated to pose low hazard to these two endangered species, there is uncertainty about the actual level of selenium in the biota in the system downstream of the project and of the chronic toxicity to razorback sucker. The low hazard rating still leaves some possibility for effect, although the effect is not likely to be adverse to the recovery of these species.

NIIP Representation in the Model. In as much as NIIP return flows are delayed substantially, the net impact to the river for some period of time will exceed the average equilibrium depletion of 270,000 AF per year. Referring to Figure 9, the net impact to the river reaches 280,600 AF in 2014 and remains at that level for 10 years before starting to decline as return flows increase. This extra 10,600 AF per year was represented in the model as going into groundwater storage, with a constant leakage out of groundwater to the river of 54,000 AF per year. The NIIP demands and impacts to the San Juan were time varying due to variation in climatic conditions, but the long term average diversion in the model was 337,500 AF per year and the total impact to the San Juan River averaged 280,600 AF per year. After 2032, return flow will increase and additional water will be available to meet downstream demands.

Reservoir Operating Rules. The Navajo reservoir operating rules presented in the flow recommendation report were used for this analysis, with the maximum release capacity set at 5,000 cfs. All rules associated with the 5,000 cfs release capacity were utilized. It was assumed that the reservoir could be drawn down to elevation 5085 during the non-irrigation season in times of drought, as in the flow recommendation report. The present reservoir operation uses an elevation of 5090. This change is not considered a significant limitation, since the 5090 level is maintained to accommodate NIIP release capacity during the summer and would not be affected in the winter when the rule applies.

The calibration parameters for operation are as follows:

Full capacity	1,701,300 af at spillway elevation (6085 ft)
Inactive capacity	625,675 af at 5,985 ft
Minimum available storage - end of July	1,481,000 af
Center date of release	June 4
Maximum release	5,000 cfs

Model Results. The results of modeling with this configuration are summarized in Tables 5 and 6 for hydrology and habitat parameters in a format compatible with the results presented in the flow recommendation report. Table 7 presents the table of frequencies of other flow durations, demonstrating that both primary and secondary recommendations are met. All conditions of the flow recommendation are met or exceeded. Resulting backwater habitat availability for Reaches 1-5 is predicted to be 7% greater than under pre-dam conditions and 23% greater than the historic post-dam conditions. Table 8. presents the average depletions and the range of depletions that could be expected over a 65-year period of time representing range in demand due to climate variation. Also shown in the table are the environmental baseline depletions associated with the earlier consultations.

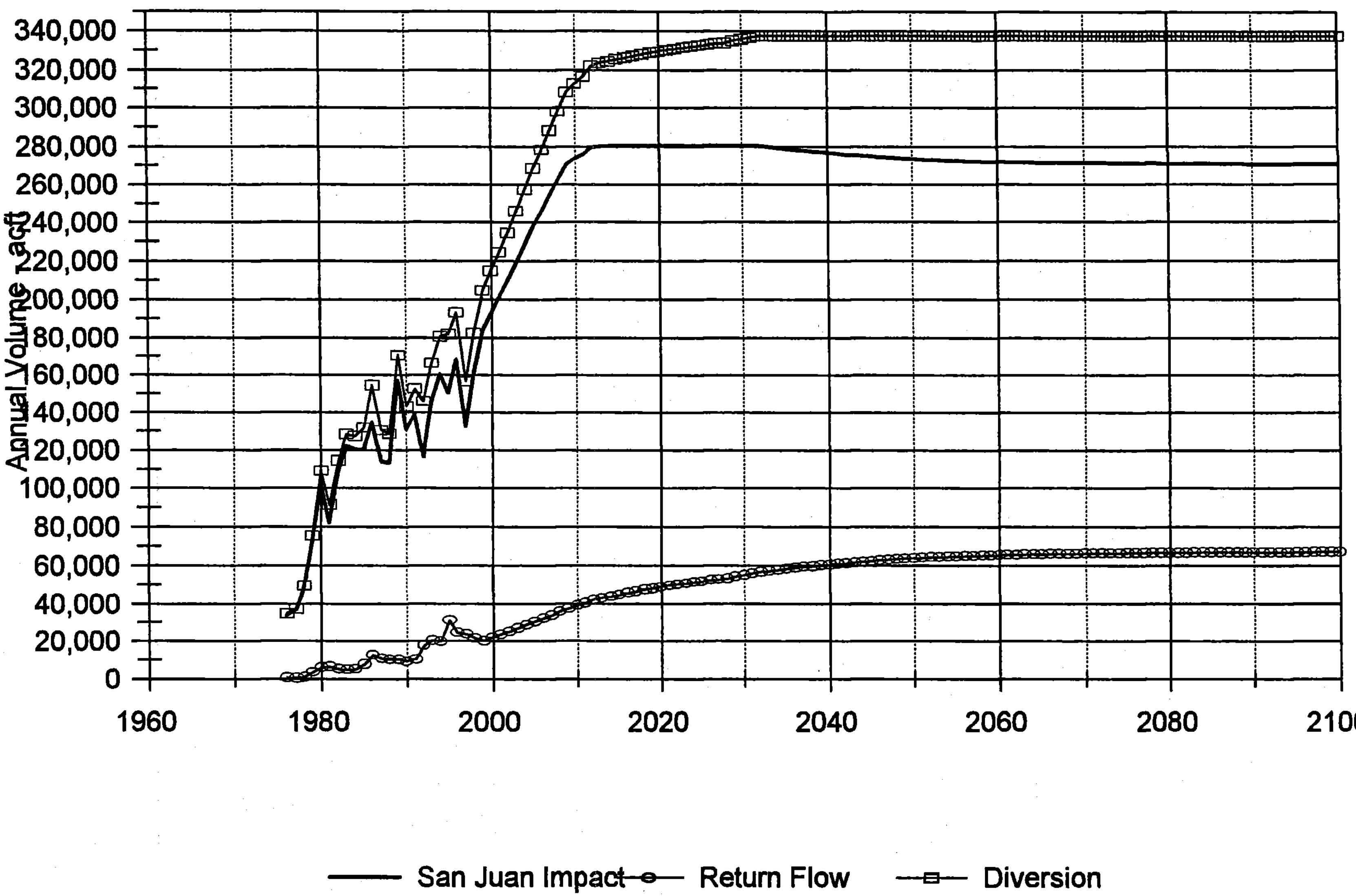


Figure 9. Timing of irrigation demand, return flow and impact to the San Juan River as a result of NIIP irrigation.

Table 5. Summary of hydrograph statistics for historic conditions and projected future conditions for current, baseline and baseline plus full NIIP with 10,600 af/year additional depletion due to groundwater storage.

Parameter	Pre-dam	Post-dam	Study Period	Current	Baseline	Full NIIP plus 10600 af g.w. Storage
Average Peak Daily Runoff - cfs	12,409	6,749	8,772	10,041	9,780	8,879
Average Runoff - af	1,263,890	891,712	1,132,899	1,042,635	958,842	861,036
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency
Peak > 10,000 cfs	55%	20%	33%	43%	43%	43%
Peak > 8,000 cfs	67%	37%	83%	77%	71%	62%
Peak > 5,000 cfs	91%	53%	83%	97%	97%	75%
Peak > 2,500 cfs	100%	90%	100%	100%	100%	97%
AF > 1,000,000	55%	40%	67%	42%	38%	34%
AF > 750,000	67%	47%	83%	63%	57%	51%
AF > 500,000	91%	67%	83%	82%	74%	69%
> 10,000 cfs for 5 days	39%	13%	33%	35%	32%	31%
> 8,000 cfs for 8 days	48%	27%	50%	48%	46%	42%
> 8,000 cfs for 10 days	45%	17%	50%	46%	45%	42%
> 5,000 cfs for 21 days	64%	37%	83%	68%	60%	58%
> 2,500 cfs for 10 days	100%	83%	100%	97%	97%	85%
Maximum years between flow events for minimum duration						
10,000 cfs - 5 days	4	14	n/a	6	6	9
8,000 cfs - 10 days	4	7	n/a	6	6	6
5,000 cfs - 21 days	4	7	n/a	3	4	4
2,500 cfs - 10 days	0	1	n/a	1	1	2
Non-corrected Perturbation	12%	27%	0%	17%	20%	22%
Average Date of Peak	31-May	01-Jun	07-Jun	04-Jun	04-Jun	04-Jun
Standard Deviation of Peak Date	23	35	8	12	12	15
Days > 10,000 cfs	14	3	2	6	5	5
Days > 8,000 cfs	23	8	10	16	14	13
Days > 5,000 cfs	46	28	51	43	38	32
Days > 2,500 cfs	82	67	90	71	65	55
Meets recommendation	yes	no	yes	yes	yes	yes

Table 6. Summary of backwater habitat area for historic conditions and projected future conditions for current, baseline and baseline plus full NIIP with 10,600 af/year additional depletion due to groundwater storage.

Parameter	Pre-dam	Post-dam	Study Period	Current	Baseline	Full NIIP plus 10,600 af g.w.
Backwater availability, Reach 1-4 - acres						
Average before storms	21.32	14.34	23.05	23.53	24.16	22.68
August	16.94	11.89	17.69	18.65	19.19	18.10
September	14.92	11.69	15.22	17.08	17.67	16.46
October	13.75	10.46	14.61	16.16	16.80	15.61
November	14.78	11.04	14.10	16.26	16.77	15.76
December	15.92	10.29	15.66	15.61	16.31	15.60
Average (Aug-Dec)	15.26	11.07	15.46	16.75	17.35	16.30
Average Perturbation	28%	23%	33%	29%	28%	28%
Change from pre-dam conditions		-27%	1%	10%	14%	7%
Backwater availability, Reach 1-5 - acres						
Average before storms	26.36	19.39	26.51	28.36	29.36	28.26
August	21.67	17.35	21.24	23.48	24.31	23.44
September	19.89	17.53	18.28	22.20	22.92	21.64
October	18.36	15.21	17.69	20.99	21.80	20.69
November	19.76	15.36	17.15	21.37	22.22	21.26
December	21.54	14.76	19.80	20.47	21.75	21.19
Average (Aug-Dec)	20.24	16.04	18.83	21.70	22.60	21.68
Average Perturbation	23%	17%	29%	23%	23%	23%
Change from pre-dam conditions		-21%	-7%	7%	12%	7%
Razorback sucker backwater availability, Reach 1-4 - acres						
May	14.64	15.29	18.53	15.67	16.07	15.60
June	14.11	14.72	17.22	17.21	16.59	16.37
July	16.35	17.34	14.56	19.50	20.78	19.06
Razorback sucker backwater availability, Reach 1-5 - acres						
May	21.65	19.02	20.34	21.80	21.81	21.44
June	21.24	18.60	22.48	23.96	23.17	22.65
July	22.20	21.57	25.58	23.84	25.44	23.66

Table 7. Compliance with frequency distribution for flow/duration recommendations

Duration	Discharge			
	>10,000 cfs	>8,000 cfs	>5,000 cfs	>2,500 cfs
	Average Frequency - Recommendation (Full NIIP)			
1 day	30% (42%)	40% (62%)	65% (77%)	90% (97%)
5 days	20% (31%)	35% (51%)	60% (72%)	82% (89%)
10 days	10%(20%)	33% (40%)	58% (68%)	80% (86%)
15 days	5% (11%)	30% (34%)	55% (60%)	70% (78%)
20 days	(8%)	20% (28%)	50% (58%)	65% (74%)
30 days		10% (14%)	40% (48%)	60% (68%)
40 days			30% (32%)	50% (60%)
50 days			20% (26%)	45% (51%)
60 days			15% (20%)	40% (42%)
80 days			5% (12%)	25% (28%)

Table 8. Summary of depletions resulting from full NIIP development plus environmental baseline listed in Table 4.

Category of Depletion	Environmental Basline + NIIP (ac-ft)	Depletion Range (1929 to 1993) (Max ac-ft)	(Min ac-ft)	1996 Opinion BL (ac-ft)
Navajo Lands Irrigation Depletion				
Navajo Indian Irrigation Project	280,600 *	307,803	235,396	149,400
lHogback	12,100	14,216	9,592	12,100
Fruitland	7,898	9,279	6,432	7,900
Cudei	900	1,058	687	900
Subtotal	**301,498**			**170,300**
Non-Navajo Lands Irrigation Depletion				
Above Navajo Dam - Private	733	1,032	498	850
Above Navajo Dam - Jicarilla	2,195	3,094	1,500	450
Animas River	36,725	42,671	29,418	31,700
La Plata River	9,639	11,218	7,375	5,100
Upper San Juan	9,137	10,735	7,347	8,200
Hammond Area	10,268	12,063	8,256	9,200
Farmers Mutual Ditch	9,559	11,272	7,813	8,700
Jewett Valley	3,088	3,757	2,604	2,800
Westwater	110			100
Subtotal	**81,453**			**67,100**
Total NM Irrigation Depletion	**382,952**			**237,400**
Non-Irrigation Depletions				
Navajo Reservoir Evaporation	27,037	31,644	19,444	26,000
Utah International	39,000	39,001	38,997	39,000
San Juan Power Plant	16,200	16,201	16,199	16,200
Industrial Diversions near Bloomfield	2,500			2,500
Municipal and Indutrial Uses	8,963			8,900
Scattered Rural Domestic Uses	1,400 **			1,400
Scattered Stockponds & Livestock Uses	2,200 **			2,200
Fish and Wildlife	1,400 **			1,400
Total NM Non-Irrigation Depletion	**98,700**			**97,600**
San Juan Project Exportation	107,514	201,046	23,456	110,000
Unspecified Minor Depletions	4,500 +			1,500
Total NM Depletions (Excluding ALP)	**593,667**			**446,500**
Colorado Depletions				
Upstream of Navajo				
Upper San Juan	10,858	13,905	7,341	7,800
Navajo-Blanco	7,865	10,345	5,015	6,500

Category of Depletion	Environmental Basline + NIIP (ac-ft)	Depletion Range (1929 to 1993) (Max ac-ft)	(Min ac-ft)	1996 Opinion BL (ac-ft)
Piedra	8,514	14,585	3,965	6,500
Pine River	69,718	96,958	42,112	58,100
Subtotal	**96,955**			**78,900**
Downstream of Navajo				
Florida	28,602	39,360	20,878	18,100
Animas and La Plata Rivers	39,569	52,628	29,698	32,800
Mancos	19,913	24,822	14,536	16,200
Subtotal	**88,085**			**67,100**
Total CO Depletions (Excluding ALP)	**185,039**			**146,000**
CO & NM Combined Depletions	**778,706**			**592,500**
ALP	57,100			57,100
Subtotal	**835,807**			**649,600**
McElmo Basin Imports	-15,176	-28,334	5,717	-25,000
Utah Depletions	10,929 ***	1,705	1,705	-
Arizona Depletions	12,419 **			-
NET NM, CO, UT, AZ Depletion	**843,979**			**624,600**
NM Off River Depletions				
Chaco River	4,608 **			
Whiskey Creek	649 **			
GRAND TOTAL	**849,236**			**624,600**

* Includes 10,600 af of annual groundwater storage. At equilibrium this drops to 270,000 af

** Indicates offstream depletion accounted for in calculated natural gains

*** 1,705 San Juan River depletion, 9,224 off stream depletion

\+ 1,500 af of depletion from minor depletions approved by SJRIP in 1992. 3,000 af from 1999 Intra-service consultation, a portion of which may be in Colorado

WATER QUALITY ANALYSIS

Statement of Problem

Water quality concerns associated with NIIP were first identified in the preliminary findings of a Department of Interior study to assess water quality impacts of federal projects on the San Juan River (U.S. Dept. of Interior, 1991). The preliminary results found no pesticide contamination in water, sediments or biota attributable to NIIP. Of the other contaminants found, only selenium was found to be directly associated with NIIP. There was continuing concern over polycyclic aromatic hydrocarbons (PAH) and the possibility of irrigation return flow transmitting them to the river, although no direct evidence was found.

Since that time monitoring programs have been in place to find the concentration of selenium and PAH in the waters associated with NIIP, in the San Juan River and in its tributaries. In addition detailed analytical studies of soils and of bedrock have been carried out for various contaminants including selenium. Ground water models for both the Gallegos and Ojo Amarillo drainage areas have been calibrated and developed. These models have aided in understanding how soluble contaminants move within the ground water system and their potential transport into the San Juan River.

Based on results of the DOI study and of the acute toxicity studies of larval Colorado pikeminnow and razor sucker, the elements of greatest concern are selenium, copper, arsenic, and zinc. Therefore, water quality studies have concentrated on identification of the source and transport mechanism for these substances. Analyses for other potential organic contaminants such as PAH and pesticides have also been completed.

Approach

Source Identification - Selenium. To allow assessment of the process by which selenium enters the irrigation return flow, identification of the source becomes important. Three potential sources exist for selenium: (1) concentration of selenium in the irrigation water by evaporation, (2) selenium leaching from the soils that are irrigated, (3) selenium pickup in the shale beds underlying the irrigated areas.

The relative importance of concentration of irrigation water can be seen in the following example. The ground water leaving the project contains typically 20 ppb selenium. The selenium level is <1 ppb in the supply water. Based on the ratio of consumptive use to applied water for NIIP, salts in irrigation water are concentrated by a factor of about 5, assuming no dissolution or precipitation. This fact suggests that the irrigation water could not be a significant contributor to the selenium concentration. Further, sampling of the saturation extract of the soils that have been irrigated for some time yield concentrations below detection, indicating that even with the concentrating effect of evapo-transpiration, the contribution of selenium in the supply water is negligible.

This conclusion leads to the soils or bedrock as the likely sources. An early review of existing soils data was inconclusive in relating total soil selenium to selenium concentrations in the perched ground water. Therefore, over the course of 6 years, a drilling and sampling program was carried to try and understand the relationship between selenium in NIIP soils/bedrock and in NIIP ground water. Numerous drill sites were located both inside and outside irrigated fields and also in the proposed future blocks. Most of the holes were drilled with a hollow stem auger and samples collected with a continuous sampler. Casing and screens were installed for eventually monitoring the ground water in most of the new locations. During drilling, composite soil and rock samples were collected from approximately 5 ft increments with additional intervals if obvious changes occurred. Often the hole was completed in the underlying bedrock and bedrock samples were collected. The bedrock under irrigated fields was highly weathered from contact with the irrigation percolation. For the deep bedrock studies 4 drill holes extending about 150-175 feet below the ground surface gave unweathered bedrock samples for study. In all more than 650 soil and rock samples were collected in these studies and analyzed for total and dissolvable selenium and several other elements.

The study looked at the total and dissolvable selenium in the soil and rock samples and tried to correlate those concentrations with the dissolved selenium observed in observation wells, seeps and washes scattered throughout the project. From the relationships developed in the irrigated portions of the project, the selenium concentrations can be projected in the new irrigated blocks. Water at various sites has been sampled regularly since 1991 - washes monthly and wells semiannually.

Source Identification - Copper, Arsenic and Zinc. The sources of these elements are identical to those for selenium - the irrigation water, the soils or the underlying bedrock. The ground water leaving the project during the winter contains typically 20 ppb copper, 5 ppb arsenic and <10 (detection) ppb zinc. The concentrations are less than detection in the supply water. Based on the discussion concerning concentration of supply water by evapotranspiration in the previous section, the irrigation water is likely not a significant contributor for arsenic and zinc. Since the detection limit is 5 ppb for copper, it is possible that the source water is being concentrated to levels near 20, but a positive source identification cannot be made based on this possibility. However, given the response of the other elements and the fact that none of the water samples reach detection, the supply water is likely not a major source for any of these constituent elements.

This conclusion leads to the soils or bedrock as the likely sources. Some analyses of NIIP soils and bedrock have been carried out. The surface and ground waters on the project have been monitored for these elements.

Source Identification - Pesticides and PAH. These organic compounds have low solubility in water and are therefore not very mobile. For them to enter the river with irrigation return flow would require sufficient flow through a source to move sediment as well as water. We were looking to see if point sources on the project could be located and how the project as a potential diffuse source might affect the river. The potential point sources for pesticides would be runoff from irrigated fields. The potential point sources for PAH could be oil wells or storage tanks within the main drainage channels, the Chaco Gas Plant or airborne effluents from a small oil refinery located east of the project. A field survey was completed to locate wells in Gallegos and Ojo Amarillo Canyons. One well was located within Gallegos Canyon where seepage water was running through the containment pad around the storage tank. The water discharging from the pit was sampled and analyzed for PAH. This was considered a worst case scenario. Also water samples were collected in Gallegos and Ojo Amarillo Canyon for analysis. A semipermeable membrane device (SPMD) sampler was set up on the east of the project to collect airborne PAH. Other sites in irrigation canals and in the San Juan River and in its tributaries were also sampled for PAH. These river sites were studied over several years using SPMD samplers and the distribution of PAH along the rivers determined. Pesticides analyses were performed on selected water samples.

Identification of NIIP Sampling Sites. The DOI study identified some potential problem areas as indicated by high selenium levels in water, sediments or biota. These data were used as a guide in targeting locations in the field to begin investigations in 1991. The sampling program was begun in April 1991 to identify and sample water, sediments and biota (plants and/or macro invertebrates) at ponds, major seeps and surface water at several locations along Gallegos, Ojo Amarillo, Kutz and Horn Canyons. In addition, alluvial ground water samples were taken at several locations along the two major drainages to observe any trends in concentrations and the relationship to surface water.

Other NIIP sites which have been monitored monthly since 1991 include (1) Gallegos Wash at the old USGS gauging site, near the mouth (2) Ojo Amarillo Wash at the USGS gauging site, the (3) confluence of Ojo Amarillo Wash and spill from the Fruitland Canal, the (4) Ojo Amarillo ponds near fields 2-21 and 2-22, and(5) the unnamed wash by field 2-74. Several stock ponds nears fields 1-18, 1-25 and 1-35 were monitored until February 1996 at which time the pond dikes were breached and the ponds were drained after discussion with U.S. Fish and Wildlife Service (FWS).

Although the potential impact to birds utilizing these areas is important, no additional samplings were made beyond those completed by U.S. Fish and Wildlife Service. Timing, permit availability, low populations and the existence of high concentrations of selenium in some of the bird samples previously taken led to the decision to rely on the previously collected data. Additional sampling of birds would not have helped in identifying problem areas on the project. However, in selected ponds sampling of Tiger Salamanders continued through 1995 after which the ponds were breached and drained.

Impact to San Juan River. In addition to any on-site impacts to wildlife, impact of the project on selenium levels in the San Juan River must be identified due to the potential affects on the Colorado pikeminnow and Razorback sucker. Separating out the impact of NIIP on the potential contaminants concentrations in the San Juan River from the impact of all the other irrigation projects, sewage treatment plants, refineries and coal mining activities in the area becomes somewhat difficult.

An initial survey study was carried out in 1991 beginning at Archuleta which is upstream of any potential effect of NIIP on the river and continuing at regular intervals down to Shiprock, being the lowest potential impact point. At each location, water, bed sediments and macro-invertebrates were collected, with separate samples on the north and south sides of the river (river right and river left, respectively). Since any surface or ground water contribution from NIIP would occur on the south side of the river, having sampling points on each side made it possible to differentiate effects from activities on the north side which could not be related to NIIP from those on the south.

To examine the effect on fish, flannelmouth and bluehead suckers were also collected in locations corresponding to the other sampling stations. Due to difficulties in obtaining permits, it was necessary to complete the fish sampling about 1 month after the water, sediment and macro-invertebrate sampling. Unfortunately, no consistently available predators were available to simulate Colorado pikeminnow. Therefore, potential for bioaccumulation up the food chain was assessed by comparison with bio-magnification in Northern Squawfish found in the Columbia River drainages.

The above activities assessed the effect of the project in 1991. Subsequently the San Juan River and selected tributaries have been sampled monthly at about 20 different sites. The sampling sites were extended to Mexican Hat, the Mancos River and upstream in the La Plata and Animas Rivers into Colorado. Other minor tributaries included in the sampling locations were Gobernador Canyon, Red Canyon, McElmo Creek and Montezuma Creek To project the long term effect, including future development, requires tracing the irrigation return flow from the project to the river. That mechanism is described under **HYDROLOGY** above. To assess the contaminant impact, all the historic water quality data on the San Juan River and its tributaries were compiled and analyzed. The historical analysis looked at selenium, copper, arsenic and zinc dissolved in these surface waters. Combining the results of the irrigation return flow analyses reported under **HYDROLOGY**, with the results of selenium concentrations in the various return flow components, a time line of impact to the selenium levels in the San Juan River was produced. These projections assume no precipitation of selenium, no biological uptake, and no loss to bed sediments of the irrigation water before it reaches Bluff. Because of these assumptions, projections are for worst case conditions.

Results

Water Quality Analysis of Soils.

In 1991 a series of 14 holes was drilled to determine the distribution of selenium in soil profiles near observation wells in NIIP lands. In 1994 another series of 18 holes were drilled, in 1995 and 1996-1997 a total of 44 were drilled. In these drilling studies a total of 655 soil and rock samples were collected and analyzed.

The selenium distributions, both in the saturation extract and in the solids, are depicted in the Figures 10 and 11. These samples include the total set of all soil and bedrock samples analyzed between 1991 and 1997. The soil and rock designations are: cl=clay, cong=conglomerate, gms=silty gravel with sand, sc=clayey sand, sh=shale, sls=siltstone, sm=silty sand, smsc=silty clayey sand, sp=poorly graded sand, spsc=poorly graded sand with clay, spsm=poorly graded sand with silt, ss=sandstone and sw=well graded sand. These box plots show (i) the median values (the line within the box), (ii) the box containing approximately 50% (interquartile or from 25% to 75%) of the values, (iii) the vertical lines encompassing about 95% of the values and (iv) asterisks for values outside the 95% bounds.

A statistical analysis of the mean selenium concentrations, both in the saturation extract and in the soil itself, shows that the mean concentrations are different by soil type. In Figure 10, the dissolved Se in the saturation extract shows no strong trends, although the median selenium concentrations in extracts from shales and clays are the highest. These concentration ranges are more pronounced for soil total selenium depicted in Figure 11. The total selenium concentrations are highest in clays and shales, except for conglomerates and silty gravel with sand for which the sample sizes are very small and may not be representative. The total concentrations are most variable in shales, the highest values being in shales recovered from bedrock cores taken 50-90 feet in depth. Some shale samples were analyzed using electron microprobe techniques searching for any selenium association with specific minerals. No specific association was found and selenium appeared to be dispersed throughout the shales investigated.

A scatter plot, Figure 12, depicts the relationship between the selenium dissolved in a saturation extract and total selenium measured in the same sample. The detection limits for selenium analyses in solution were 0.5 to 1 ppb (dissolved selenium ppb = microgram per liter) and was 50 ppb for soils or rock (total selenium = microgram per kilogram). The analytical results are compiled in the appendix. For plotting purposes selenium concentrations below the detection limits were calculated to equal ½ of the detection limits, e.g., 0.25 = <0.5 ppb for saturation extracts and 25 = <50 ppb for total selenium. A comparison of these selenium concentrations shows no correlation between the soil content and its saturated extract.

The lack of good correlation shows that the total soil selenium is not readily soluble in water extracts. The conclusion is that there is no relationship in a NIIP soil or rock sample between the total selenium concentration and the dissolved selenium concentration in a saturation extract of the same sample. The concentration of one selenium form does not follow from the measurement of the other form.

During these study, 404 soil and rock samples were analyzed for total selenium and the saturation extracts of 621 samples were analyzed for dissolved selenium. Table 9 summarizes some statistical properties of these measurements. The mean total selenium concentration in the soils and rocks, 149 ppb, is less than the reported mean selenium concentration in western soils, 500 ppb. Most of the total selenium values are below 100 ppb. However, there were some values exceeding 200 ppb which skew the mean upward.

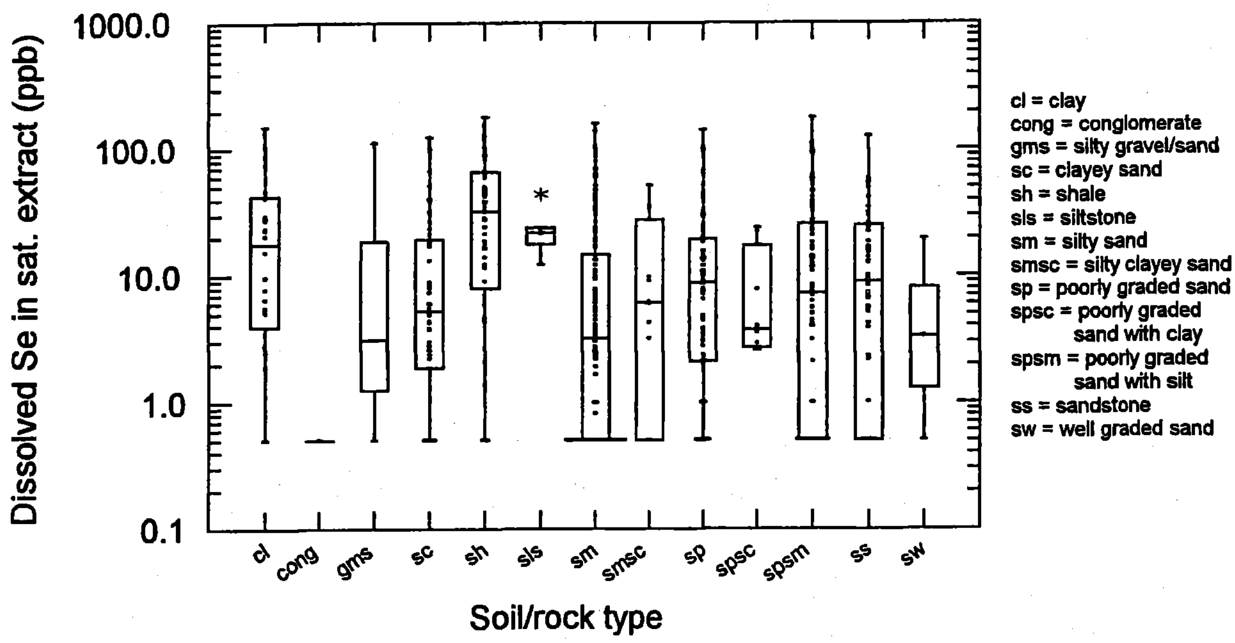


Figure 10. Dissolved Selenium Content by soil/rock type from NIIP borings.

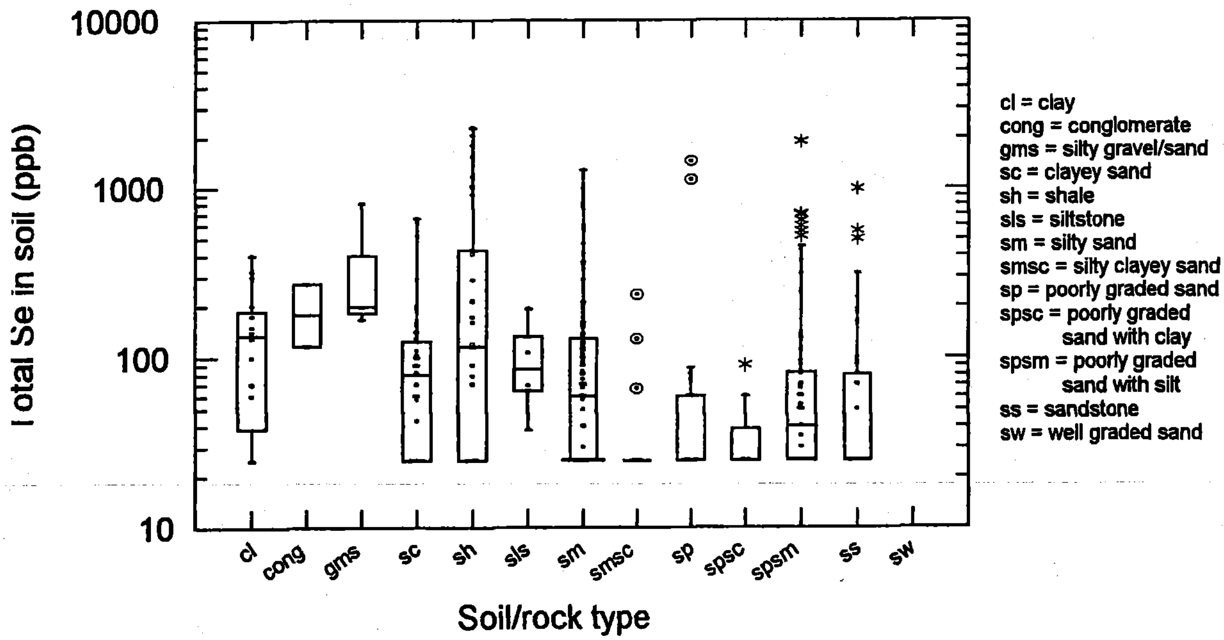


Figure 11. Total Selenium Content by Soil/Rock type for NIIP borings.

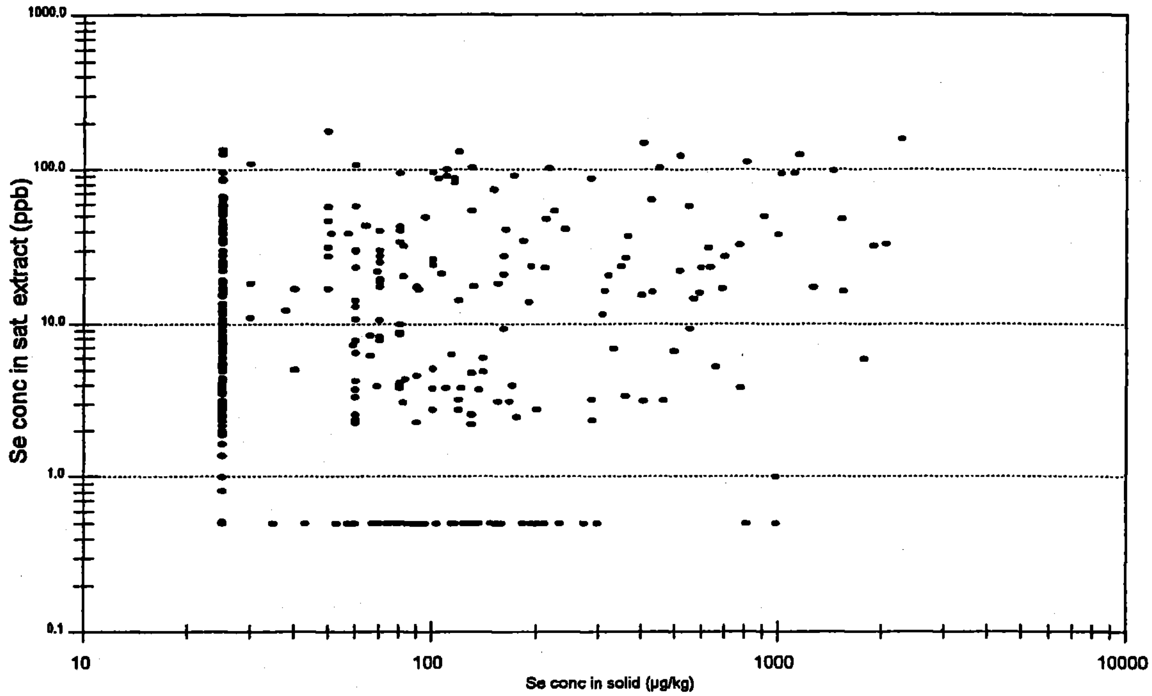


Figure 12. Dissolved vs. Total Selenium in NIIP borings.

Table 9. Measured concentrations of dissolved and total selenium.

Parameter	Dissolved Se (µg/l)	Total Se (µg/kg)
median	6.8	53
mean	20.0	149
maximum	179.6	2280
minimum	0.5	25
number	621	404

Effects of Irrigation on Selenium Distribution in Soils. A series of drill holes were completed inside and outside of irrigated fields to find any effect of irrigation on the vertical selenium distribution. The boreholes were drilled to bedrock on 13 fields with varying irrigation periods from 1 to 19 years. The profiles of total and dissolved selenium are shown in Appendix B, Figures B-1 through B-26. Numbering corresponds to the block and field sampled with and I or O to indicate inside or outside boreholes. Two additional borings were completed in Block 7, fields 37A and 46B, prior to any irrigation (see Figures B-27 and B-28). They will be sampled again after 3 and 5 years of irrigation.

The most striking feature of most profiles inside the fields is that concentrations of dissolved selenium are near the detection limits in the upper 15 feet within less than 8 years (see DH 01-32A-I, 01-35-I, 02-49-I, 03-36B-I, 05-34B-I, 06-19A-1, 06-43C-I), regardless of the soil type or underlying bedrock. For an irrigation period in the 1-3 year range, dissolved selenium seems to be moving downward with concentrations in the 25-50 ppb range (see DH 02-09B-I, 06-19A-I, 07-26A-I, 7-29A-I). If a water table is present, the dissolved selenium typically increases to about 20 ppb below the water table (see DH 02-32A-I, 02-35-I, 03-36B-I, 06-43C-I). The total selenium concentrations inside the fields ranged from <50 to 300 ppb. Comparison of corresponding profiles inside and outside the fields was difficult. Even though the boreholes were often less than 100 ft apart the total selenium profiles were generally quite different. The dissolved selenium profiles showed the typical concentration hump at 10-15 feet which was absent inside the irrigated fields.

Differential weathering of the contact bedrock layer between inside and outside locations was noted. Usually the bedrock depth inside the field was deeper than outside. The depth difference grew with increasing irrigation period. Cores recovered from the boreholes showed that the bedrock, predominately sandstone but including shales, weathered readily inside the fields.

The conclusions are (1) natural precipitation has leached soluble selenium downward into a zone about 10-15 feet in depth under non-irrigated conditions, (2) there is no relationship between soluble and total selenium concentrations in rocks and soils under natural or irrigated conditions (infers that selenium is in forms that can only be slowly oxidized) and (3) irrigation removes readily soluble selenium from the upper 15 feed of soil in a few irrigation seasons. Inside of the irrigated fields the profiles show no selenum redeposition within the water table or at the bedrock interface. The poor correlation between soil and water soluble selenium will complicate modeling the migration of selenium within a profile.

Observation Wells. In the early 1980's observation wells were drilled in Blocks 1- 6. The wells consisted of 4-inch hand slotted PVC pipe installed in holes drilled to bedrock. The well casings were backfilled with a gravel pack and mounted with protective covers. Additional wells in blocks 2, 3, 6 and 7 were installed for the soil and ground water studies. In proposed blocks 8, 9, 10 and 11 several wells were also installed. These later wells were installed in a similar manner to the early wells, but with manufactured well screen and the upper part of the gravel pack was filled with bentonite and the tops were sealed with grout.

The wells in blocks 1-7, the blocks currently, under irrigation, are monitored regularly. The water levels were measured twice each year in the late 1980's and early 1990's. Since 1992 the water levels have been read monthly. Twice each year the wells with water are pumped to remove stagnant water and several days later ground water samples are taken. The selenium concentrations measured in the observation wells are shown in the following figures. Figure 13 shows the concentrations measured by block. There are many wells in blocks 1, 2 and 3 which contain water. Blocks 4, 5 and 6 only have several each and there are no wells in block 7 as yet which contain water. Ground water in blocks 1 and 2 show the greatest variability in dissolved selenium. There are no consistent selenium concentrations across wells. Some wells have consistently higher concentrations than others which show that the distribution of the selenium in the underlying soils is highly variable.

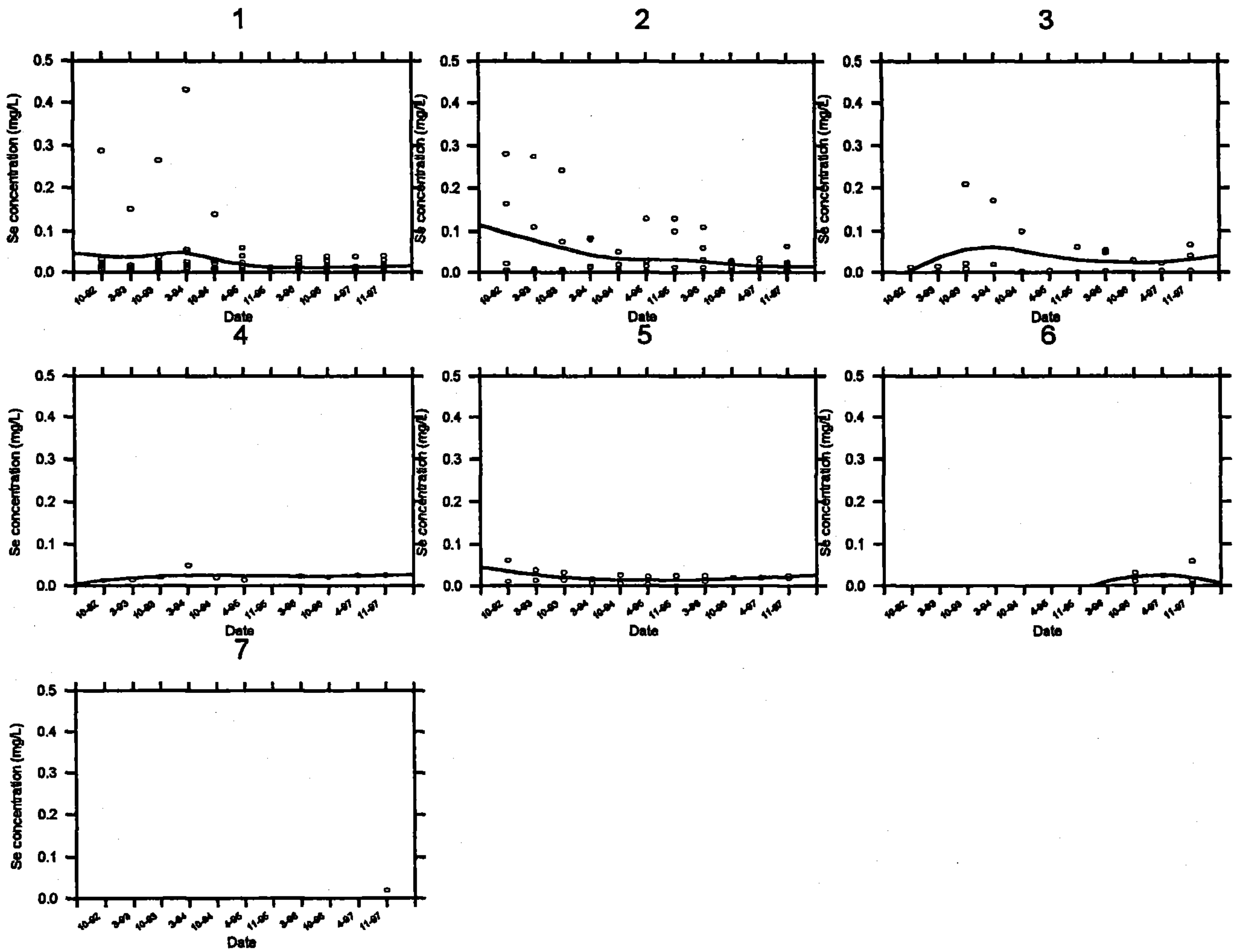


Figure 13. Time Series Plots of Selenium Concentration in NIIP Observation Wells by Block

The overall trend of the mean selenium concentration in a composite of all wells is shown in Figure 14. The mean value of all wells was 51 ppb in October of 1992. By November 1997 the mean concentration had decreased to 18 ppb. The figure also shows that most wells are less than 20 ppb, with a few high readings. These high readings have been decreasing with time with more of the wells reading in the <1 to 50 range. The high readings are likely in areas of very low growndwater movement in shales. The continual pumping of the wells for sampling may be gradually be depleting these wells of the readily soluble selenium. There are no data to indicate how big the radius is of the solubility influence but the depletion could be localized around each well. In terms of discharging groundwater, the reduced mean value more closely matches the concentration at discharge locations and, is likely closer to the average of the groundwater that is sufficiently mobile to flow to discharge points.

Seeps and Springs. Due to irrigation of fields, seeps have formed along the exposed bedrock contacts around the perimeters of the Gallegos and Ojo Amarillo. In 1991 water from these seeps was sampled on a monthly basis to determine the seasonal change in the selenium concentrations. Samples were collected in the groundwater seeps on the east (irrigated) side of Gallegos Canyon and on both sides of Ojo Amarillo Canyon. Also included with Ojo Amarillo is a seep data set collected in Jan 1996. The results found in each wash are summarized in Figures 15 and 16 for Gallegos Canyon and Ojo Amarillo, respectively.

The Gallegos seeps had concentration range from 0.001 to 0.129 mg/l (1 ppb to 129 ppb). The smoothed mean plot showed a slight decrease in summer to about 19 ppb and an increase in the winter to about 27 ppb. The median concentration of all measurements was 17 ppb (mean = 22 ppb). For comparison of seeps and wells, the median selenium concentrations in the wells along Gallegos Canyon (Blocks 1,4 and 5) were 17 ppb in 1992.

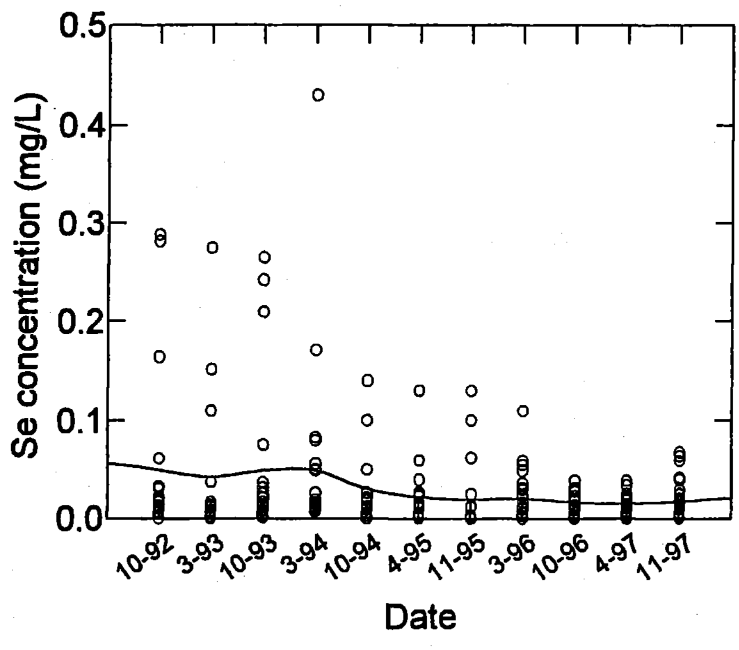


Figure 14. Time Series Plot of Selenium Concentration for all NIIP Observation Wells

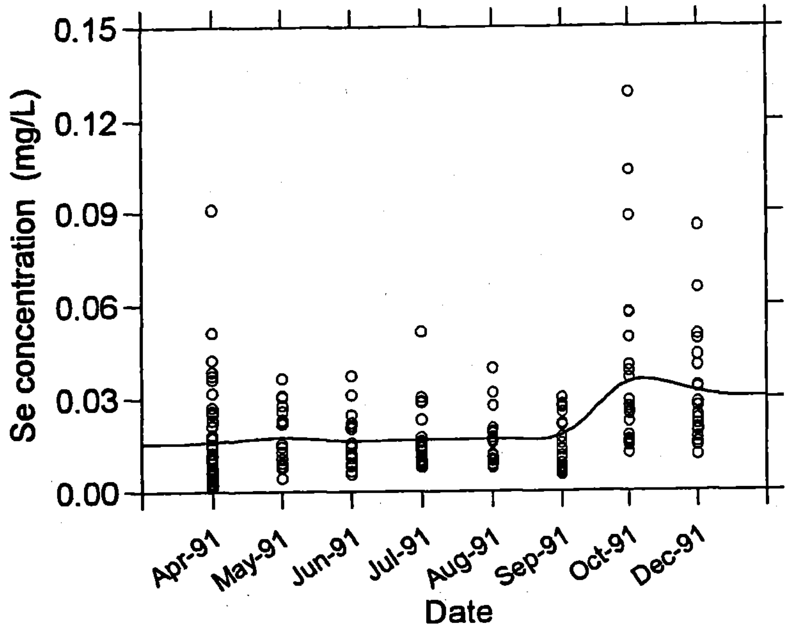


Figure 15. Time Series Plot of Selenium Concentration for Gallegos Canyon Seeps - 1991

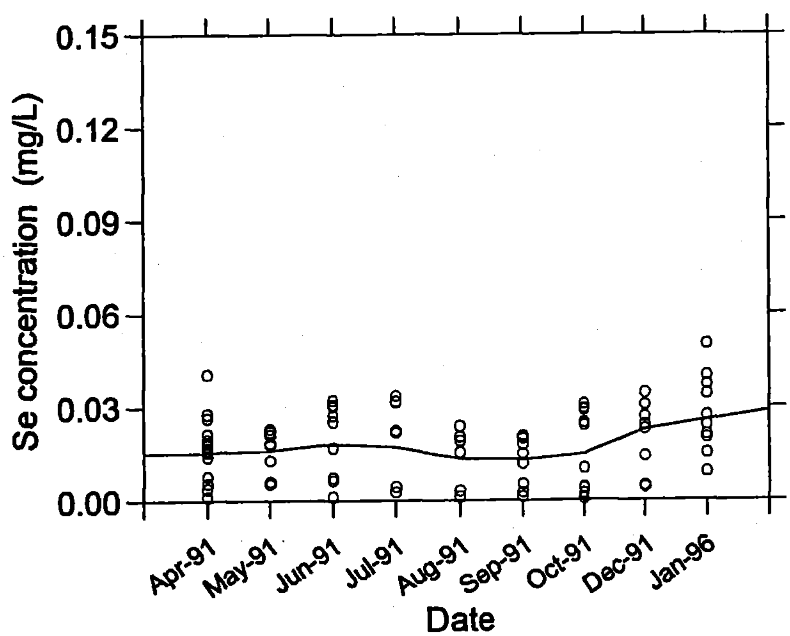


Figure 16. Time Series Plot of Selenium Concentration for Ojo Amarillo Seeps

The seeps around Ojo Amarillo Canyon ranged from 0.001 to 0.050 mg/l (1 ppb to 50 ppb) in concentration. The smoothed mean plot showed a slight decrease in summer to about 15 ppb and an increase in the winter to about 26 ppb. The median concentration of all measurements was 19 ppb (mean = 18 ppb). For comparison of seeps and wells, the median selenium concentrations in the wells along Ojo Amarillo Canyon (Block 2) was 21 ppb in 1992. For each wash, the selenium concentrations in the seeps were near to the concentration measured in the neighboring wells. The January 1996 reading indicates that there has been little change since 1991 when comparing this data point to the winter values in 1991.

Ponds. During 1990 DOI sampled several of the NIIP ponds for heavy metals, hydrocarbons, and pesticides. The data indicated that selenium was elevated in several Gallegos drainage ponds, Ojo Amarillo drainage ponds and four non-tributary ponds. The Ojo Amarillo pond had high selenium concentration in April 1990 with concurrent high levels in invertebrates, amphibians, and birds. During 1990, site I-2 (middle pond in Gallegos Canyon) was also found to have elevated Se concentration in water, plants, invertebrates, and amphibians. Selenium measurements, taken in 3 non-tributary ponds, showed the south pond (1-35) to have a mean value of 0.004 mg/l, the middle pond (1-25) a mean of 0.025 mg/l and the north pond (1-18) a mean of 0.004 mg/l. Due to the high Se concentration in the biota collected in and around the ponds, a monitoring program was begun to follow the concentration in both water and Tiger salamanders.

Stock ponds are traditionally fed with irrigation water during the irrigation season with some water from springs or seeps. The ponds studied in this investigation are denoted on Plate 3. The observed selenium concentrations in four different ponds are shown in Figure 17. An annual cycle in the concentrations in each pond can be seen. During the summer, the selenium concentrations are low, less than 0.005 mg/l. The winter concentrations are highly variable among ponds and change from year to year. Beginning in 1993 additional irrigation water was added to the ponds for RIP dilution. As a result the pond concentrations were lower after summer 1993. During the dilution period, tiger salamanders were collected and analyzed for selenium, the results of which are shown in Table 10. Concentration values are missing from the table when no salamanders could be caught.

No decrease of selenium in the salamanders was found. Apparently the selenium was traveling up the food chain from other sources (presumably from sediments) than the water. So, the dikes of ponds 1-18, 1-25 and 1-35 were breached and these stock ponds were eliminated. The Ojo Amarillo pond, which is still active, shows a similar annual cycle in the selenium concentration, but at 0.001 mg/l to 0.015 mg/l. Since the Tiger salamander levels were reasonable and the water concentrations lower, the Ojo Amarillo pond was not breached and is still being monitored.

Drainage Channels. In the DOI study small amounts of Se were found during the 1990 sampling of Chaco Wash. In April 1991, selenium was found in Chaco Wash surface waters south of the Hogback, but was not detected near the mouth. Water in Chinde Wash both in the 1990 and 1991 samples contains just detectable Se. In Ojo Amarillo, the water branching into the wash contained varying amounts of Se. The DOI study found ranges from <1 to 67 μg/l during 1990. At the canyon's mouth the concentration gradually increased from 33 to 67 μg/l during the year. In 1991 at 11 sampling locations in the canyon, the BIA study found ranges from 2 to 32 μg/l. The concentration at the canyon's mouth increased from 17 to 28 μg/l in early 1991. In the mouth of Gallegos Canyon, the DOI study found that the concentration gradually increased from 8 to 15 μg/l during 1990. In 1991, the concentrations within the wash varied from <2 to 23.5 μg/l. The concentration at the canyon's mouth increased from 7 to 9 μg/l in early 1991. In Horn, Kutz and Armenta Canyons and in Canon Largo, selenium concentrations in the surface waters were below the detection limit.

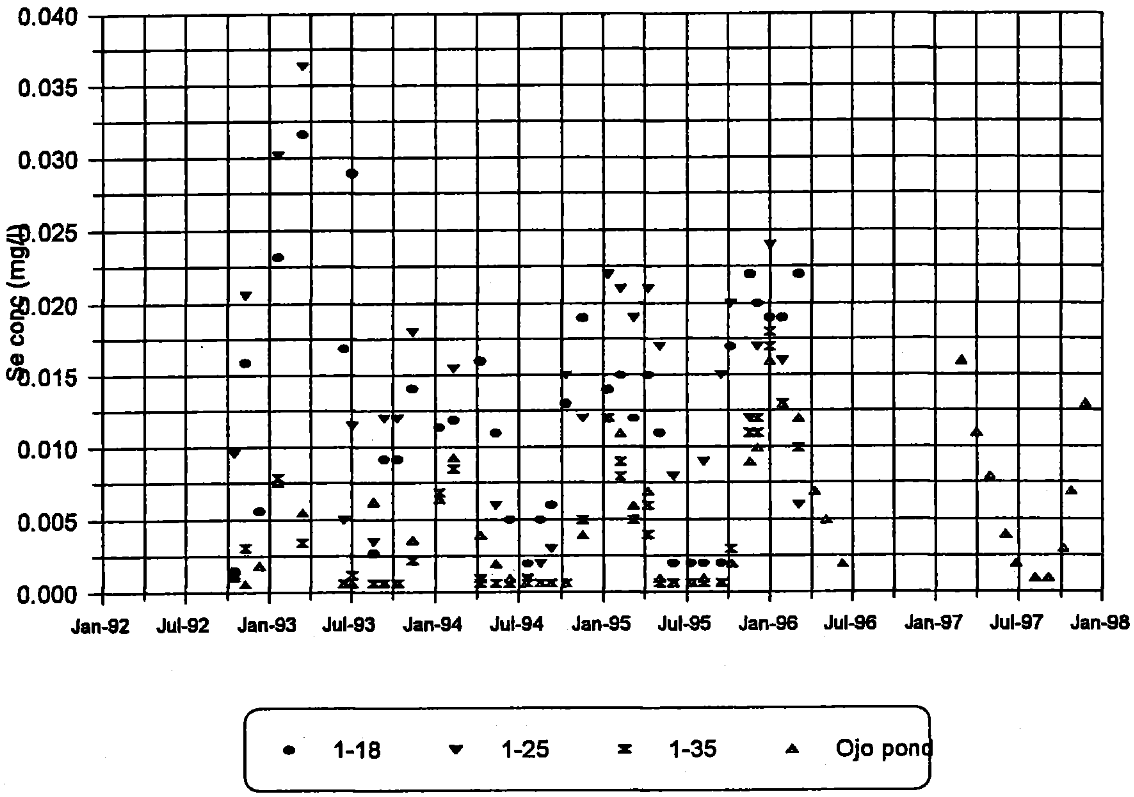


Figure 17. Selenium Concentrations in NIIP Ponds.

Table 10. Selenium concentratioin of whole body composite - Tiger salamanders (mg/kg-dry wt).

Pond	Oct 92	Mar 93	Nov 93	Mar 94	Sep 94	Apr-95
1-18	-	34.4	45.9	40.7	-	48.6
1-25	30.8	3.6	36.5	16.1	20.2	22.3
1-35	2.3	4.8	5.8	9.0	-	7.6
Ojo Amarillo	4.9	4.7	3.2	-	8.7	-

The two major washes, Gallegos and Ojo Amarillo, have flow through the entire year. The unnamed wash has stagnant water during the winter. During the summer, flow in these washes is somewhat erratic consisting of a base flow with superimposed operational or RIP dilution spills. In Figure 18, a time series of the selenium concentrations are depicted which were measured in each wash. The summertime, dilution in each wash is readily seen in the time series plot. The annual median concentrations in the washes taken over both summer and winter seasons are: Gallegos 0.007 mg/l, Ojo Amarillo 0.025 mg/l and unnamed 0.041 mg/l. It should be noted that the Ojo Amarillo sample is taken above the dilution point below the confluence with the overflow from the Fruitland canal. Below this dilution point, the concentrations drop below 5 ppb in the summer. The median concentrations by season are summarized for each wash in Table 11.

The measured concentrations in each wash are plotted by month in three Figures 19, 20 and 21. The dip in concentrations during the irrigation season is readily seen in each figure. The line is derived as a distance weighted least squared smoothing of all the data. Both Gallegos and unnamed washes show lower selenium concentrations in the summer than Ojo Amarillo Wash. These former two washes have the project operational spills while Ojo Amarillo has only small RIP dilution flows during the irrigation season. Since the Fruitland canal wasteway discharge accomplishes dilution, planned releases down Ojo Amarillo were discontinued after 1995.

The gradual decrease of the selenium concentration occurring in the wells implies that the selenium concentration of water in seeps and washes should gradually decrease. Due to the amount of selenium in the soil the decrease will appear more slowly than in the well data. To date no decrease of the selenium concentration has been detected in the washes. Confirmation of a decrease is also complicated by the dilution water during the irrigation season. The best measure of change would be comparison of winter concentrations that are not diluted. Further, the relative winter concentrations are somewhat related to flow. Gallegos has the highest flow, followed by Ojo Amarillo. Unnamed wash has very nearly 0 flow in the winter. In terms of change with time, Gallegos has been receiving irrigation return flow longer than Ojo Amarillo or unnamed wash, with the possibility of some decrease in concentration with time.

Historic Water Quality Analysis of the San Juan River. The available dissolved selenium data for reaches of the San Juan, Animas, LaPlata and Mancos Rivers were compiled from the EPA STORET database on CD-ROM available from Hydrosphere (Boulder CO). The database was searched for dissolved selenium sampling collected at any station between the Archuleta, NM and the Bluff, UT gaging stations, including all possible stations on tributaries of the San Juan River. A few selenium data were collected in 1958-1959 by the USGS. The bulk of the data was collected in the 1970's and 1980's. The concentration data compiled from the search were combined with the concentration data collected by BIA-Farmington personnel during 1991-1997. If the BIA sampling sites were near USGS gages, the sites were given the same station number. BIA sites located between gages were assigned numbers interpolated between the USGS gages. Table 11 shows the sites and the range of the sampling periods. Any interpolated station numbers are also denoted in Table 12.

Table 11. Concentration of dissolved selenium in washes in ppb (1 ppb = 0.001 mg/l) .

	Gallegos		Ojo Amarillo		unnamed	
	winter	summer	winter	summer	winter	summer
median	15	3	30	19	90	6
mean	17	5	30	19	102	23

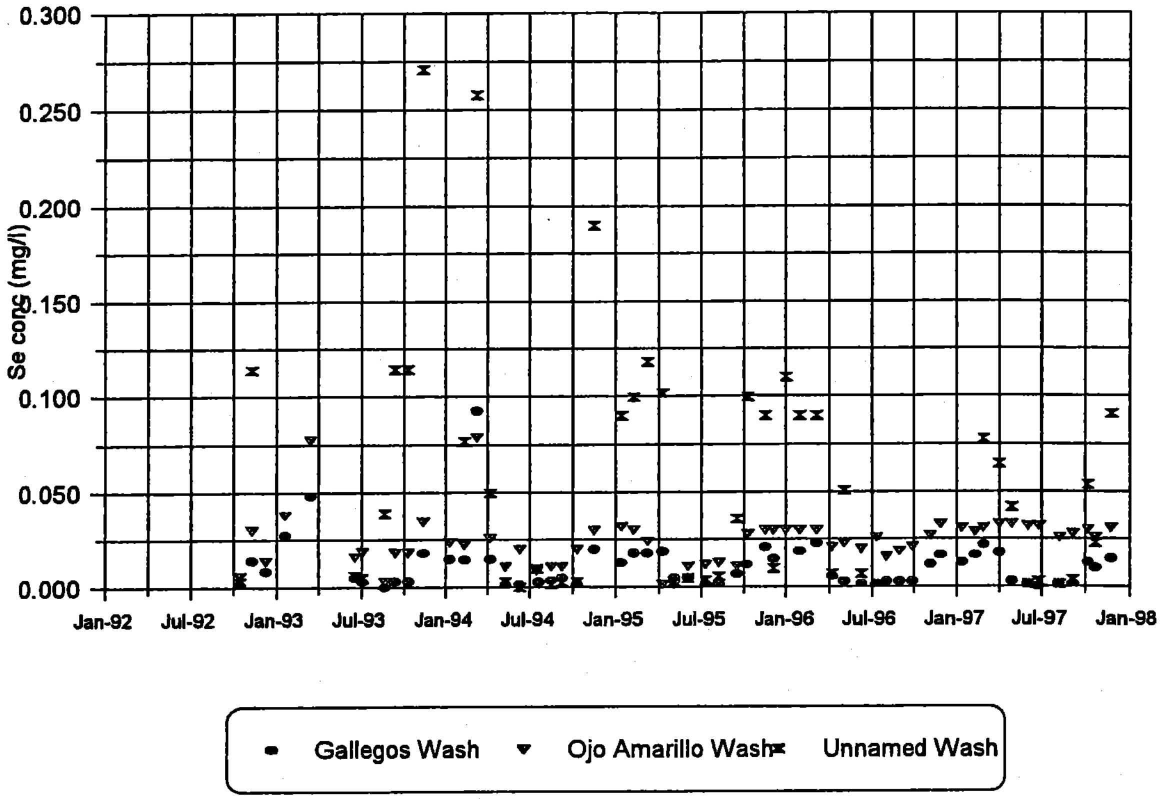


Figure 18. Selenium Concentrations in NIIP Outflow Channels.

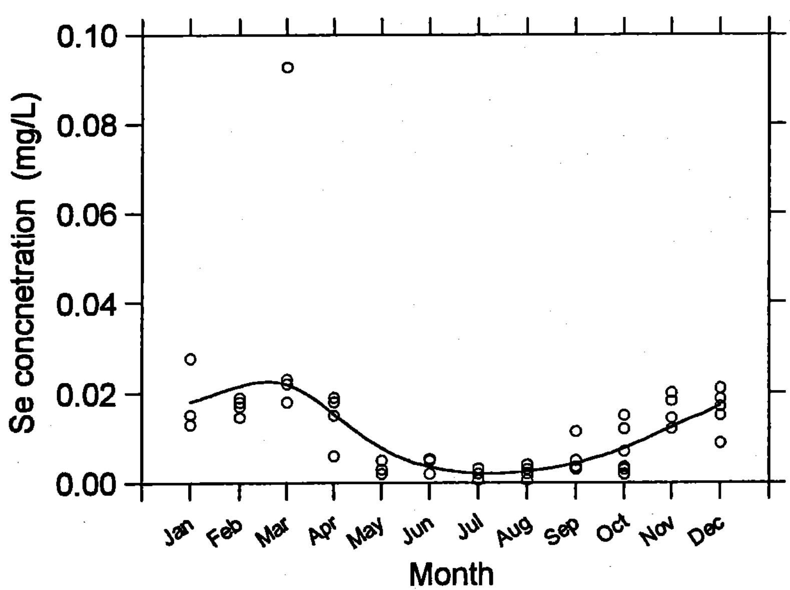


Figure 19. Monthly Distribution of Selenium Concentration in Gallegos Canyon.

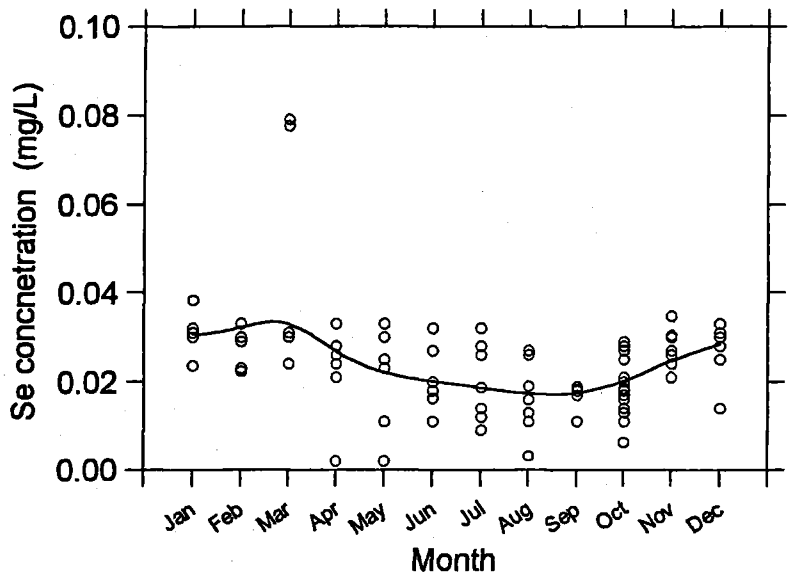


Figure 20. Monthly Distribution of Selenium Concentration in Ojo Amarillo.

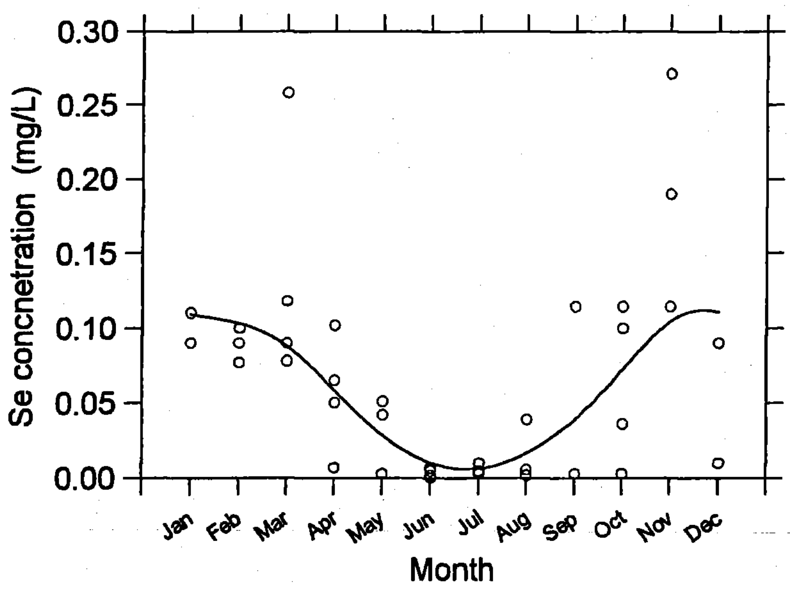


Figure 21. Monthly Distribution of Selenium Concentration in Unnamed Wash.

Table 12. Summary of Stations in Dissolved Selenium Database.

Station Name	Station ID	USGS Sampling Period	BIA Sampling Period
SAN JUAN RIVER NR ARCHULETA, NM	9355500	1958-1984	
SAN JUAN RIVER NR ARCHULETA BRIDGE	9355500*		1991-1996
SAN JUAN RIVER NR BLANCO BRIDGE	9356500*		1991-1996
CANON LARGO NR BLANCO, NM	9356565	1958-1981	
SAN JUAN RIVER AT BLOOMFIELD BRIDGE	9357000*		1991-1996
SAN JUAN RIVER AT HAMMOND BRIDGE NR BLOOMFIELD, NM	9357100	1977-1981	
SAN JUAN RIVER AT LEE ACRES BRIDGE	9357100*		1991-1996
GALLEGOS CANYON NR FARMINGTON, NM	9357250	1979-1981	1991-1996
SAN JUAN RIVER AB ANIMAS RIVER AT FARMINGTON, NM	9357300	1958-1959	
ANIMAS RIVER AT DURANGO, CO	9361500	1958-1981	
FLORIDA RIVER AT BONDAD, CO	9363200	1958-1989	
ANIMAS RIVER NR CEDAR HILL,NM	9363500	1958-1959	
ANIMAS RIVER AT BONDAD BRIDGE	9363500*		1991-1996
ANIMAS RIVER AT AZTEC BRIDGE	9363505**		1991-1996
ANIMAS RIVER AT FLORAVISTA BRIDGE	9363510**		1991-1996
ANIMAS RIVER AT FARMINGTON, NM	9364500	1958-1992	
ANIMAS RIVER AT MILLER STREET BRIDGE	9364500*		1991-1996
SAN JUAN RIVER AT FARMINGTON, NM	9365000	1974-1991	
SAN JUAN RIVER AT FARMINGTON BRIDGE	9365000*		1991-1996
LAPLATA RIVER AT CO-NM STATELINE	9366500	1958-1991	
LAPLATA RIVER AT BREEN BRIDGE	9366500*		1991-1996
LAPLATA RIVER AT LAPLATA BRIDGE	9366505**		1991-1996
LAPLATA RIVER NR FARMINGTON, NM	9367500*	1977-1991	1994-1996
OJO AMARILLO CANYON	9367505*		1993-1996
SAN JUAN RIVER NR FRUITLAND, NM	9367540	1997-1990	
SAN JUAN RIVER AT FRUITLAND BRIDGE	9367540*		1991-1996
SAN JUAN RIVER ABOVE HOGBACK DIV	9367550**		1992-1996
SHUMWAY ARROYO NR FRUITLAND,NM	9367555	1978-1982	
SHUMWAY ARROYO NR WATERFLOW, NM	9367561	1974-1982	
CHACO RIVER NR BURNHAM, NM	9367938	1978-1982	
CHACO RIVER NR WATERFLOW, NM	9367950*	1978-1989	1991-1996
SAN JUAN RIVER AT SHIPROCK, NM	9368000	1958-1992	
SAN JUAN RIVER AT SHIPROCK BRIDGE	9368000*		1991-1996
MANCOS RIVER NR TOWAOC, CO	9371000	1975-1994	
NAVAJO WASH NR TOWAOC, CO	9371002	1990	
MANCOS RIVER NR FOUR CORNERS	9371005**		1991-1996
SAN JUAN RIVER AT FOUR CORNERS, CO	9371010	1977-1990	
Station Name	Station ID	USGS Sampling Period	BIA Sampling Period
SAN JUAN RIVER AT FOUR CORNERS BRIDGE	9371010*		1991-1996

Station Name	Station ID	USGS Sampling Period	BIA Sampling Period
SAN JUAN RIVER AT ANETH	9371400**		1991-1996
MCELMO CREEK NR CORTEZ,CO	9371500	1990	
MCELMO CREEK NR CO-UT STATELINE	9372200	1977-1991	
MCELMO CREEK NR ANETH, UT	9372200**		1991-1996
SAN JUAN RIVER AT MONTEZUMA BRIDGE	9378610**		1991-1996
SAN JUAN RIVER AT BLUFF BRIDGE	9379495**		1991-1996
SAN JUAN RIVER NR BLUFF, UT	9379500	1974-1993	
SAN JUAN RIVER AT MEXICAN HAT	9379500*		1991-1996

*BIA Sampling Sites and ** interpoleted station number

After investigating the accuracy of the dissolved selenium measurements in the database, some specific values from excluded from consideration. The USGS circulated a memorandum that selenium concentration values measured before 1978 were suspected to be reported higher than actual. Also the water samples analyzed between May 1991 and February 1994, appeared to have randomly high selenium values with no apparent reason. The spuriously high concentrations appear to occur on certain analysis dates. The samples collected in the May 1992, August 1992, January 1993 and March 1993 were excluded from the database. After the suspect USGS and BIA values were excluded, the count of valid measurements totaled 2301 values - 1175 values on the main stem of the San Juan River and 1126 values on its tributaries.

Of the 2301 measurements taken as valid, about 60% of the selenium concentrations were below the detection limit, usually < 1 ppb. Specifically 821 of the main stem river samples and 561 of the tributary water samples were below the detection limit. The analyses were for the most part carried out using all samples after interpolating values below the detection limit. A candidate distribution of dissolved selenium values was estimated to be a gamma distribution (density function = $\Gamma(\alpha)^{-1}\beta^{-\alpha} x^{\alpha-1} e^{-x/\beta}$) with shape and scale factors: ΰ = 3.2 and β= 0.27 respectively. Concentrations below the detection limit (1ppb) were assigned values drawn randomly from the gamma distribution (bounded by $x < 1.0$). The mean of the 3,000 values drawn from the bounded gamma distribution was 0.59 ppb. Hence, for the values below the detection, the Se concentration was assigned as 0.6 ppb for purposes of calculation and plotting the Se distributions of the San Juan River and its tributaries.

The distribution of measured Se concentration along the main stem is shown in Figure 22. The Se concentration is gradually increasing moving downstream on the San Juan River. The trend indicates that selenium is accumulating in the river by tributary and wash contributions. Trends in the monthly distribution begin to develop as one moves downstream. Such a distribution, depicted in Figure 23 for San Juan River at Mexican Hat Bridge show similar characteristics - elevated values near 2 ppb during January and February, low values below the detection limit during April, May and June, another peak during July, August and September. It is possible that concentration peaks in February and August indicate that selenium is mobilized during surface runoff in the lower basin (e.g. early spring or late summer storm runoff) as the elevated values typically occur during or following storm events or snowmelt runoff in the lower portion of the drainage.

Main Stem Arsenic. There were 1,298 analyses for dissolved arsenic in water at the stations on the main stem of the San Juan River. Of the analyses 56% were below the detection limits which ranged from 0.5-100 ppb. The most common detection limit was 0.005 mg/l (5 ppb). The mean concentration was 2 ppb and the median concentration was also 2 ppb. No general trends with time, location, nor flow can be determined for As concentrations.

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Main Stem Copper . There were 435 analyses for dissolved copper in water at the main stem stations. Of the analyses 42% were below the detection limits which ranged from 1-10 ppb. The most common detection limit was 0.005 mg/l (5 ppb). The mean concentration of all samples was 4 ppb and the median concentration was 3 ppb and the variability in the measured concentration is small. A seasonal pattern develops on moving downstream to Bluff. Median copper concentrations rise during winter to about 5 ppb. The summer concentrations are near 3 ppb. Measured values can randomly exceed 10 ppb, but the variability also increases moving downstream. The mean Cu concentration increases slightly from 3 to 4 ppb from Archuleta to Bluff.

Main Stem Zinc . There were 1300 analyses for dissolved zinc in water at the main stem stations. Of the analyses 55% were below the detection limits which ranged from 2-50 ppb. The most common detection limit was 0.01 mg/l (10 ppb). For all samples, the mean concentration was 19 ppb and the median concentration was 5 ppb. For San Juan River, the concentration of zinc increases moving downstream from about 5 to 10 ppb. The variability in the measured concentration also increases moving downstream. No seasonal trend can be discerned. Due to the skewed distributions of measured zinc concentrations, the median concentration increases from 5 to 10 ppb from Archuleta to Bluff while the mean Zn concentration appears to increase from 11 to 33 ppb from Archuleta to Bluff.

Organic contaminants. In the USGS sampling programs, no PAH have been detected in water samples on the main stem of the San Juan River. In 1993 and 1994 the USGS analyzed water samples collected in the Gallegos and Ojo Amarillo drainages for PAH and chlorinated hydrocarbons. None were detected in samples of either surface water or spring water. Similarly BIA analyses showed no detectable PAH and chlorinated pesticides in samples in the San Juan River between Gallegos Canyon and Fruitland or in water from Ojo Amarillo Wash. USGS water samples from Hammond Canal immediately downstream of the Bloomfield oil refinery did not contain detectable amounts of PAH either. The FWS installed semipermeable membrane devices (SPMD) in the Hammond Canal and downwind of the refinery. Over several months these devices were allowed to absorb organic pollutants from water or air. The device were then extracted and the absorbed organics were analyzed. In these samples there appeared to be no detectable PAH. Similar devices were installed in the San Juan River and its major tributaries. PAH compounds were not detected above or below the Bloomfield Refinery. There were PAH compounds found in the Animas above Farmington and in the San Juan River near Montezuma Creek. Other San Juan reaches were near or below detection limits including those above and below potential NIIP influence.

Biological Concentration of Selenium in the San Juan River. Biological samples (periphyton, macroinvertebrates, and fish) have been collected at least annually along the San Juan River. Beginning in 1991 the biological samples collected between river miles 92 (Montezuma Creek Bridge) and 224 (Navajo Dam) were analyzed for trace elements. Selenium has been the element of major concern in these samples and this section summarizes the findings through 1997. The focus is the impact of NIIP return flow on the water quality of the San Juan River, so we will only consider those samples collected below the inflow of Gallegos Canyon (river mile 187) to the Montezuma Creek Bridge (river mile 92), the lowest extend of biological sampling.

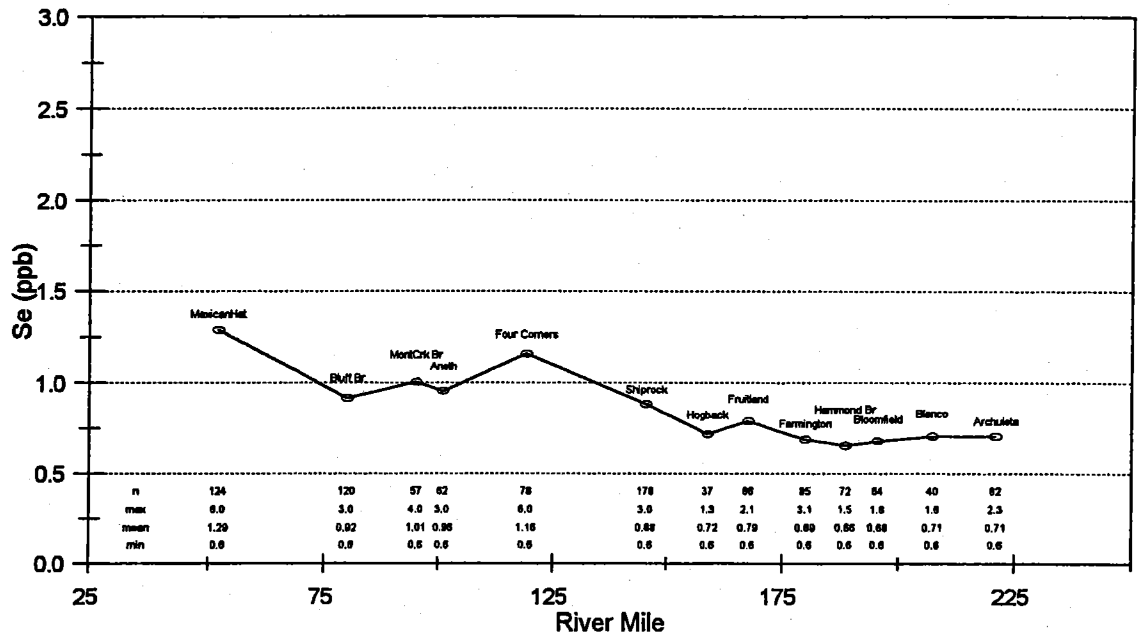

Figure 22. Longitudinal selenium distribution in the San Juan River

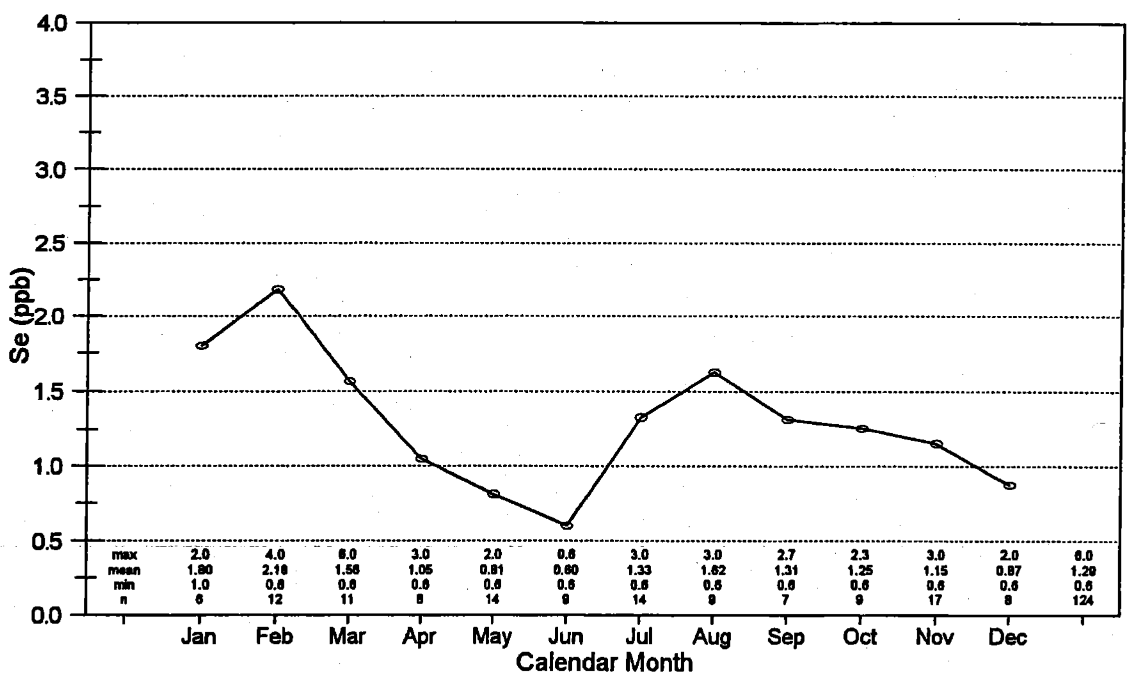

Figure 23. Monthly selenium concentration distribution in the San Juan River at Mexican Hat, UT.

In all, 409 whole organism or whole fish samples are part of this compilation. Their distributions are shown in Table 13. As noted above the selenium concentrations were reported on a dry weight basis as mg/kg for whole organisms. The small fish category consisted of seine hauls of predominately speckled dace, fathead minnow, some red shiners and others. If the trophic levels are periphyton, macroinvertebrates and small fish, then there is an apparent accumulation of selenium across levels. The small fish had the highest mean Se concentration and standard deviation of any group or species analyzed in this data set. However, predators above small fish did not show concomitant increase in selenium showing that whole body selenium content may be influenced by other factors in addition to diet.

In this set of organism groups, the Se analyses show distinct trends by river mile. These trends are depicted graphically in the Figure 24.

The Se concentrations measured in each species or group are plotted as a function of location expressed in river miles. Most notable is that the dispersion about the mean decreases moving downstream. This is especially seen in the small fish plot. The mean concentrations in carp and razorback suckers are increasing downstream. The mean concentration in macroinvertebrates is decreasing. The remaining group show no significant changes in mean Se concentrations as a function of river mile. As more samples are collected in future years, concentration changes may be come more apparent.

The upstream and downstream comparisons at the two washes, Gallegos Wash and Ojo Amarillo Wash are based on the selenium concentrations measured in organisms collected in the San Juan River from 1991 to 1997. The sample distribution of the fish, macroinvertebrates and periphyton are show in Table14.

Table 13. Mean selenium concentrations (mg/kg) in biological samples collected 1991-1997.

Sample type	All Fish	Bluehead sucker	Brown Trout	Common Carp
Number	350	108	7	45
Se concentration	2.61	1.65	4.73	2.95
Standard deviation	1.67	0.58	1.17	1.38

Sample type	Channel catfish	Flannelmouth sucker	Razorback sucker	Small fish
Number	10	127	11	42
Se concentration	2.23	2.10	4.39	5.51
Standard deviation	0.78	0.71	0.56	2.30

Sample type	Macroinvertebrates	Periphyton	Sediment	Flannelmouth Ovaries
Number	34	24	18	48
Se concentration	3.28	1.05	0.44	4.30
Standard deviation	1.16	0.65	0.31	0.92

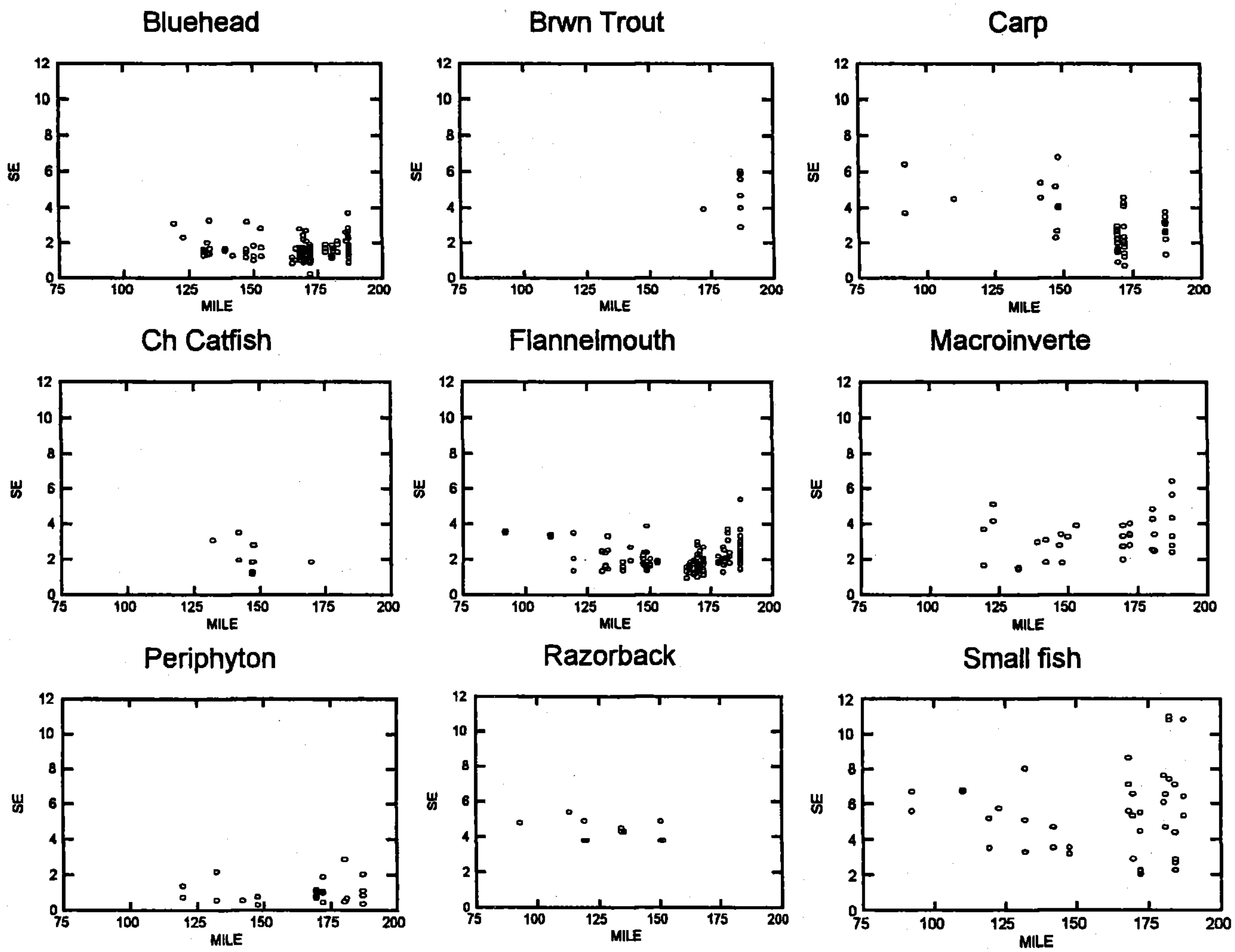

Figure 24. Selenium concentrations measured in fish plotted by river mile.

Table 14. Numbers of sample types at the various locations.

Gallegos Wash		
	Above	Below
Fish	25	78
Macroinvertebrates	5	6
Periphyton	3	4
Ojo Amarillo Wash		
	Above	Below
Fish	54	51
Macroinvertebrates	4	5
Periphyton	4	4

The mean concentrations were test using ANOVA across types and locations. There were no statistical differences in selenium concentrations in biota collected upstream or downstream at either wash location. Selenium in inflow from the washes was not affecting the concentration in the organisms in the San Juan River. However there was a statistical difference in the mean concentrations in biota between the two washes. The organisms collected around the Gallegos inflow contained more selenium (mean concentration 2.8 ppm) than those collected around the Ojo Amarillo inflow (mean concentration 2.0 ppm). This differences appeared in the fish and macroinvertebrates, not the periphyton. Hence the conclusion is that although irrigation return flow is entering the river in both Gallegos and Ojo Amarillo Washes, the dissolved selenium does not appear to concentrate in the biota at these two inflow points.

Influence of Completion of NIIP Development on Contaminants in the San Juan River. To analyze the impact of future NIIP return flow on the quality of water in the San Juan River, the results of the groundwater modeling and return flow timing projections were combined with the selenium concentration sampling results discussed in this section. It was assumed that the natural return flow from the projects would continue at their mean winter concentrations (no dilution water effect) without change in the future. Therefore, Gallegos natural discharge would have a selenium concentration of 15 ppb, Ojo Amarillo 30 ppb and all other drainages 23 ppb (average of Ojo Amarillo and Gallegos values).

Water returning through the artificial drainage system was assumed to have a concentration of 1.0 ppb after 5 years. Drain concentration would start at 20 ppb (average groundwater value) and decrease by 50% each year until reaching 1 ppb in year 6 after drain installation. This improvement in quality over six years reflects the mixing of in-place groundwater at a concentration of about 20 ppb (it is actually lower in the upper portion of the profile from the field sampling) with the deep percolation water which is assumed to be 1 ppb (measured values are below detection). The initial drainout of the stored groundwater above the drain upon installation will occur within a few weeks, leaving the primary deep percolation water with some mixing with existing drain water at distance between the drains. The drains were assumed to be installed over a 20 year period beginning in 1999 for the Gallegos and Ojo Amarillo Drainages and in 2029 for areas draining to Chaco Canyon.

The time line of concentrations were combined for the various sources with the expected discharge volume of each source to arrive at a weighted return flow concentration with time. The resulting time line of drain water selenium concentration is shown in Figure 25. Also shown in Figure 25 is the time line of expected mean selenium concentration in the San Juan River at Mexican Hat at a base flow of 500 cfs, with a starting concentration in the model of 1.42 ppb. This level produces a mean concentration

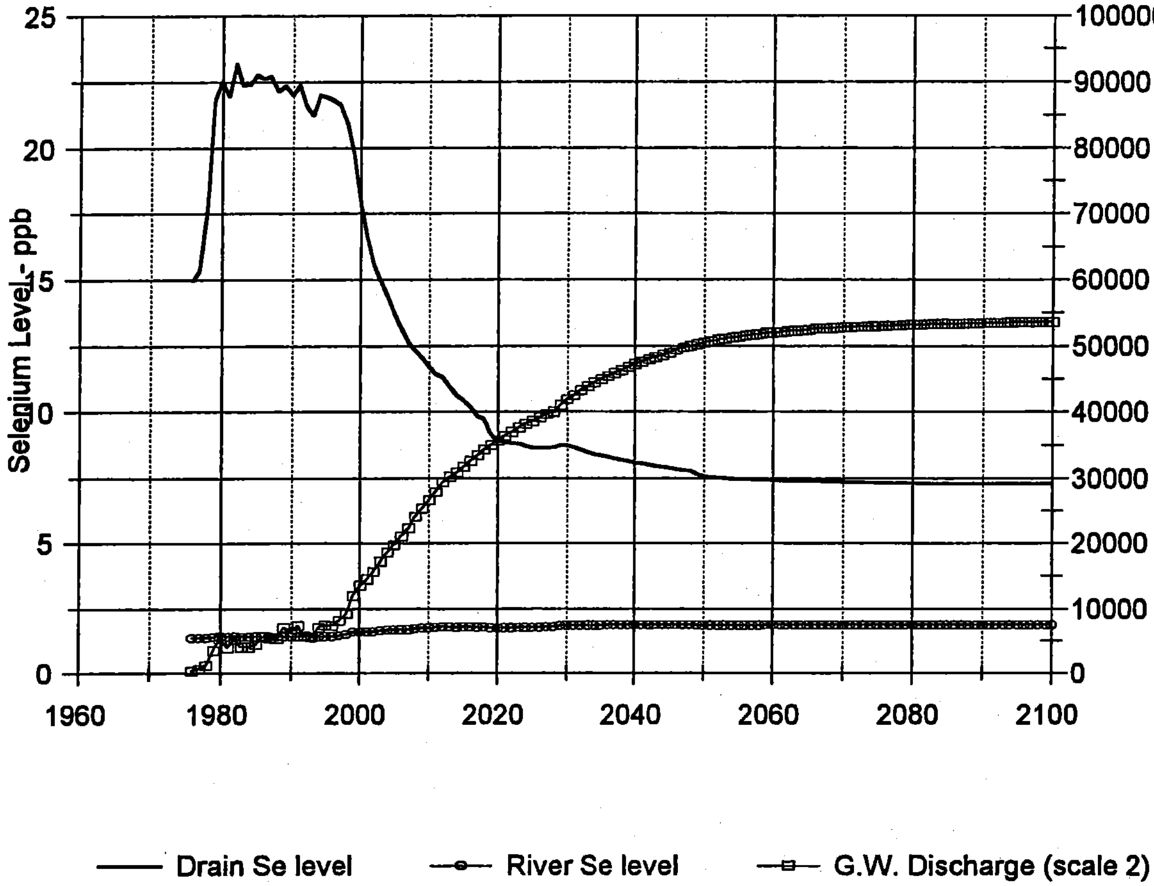

Figure 25. Projected Selenium Concentrations in NIIP Return Flow and at 500 cfs in the San Juan River

for the period 1994-1998 of 1.45 ppb, matching the measured mean value at Mexican Hat for flows under 750 cfs (mean 520 cfs).

This analysis shows that the return flow from NIIP will increase the mean concentration of selenium at base flow (500 cfs) from 1.45 ppb to 1.90 ppb by the time equilibrium is reached in about 2042, assuming all contributed selenium stays in solution. A portion of the 0.40 ppb increase will occur as a result of the existing level of development. By the end of 1997, it is estimated that about 28% of the return flow expected from the development allowed under the 1991 consultation will be returning to the river. The remaining return flow from the approved portion of the project will contribute about 27% of the gain expected or about 0.12 ppb. Therefore, the additional irrigation expected with the completion of NIIP past Block 8 will be responsible for an increase in selenium levels of about 0.23 ppb at base flow.

In terms of selenium mass, the project is discharging approximately 447 lb of selenium per year (ave 1994-1998) to the San Juan River. When the approved portion is in equilibrium, the contribution will be about 592 lbs for this level of development. The total contribution at equilibrium (worst case) is 1,068 lbs, for an increase of 476 lbs per year. Based on the average of the 1994 to 1998 selenium data collected at Mexican Hat, the average daily selenium load is about 8.8 lbs, for an annual load of about 3,200 lb. This will increase by about 621 lbs or 19% due to future return flow from NIIP, of which 476 lb is attributable to the next phase of development for a net increase due to future development of about 14%. At base flow, the concentration is expected to increase by 31%, with a 22% gain attributable to the future development.

To test the question of conservation of mass, the selenium load upstream and downstream of NIIP examined for the period 1994-1998. During this period there is no measurable increase in selenium in the river between the Hammond Bridge on the San Juan River (upstream of Gallegos Canyon) and the San Juan River at Shiprock. Most of the values are below detection and the impact of NIIP is sufficiently low to keep it from increasing to a detectible level. However, an examination of the number of detection values at each sampling point reveals a probable increase in selenium with distance down river. Table 15 lists the percentage of samples that were above detection and the maximum concentration at each site for the period 1994-1998. While there is an increase across the NIIP range of influence (Hammond Bridge to Shiprock, NM), the increase is much greater below Shiprock. Since the number of detectible samples increases across the NIIP range of influence, some effect is being seen in the river, although it cannot be quantified on the basis of measured gain in the river.

Applying the computed selenium gain from NIIP, assuming full conservation of mass and applying that gain to base flow conditions at Mexican Hat, computes a worst case condition. Levels higher in the system will be lower and concentrations during times other than base flow will be much lower.

Determining the impact to the system from potential increases of arsenic, copper and zinc is more problematic, since they have not been studied as intensely. Based on the available data it appears that the levels of zinc in the return flow are no higher than the river, so no impact is expected.

Arsenic levels are about 2.5 times the river levels, at 5 ppb vs 2 ppb. If this concentration continues at equilibrium conditions, the expected impact to the San Juan River will be an increase of about 0.45 ppb to an average level of 2.45 ppb at a base flow of 500 cfs.

Table 15. Portion of water samples from various stations on the San Juan River having selenium levels above detection and the maximum recorded value for the period 1994-1998.

Station	Total Samples	Detectible Se	Percent Detectible	Maximum Se, ppb
Hammond Bridge	58	1	1.7%	1
Farmington, NM	58	3	5.2%	2
Fruitland, NM	58	8	13.8%	1
Shiprock, NM	119	9	8%	1
Four Corners, NM	59	25	42%	2
Aneth, UT	51	24	47%	3
Montezuma Cr. Bridge	55	26	47%	4
Bluff, UT Bridge	113	47	42%	2
Mexican Hat, UT	58	28	48%	2

Copper levels during the non-diluted periods in Ojo Amarillo and Gallegos Canyon average about 20 ppm, while the average of the groundwater in the observation wells is about 10 ppb. It is expected that the long term discharge, including pipe drain discharge, will average about 10 ppb as the discharge comes into equilibrium with the groundwater. At this level of return flow concentration, concentration in the river may increase by as much as 1.2 ppb to a mean level of 5.2 ppb at a base flow of 500 cfs. Average annual increase would be much lower due to dilution during higher flow periods.

Biological Implications of Selenium Increase. If it is assumed that the percentage increase in annual selenium load in the water translates to the same proportionate increase in the biota, then the expected concentrations in each trophic level can be computed. Utilizing the information in Table 12 and increasing each value by 19%, the projected selenium levels for the biota are computed in Table 16.

Conclusions

Selenium. Based on the results of acute toxicity studies completed by Hamilton and Buhl (1995, 1996) for waters in the San Juan Basin for larval Colorado pikeminnow and razorback sucker, selenium levels, when in the more toxic selenite form, would have low risk of environmental hazard for Colorado pikeminnow below 20 ppb and for razorback sucker below 11 ppb. These studies show that Selenium LC_{96} concentrations are lowest for razorback sucker larvae followed by flannelmouth sucker, with Colorado pikeminnow being the least sensitive. The ratios are: 0.69 - razorback sucker to flannelmouth sucker and 0.49 - flannelmouth sucker to Colorado Pikeminnow when averaging selenate and selenite. For all three species, selenium concentrations in the river represent low hazard.

Table 16. Mean projected selenium concentrations (mg/kg) in biota based on samples taken during 1991-1997.

Sample type	All Fish	Bluehead sucker	Brown Trout	Common Carp
Number	350	108	7	45
Se concentration	3.11	1.96	5.63	3.51

Sample type	Channel catfish	Flannelmouth sucker	Razorback sucker	Small fish
Number	10	127	11	42
Se concentration	2.65	2.50	5.22	6.56

Sample type	Macroinvertebrates	Periphyton	Sediment	Flannelmouth Ovaries
Number	35	24	18	48
Se concentration	3.90	1.25	0.52	5.12

A study completed by Hamilton and Buhl (1998) on chronic toxicity and reproductive effect of selenium in feed and water on Colorado pikeminnow demonstrated no effect at feed concentrations of 11.8 ppm and water at 7.9 μg/l. There was no difference between control conditions and the highest concentration conditions in terms of spawning success, hatching success or growth of larval fish , although lack of replication limited the statistical analysis that could be completed. There was a difference in the selenium concentration in the adult fish muscle, eggs and larvae, with the eggs and swim-up larvae having about the same selenium concentration as the feed. Therefore, the toxic threshold for reproductive impairment for Colorado Pikeminnow is higher than 11.8 ppm in feed and 7.9 ppb in water.

If the ratios of acute toxicity apply to chronic toxicity and reproductive impairment, then applying the ratio of LC_{96} for selenium for razorback sucker to pikeminnow of 0.34 to the feed concentration of 11.8 ppm and water of 7.9 ppb would suggest no effect to razorback sucker with feed at 4.0 ppm and water at 2.7 ppb. Projected levels for feed and water are both below these no-effect levels.

Beyers (Personal Comm, April 1999) is in progress with chronic selenium toxicity studies for larval razorback suckers. Preliminary results from 1998 indicated no effect at feed concentrations of 1.5 ppm Se and water concentrations of 20 ppb.

To further assess the probability of adverse effect, the method for assessing toxic threat proposed by Lemly (1996) was applied. This process computes an index of combined toxicity for selenium concentrations in water, bottom sediments, macroinvertebrates and fish eggs. Table 17 summarizes the criteria for toxicity assessment from Lemly (1996). An adjustment is applied since his method includes bird eggs for effects to water fowl for which we have no data. Since only 4 parameters exist, the cumulative effect indices proposed by Lemly (1996) and shown in the table were multiplied by 4/5 to arrive at the criteria for fish hazard. In table 16, it is assumed that all parameters will increase at the same rate (19%) as the computed increase in water concentration assuming 100% conservation of Se in the system and the same bio-concentration factors that presently exist. Also shown on Table 16 are the values from the Beyers study where no effect to larval fish was seen. Assuming no effect from sediment or fish eggs, the hazard index is the same as the present condition for the San Juan.

Table 17. Computation of cumulative selenium hazard as proposed by Lemly (1996) and as computed for the San Juan River.

	Index	Water	Sediment	Macro-invertebrates	fish eggs	Overall Hazard: fish 4 parameters	Overall Hazard: aquatic birds 5 parameters inc. bird eggs
High	5	>5	>4	>5	>20	13-20	16-25
Moderate	4	3-5	3-4	4-5	10-20	10-12	12-15
Low	3	2-3	2-3	3-4	5-10	7-9	9-11
Minimal	2	1-2	1-2	2-3	3-5	5-7	6-8
None	1	<1	<1	<2	<3	≤4	≤5
San Juan		1.4	0.47	3.28	4.3		
With NIIP		1.9	0.56	3.9	5.12		
Beyers study		20		1.5			
Hazard Index							
Present		2	1	3	2	8	Low
With full NIIP		2	1	3	3	9	Low
Beyers study		5	1	1	1	8	Low

While the values in Table 17 show an increase in the hazard index due to a change in category in fish eggs due to increased selenium load, the rating according to the system proposed by Lemly remains as low hazard.

While the information for razorback sucker is not as solid as that for Colorado pikeminnow, based on the best available data it appears that the potential risk of toxic effect is low, although not non-existent.

Arsenic. Based on the results of the acute toxicity studies listed above, the projected arsenic levels are less than 2% of the threshold value of low risk of environmental hazard for the most sensitive species tested. The level is about 5% of the no-effect level suggested by Suter and Mabrey (1994). The arsenic levels expected are not a concern.

Copper. Copper becomes of concern in aquatic systems at levels between 0.23 and 12 ppb (Suter and Mabrey, 1994). Hamilton and Buhl (1995) concluded, based on a ratio between 96 hour LC50 and environmental concentrations of 100, that copper concentrations in the San Juan River as low as 1.75 ppb would have a high risk of environmental hazard for flannelmouth sucker, the most sensitive o the three species tested. Based on the water quality data from the San Juan River, copper levels already exceed this level by 2.3 times with no apparent adverse effect on the flannelmouth sucker, the most abundant native fish in the river. Since the endangered fish have a higher tolerance to copper than flannelmouth sucker (2.7 for razorback sucker and 3.0 for Colorado pikeminnow), it is unlikely that they would be injured with the levels in the river. The projected levels of 5.2 ppb are a little below mid-range in the levels of concern proposed by Suter and Mabrey (1994). Present level of understanding of the impact of copper on the species in the San Juan does not allow a conclusion to be reached concerning impact of the NIIP return flows, other than the levels are in the range of concern. Based on the empirical evidence concerning the flannelmouth sucker, river levels of copper could be 6.2 for razorback sucker and 6.9 for Colorado pikeminnow with the same effect as now occurs for the flannelmouth sucker.

Zinc. Since zinc levels are no higher in the drain water than in the river, no adverse effect is likely due to zinc.

PAH. No measurable impacts on PAH levels in the river by NIIP could be found.

SUMMARY AND CONCLUSIONS

The completion of the Navajo Indian Irrigation Project will increase annual depletions on the San Juan River by about 120,580 af on average under equilibrium conditions and by about 137,580 af on average until return flows reach equilibrium. This level of depletion will support crop production on 110,630 acres of irrigated land, requiring an average annual diversion of about 337,500 af.

In addition to completion of construction and commencement of irrigation on all authorized lands, the project includes several features designed to benefit the endangered Colorado pikeminnow and razorback sucker. These features include:

- Reoperation of Navajo dam to mimic a natural hydrograph and meet the flow recommendations for the San Juan River.
- Construction of three fish rearing ponds to assist the augmentation program for razorback sucker and, potentially, Colorado pikeminnow.
- Removal of Cudei diversion dam to provide fish access to designated critical habitat.
- Construction of fish passage at the Hogback diversion dam to provide fish access to designated critical habitat.
- Improvement of irrigation efficiency to reduce irrigation return flow, improve water quality and reduce impacts to river flows.
- Continued funding of and participation in the San Juan River Basin Recovery Implementation Program.

Monitoring

While inclusion of these project features will positively impact the chance for recovery, some uncertainty exists concerning water quality. Therefore, the following monitoring program will be followed to track selenium levels and provide data to assess risk as additional research is completed concerning chronic toxicity, particularly in razorback sucker.

On-Farm Monitoring

Irrigation return flow from the project is the main source of selenium discharged to the San Juan River. This irrigation return flow leaves the project either through deep percolation and discharge from springs along bedrock contact lines or as artificial drain outflow. Artificial drainage was first installed in the winter of 1998-99 in two fields, with a total of three drain outfalls. The drainage system completion study is now underway to identify and prioritize drain construction to intercept groundwater before it saturates the soils within the rootzone of the fields. The on-farm selenium sampling program will have three elements: 1) groundwater wells, 2) subsurface drain outfalls, 3) main natural drain outflow.

There are 51 groundwater observation wells on the project within the confines of blocks 1-7. These wells are listed in Table 18. Much of Blocks 6 and 7 do not have water tables above the bedrock since irrigation is relatively recent. As water levels rise, observation wells will be added. Also, as blocks 8-11 develop and water tables rise, wells will be added to these Blocks. It is anticipated that there will be as many as 100 observation wells at project completion.

Water samples will be taken from these wells and selenium levels determined on a semi-annual basis. Sampling will occur in the spring, before irrigation begins, and in the fall, at the end of the irrigation season, typically March and October.

Table 18. Existing Observation Wells on NIIP.

Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Block 7
1-1	2-1	3-1	4-1	5-1	6-1	7-1
1-2	2-2	3-2	4-2	5-2	6-2	7-2
1-3	2-3	3-3	4-3	5-3	6-3	7-3
1-4	2-4	3-4	4-4	5-4		7-4
1-5	2-5	3-6	4-5	5-5		
1-6	2-7		4-6	5-6		
1-7	2-8		4-7	5-7		
1-8	2-9			5-8		
1-9	2-10			5-9		
1-10	2-11					
1-11	2-12					
1-12						

Upon installation of subsurface drains, each drain outfall to a main collector or natural drainage way will be monitored twice annually until selenium levels fall be 1.0 ppb.

Monitoring of selenium levels in the natural return flow channels to the San Juan River (presently Ojo Amarillo and Gallegos Wash) will be monitored quarterly.

San Juan River Sampling

Water quality sampling in the San Juan River is described in the San Juan River Basin Recovery Implementation Program (SJRIP) monitoring program. In addition, sediment, paraphyton, macro-invertebrates (by species), small fish and flannel mouth sucker ovaries or eggs will be monitored from above Gallegos Canyon to Bluff, Utah. In addition, non-lethal samples (muscle plugs) will be collected from endangered fish on an opportunistic basis and with the approval of the SJRIP biology committee. The sampling program will be designed to assess not only the main channel, but typical low velocity habitats used by native fish, including backwaters, secondary channels and tributary mouths. An initial sampling will take place in 2000 with subsequent sampling every 5 years or as determined in collaboration with the Fish and Wildlife Service (FWS). The details of the plan will be developed in concert with FWS staff.

Razorback Sucker Growout Pond Sampling

Selenium monitoring will continue on the razorback sucker growout ponds. They are presently sampled weekly for pH, DO, conductivity and temperature. They will be sampled quarterly for trace elements.

Prior to removing fish and stocking in the river, non-leathal (e.g. muscle plug) samples will be collected from the juvenile razorback suckers. Sample size and protocol will be developed with FWS and SJRIP Biology Committee input.

When constructed and operated as outlined the project will be able to provide the required flows in the San Juan River below the diversion point recommended by the SJRIP Biology Committee. Water quality hazard for elements of concern are either non-existent or low, based on presently available data. While there is a possibility of effect, it is insignificant in that it is likely not measurable and discountable in that it is unlikely to occur. With the monitoring program in place to continue studying the impacts and identify any problems, there is not likely to be an adverse effect. Completion of the additional project features and continued participation in the SJRIP will enhance the opportunity for recovery of the species.

With the features listed and the operation and monitoring proposed, the project is not likely to adversely affect the endangered fish or any other endangered species in the basin.

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APPENDIX A

DETAILED HYDROLOGY DATA

NIIP
ANNUAL WATER USE REPORT

1997	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			2,600	8,200	24,000	35,800	41,900	28,700	14,500	1,100			156,800
Cutter Release													
Total Metered			54	6,617	18,708	32,522	36,412	24,021	10,339	1,825			130,498
Recorded Waste			7	980	325	400	1,460	2,159	950	495			6,776
RIP Spill				246	1,721	1,567	1,937	1,648	1,576	226			8,921
Other/Contract				1	3	2	2	2	1	1			12
Total Recorded	0	0	61	7,844	20,757	34,491	39,811	27,830	12,866	2,547	0	0	146,207
Crop CIR			775	2,068	12,666	17,267	24,608	20,782	8,168	1,396	52		87,782
Conservation CIR													2,846

1996	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			2,300	13,000	30,000	39,500	40,500	38,600	22,300	6,900			193,100
Cutter Release													
Total Metered				10,410	24,316	35,426	34,767	31,140	18,964	5,709	35		160,767
Recorded Waste			15	199	220	548	505	1,243	1,554	1,799	123		6,206
RIP Spill				316	1,929	1,929	1,927	1,826	1,892	1,186	32		11,037
Other/Contract				2	21	21	21	16	16	1			98
Total Recorded	0	0	15	10,927	26,486	37,924	37,220	34,225	22,426	8,695	190	0	178,108
Crop CIR			1,011	6,302	17,121	17,775	27,881	22,115	8,739	416	59		101,419
Conservation CIR													1,750

1995	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			2,000	10,100	24,700	33,000	41,400	40,000	24,400	6,200			181,800
Cutter Release													
Total Metered				9,513	20,966	25,960	38,317	30,073	19,163	4,589			148,581
Recorded Waste				423	215	266	369	3,928	4,901	2,466			12,568
RIP Spill				354	2,048	1,966	2,251	2,226	1,892	498			11,235
Other/Contract				3						1			4
Total Recorded	0	0	0	10,293	23,229	28,192	40,937	36,227	25,956	7,554	0	0	172,388
Crop CIR			311	3,530	12,304	18,533	26,943	18,014	7,528	883	52		88,098
Conservation CIR													4,454

NIIP
ANNUAL WATER USE REPORT

1994	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			2,000	12,000	22,000	35,500	41,400	38,300	22,700	7,000			180,900
Cutter Release													
Total Metered				10,585	20,144	30,476	36,249	31,161	18,082	7,762			154,459
Recorded Waste			33	617	421	344	297	596	714	134			3,156
RIP Spill				38	674	1,909	1,753	1,783	2,013	1,534			9,704
Other/Contract				6	10	19	12	16	11	64			138
Total Recorded	0	0	33	11,246	21,249	32,748	38,311	33,556	20,820	9,494	0	0	167,457
Crop CIR			1,213	6,172	12,713	18,674	25,690	20,890	8,810	1,266	53		95,481
Conservation CIR													5,064

1993	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			2,000	13,700	23,300	32,600	39,000	28,300	21,600	6,000			166,500
Cutter Release													
Total Metered				14,022	23,932	36,500	42,139	32,784	23,120	7,554			180,051
Recorded Waste			26	825	968	880	338	675	1,108	1,028			5,848
RIP Spill				509	1,601	1,437	1,860	756	1,561	1,245			8,969
Other/Contract						1	1	3	28	10			43
Total Recorded	0	0	26	15,356	26,501	38,818	44,338	34,218	25,817	9,837	0	0	194,911
Crop CIR			792	5,968	14,432	18,330	26,611	16,868	9,622	1,218	61		93,902
Conservation CIR													1,137

1992	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			2,700	14,800	16,500	26,500	31,800	28,500	17,100	8,400			146,300
Cutter Release			1,623	12,810	15,509	26,783	30,283	27,741	14,247	8,449	135		137,580
Total Metered			90	10,861	14,384	25,023	25,077	24,341	13,629	7,563	3		120,971
Recorded Waste			103	321	266	151	183	166	295	686			2,171
RIP Spill						884	1,846	3,131	2,138	1,710			9,709
Other/Contract				1	0	0	1	2	2	3			9
Total Recorded	0	0	193	11,183	14,650	26,058	27,107	27,640	16,064	9,962	3	0	132,860
Cro[illegible]			1,745	10,473	15,047	1[illegible]	18,959	15,769	8,306	1,083	60		[illegible]8
Cons[illegible]ation CIR													[illegible],045

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1991	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			3,162	11,212	18,400	36,300	26,814	30,200	19,200	7,500			152,788
Cutter Release			2,109	10,307	17,216	24,231	35,736	26,364	14,977	6,968			137,908
Total Metered			188	8,263	15,880	22,984	32,677	26,176	18,327	9,192			133,687
Recorded Waste			386	442	319	282	258	890	241	258			3,076
Other/Contract									276	18			294
Total Recorded	0	0	574	8,705	16,199	23,266	32,935	27,066	18,844	9,468	0	0	137,057
Crop CIR			600	3,698	12,144	13,344	21,340	17,642	7,546	1,399	50		77,763
Conservation CIR													1,203

1990	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			3,423	14,393	17,454	32,533	30,945	26,526	12,056	5,658			142,988
Cutter Release			2,709	11,898	16,172	32,499	31,031	22,975	11,603	4,600			133,487
Total Metered			474	11,361	16,643	27,446	29,312	23,343	13,473	4,241	859		127,152
Recorded Waste			187	387	691	337	339	373	217	296			2,827
Other/Contract													
Total Recorded	0	0	661	11,748	17,334	27,783	29,651	23,716	13,690	4,537	859	0	129,979
Crop CIR			619	4,773	10,165	16,043	21,214	15,778	7,778	1,017	88		77,475
Conservation CIR													4,963

1989	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			5,526	16,436	25,349	35,094	33,160	28,784	16,273	10,034			170,656
Cutter Release			4,396	15,737	23,392	35,335	33,580	28,637	15,261	7,951	495		164,784
Total Metered			1,941	14,220	21,113	30,404	31,676	29,769	17,669	8,821	584		156,197
Recorded Waste			114	199	569	262	327	307	421	528	450		3,177
Other/Contract													
Total Recorded	0	0	2,055	14,419	21,682	30,666	32,003	30,076	18,090	9,349	1,034	0	159,374
Crop CIR			1,984	7,635	14,451	16,134	20,706	15,487	9,534	1,251	129		87,311
Conservation CIR													5,067

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1988	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			1,482	11,415	17,784	25,324	29,597	20,809	13,653	8,671	133		128,868
Cutter Release				11,164	14,071	21,411	29,564	18,514	12,857	10,257			117,838
Total Metered				8,378	14,147	20,951	24,924	17,670	12,392	10,002	1,500		109,964
Recorded Waste				433	81	214	164	1,425	2,551	104	6		4,978
Other/Contract													
Total Recorded	0	0	0	8,811	14,228	21,165	25,088	19,095	14,943	10,106	1,506	0	114,942
Crop CIR			331	2,691	8,860	14,284	19,500	12,006	7,742	1,863	124		67,401
Conservation CIR													7,272

1987	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			1,791	9,048	16,439	27,979	33,240	25,252	12,662	4,117			130,528
Cutter Release			1,799	8,729	15,631	27,089	32,170	24,509	12,744	4,565			127,236
Total Metered				8,328	12,266	22,350	23,627	22,573	12,211	5,028	551		106,934
Recorded Waste				208	2,997	523	133	766	531	194	6		5,358
Other/Contract													
Total Recorded	0	0	0	8,536	15,263	22,873	23,760	23,339	12,742	5,222	557	0	112,292
Crop CIR			0	2,669	8,201	15,396	21,354	13,578	7,002	1,277	0		69,477
Conservation CIR													5,376

1986	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			8,440	16,423	19,278	25,202	17,195	29,186	7,300	1,766			124,790
Cutter Release													0
Total Metered			2,823	9,597	15,054	20,816	18,747	21,727	8,892	3,137			100,793
Recorded Waste			1,405	151	445	867	1,024	1,372	633	1,289			7,186
Other/Contract													7,186
Total Recorded	0	0	4,228	9,748	15,499	21,683	19,771	23,099	9,525	4,426	0	0	107,979
Crop CIR			363	3,082	10,732	12,364	10,696	12,364	3,952	653	0		54,206
Conservation CIR													4,123

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1985	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			3,675	7,927	15,212	29,216	32,629	26,441	14,990	1,725			131,815
Cutter Release													0
Total Metered				6,631	11,381	21,055	30,988	21,460	14,272	4,369			110,156
Recorded Waste				244	199	447	672	531	306	1,115			3,514
Other/Contract													
Total Recorded	0	0	0	6,875	11,580	21,502	31,660	21,991	14,578	5,484	0	0	113,670
Crop CIR			73	2,799	11,740	17,264	18,209	15,229	5,743	618	0		71,675
Conservation CIR													1,061

1984	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			2,006	5,454	22,351	29,207	29,060	21,460	13,670	4,250			127,458
Cutter Release													0
Total Metered				2,221	18,112	27,881	24,575	20,511	11,196	5,558			110,054
Recorded Waste				466	138	100	71	151	41	349			1,316
Other/Contract													
Total Recorded	0	0	0	2,687	18,250	27,981	24,646	20,662	11,237	5,907	0	0	111,370
Crop CIR			190	2,180	12,667	14,120	17,184	12,888	6,570	569	0		66,368
Conservation CIR													982

1983	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release				6,155	16,395	22,550	32,876	29,750	19,047	1,750			128,523
Cutter Release													0
Total Metered				2,119	12,200	20,711	25,150	21,426	16,701	3,604			101,911
Recorded Waste				358	138	244	261	28	67	6			1,102
Other/Contract													
Total Recorded	0	0	0	2,477	12,338	20,955	25,411	21,454	16,768	3,610	0	0	103,013
Crop CIR			72	1,509	10,206	14,339	18,796	16,100	6,613	1,078	72		68,785
Conservation CIR													1,005

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1982	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			3,822	5,559	11,213	26,226	30,392	24,620	10,429	2,567			114,828
Cutter Release													0
Total Metered				3,841	8,158	22,574	24,453	21,273	29,109	3,586			112,994
Recorded Waste					21	40	12	18	22	41			154
Other/Contract													
Total Recorded	0	0	0	3,841	8,179	22,614	24,465	21,291	29,131	3,627	0	0	113,148
Crop CIR			121	2,815	10,898	18,177	20,952	13,432	6,434	1,448	80		74,357
Conservation CIR													0

1981	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release				4,915	11,886	19,531	22,479	22,144	10,510	55			91,520
Cutter Release													0
Total Metered				3,684	11,541	17,914	20,014	19,553	10,561	1,347			84,614
Recorded Waste				262	94	10	52	2,283		58			2,759
Other/Contract													0
Total Recorded	0	0	0	3,946	11,635	17,924	20,066	21,836	10,561	1,405	0	0	87,373
Crop CIR			29	3,829	8,365	14,610	15,612	14,198	6,274	795	0		63,712
Conservation CIR													0

1980	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release				7,431	17,635	19,415	15,452	19,960	18,827	10,832			109,552
Cutter Release													0
Total Metered				7,410	16,851	16,312	12,436	18,723	17,155	11,008			99,895
Recorded Waste				60	46	25	68	55	38	597			889
Other/Contract													0
Total Recorded	0	0	0	7,470	16,897	16,337	12,504	18,778	17,193	11,605	0	0	100,784
Crop CIR			153	2,388	10,011	16,103	20,297	13,317	5,970	918	0		69,157
Conservation CIR													0

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1979	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release				4,631	9,395	9,920	12,025	14,037	16,307	9,394			75,709
Cutter Release													0
Total Metered				3,302	8,533	9,235	11,443	12,259	17,564	12,133			74,469
Recorded Waste				77	67	12	18	21					195
Other/Contract				8	42	45	52	90	38	32			307
Total Recorded	0	0	0	3,387	8,642	9,292	11,513	12,370	17,602	12,165	0	0	74,971
Crop CIR			112	2,192	6,778	10,267	11,789	10,357	5,883	649	0		48,027
Conservation CIR													0

1978	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			746	4,514	5,420	11,003	5,710	9,152	9,024	4,206			49,775
Cutter Release													0
Total Metered				3,980	4,930	10,275	7,010	8,624	8,164	4,088			47,071
Recorded Waste							2			40			42
Other/Contract				18	23	20	24	52	186	70			393
Total Recorded	0	0	0	3,998	4,953	10,295	7,036	8,676	8,350	4,198	0	0	47,506
Crop CIR			0	1,655	4,245	7,493	9,531	7,233	2,636	429	0		33,222
Conservation CIR													0

1977	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release			306	2,770	4,423	8,142	5,973	6,509	8,123	1,279			37,525
Cutter Release													0
Total Metered				2,197	4,556	6,718	6,074	5,459	7,380	2,452			34,836
Recorded Waste					2								2
Other/Contract				86	47	63	59	49	38	24			366
Total Recorded	0	0	0	2,283	4,605	6,781	6,133	5,508	7,418	2,476	0	0	35,204
Crop CIR			114	1,785	4,545	7,140	7,723	5,824	3,355	329	0		30,815
Conservation CIR													0

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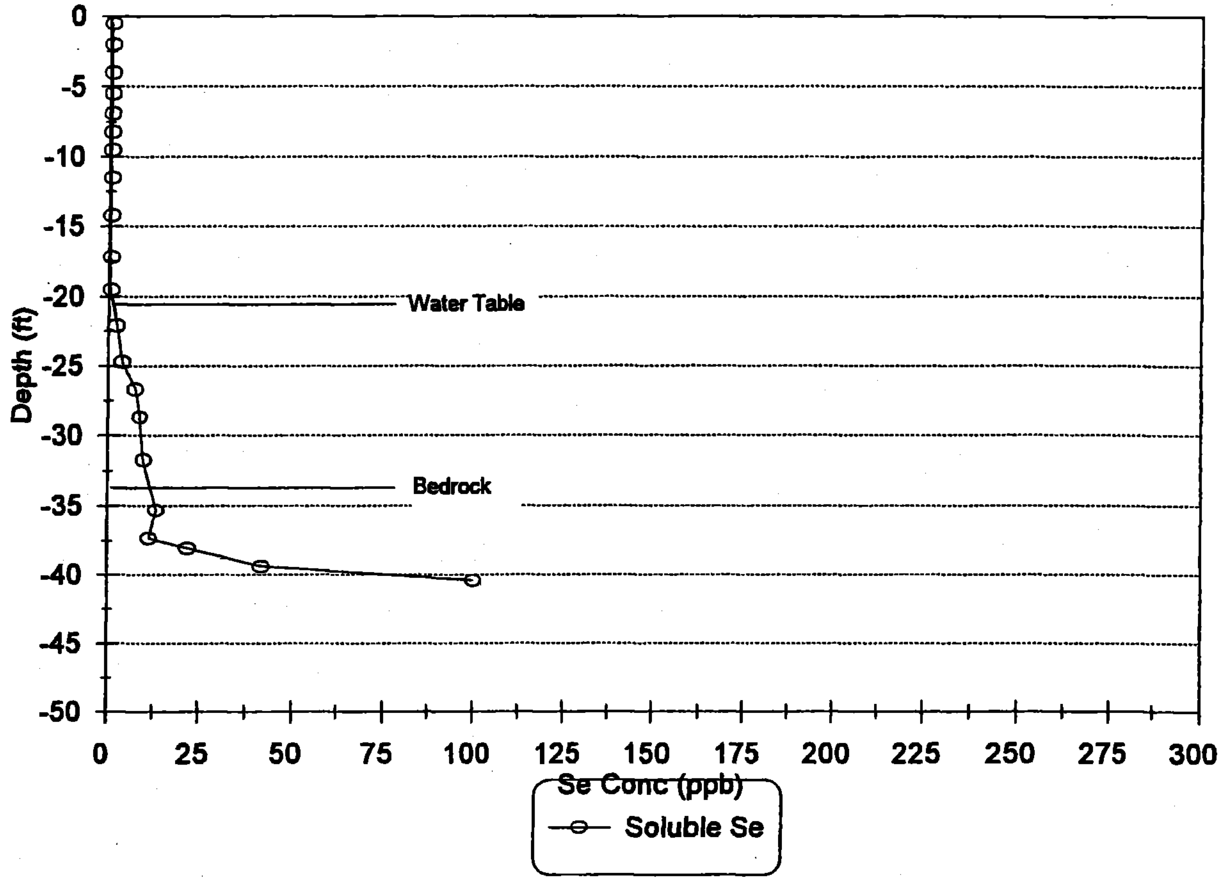
1976	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Navajo Release	83	56	2,011	2,558	3,401	7,013	8,330	4,518	5,553	1,544			35,067
Cutter Release													0
Total Metered			600	3,742	3,018	5,499	7,303	4,750	3,999	2,338			31,249
Recorded Waste			50	50	50	50	50	50	75				375
Other/Contract													0
Total Recorded	0	0	650	3,792	3,068	5,549	7,353	4,800	4,074	2,338	0	0	31,624
Crop CIR			67	946	2,662	3,904	4,451	3,674	1,390	200	0		17,294
Conservation CIR													0

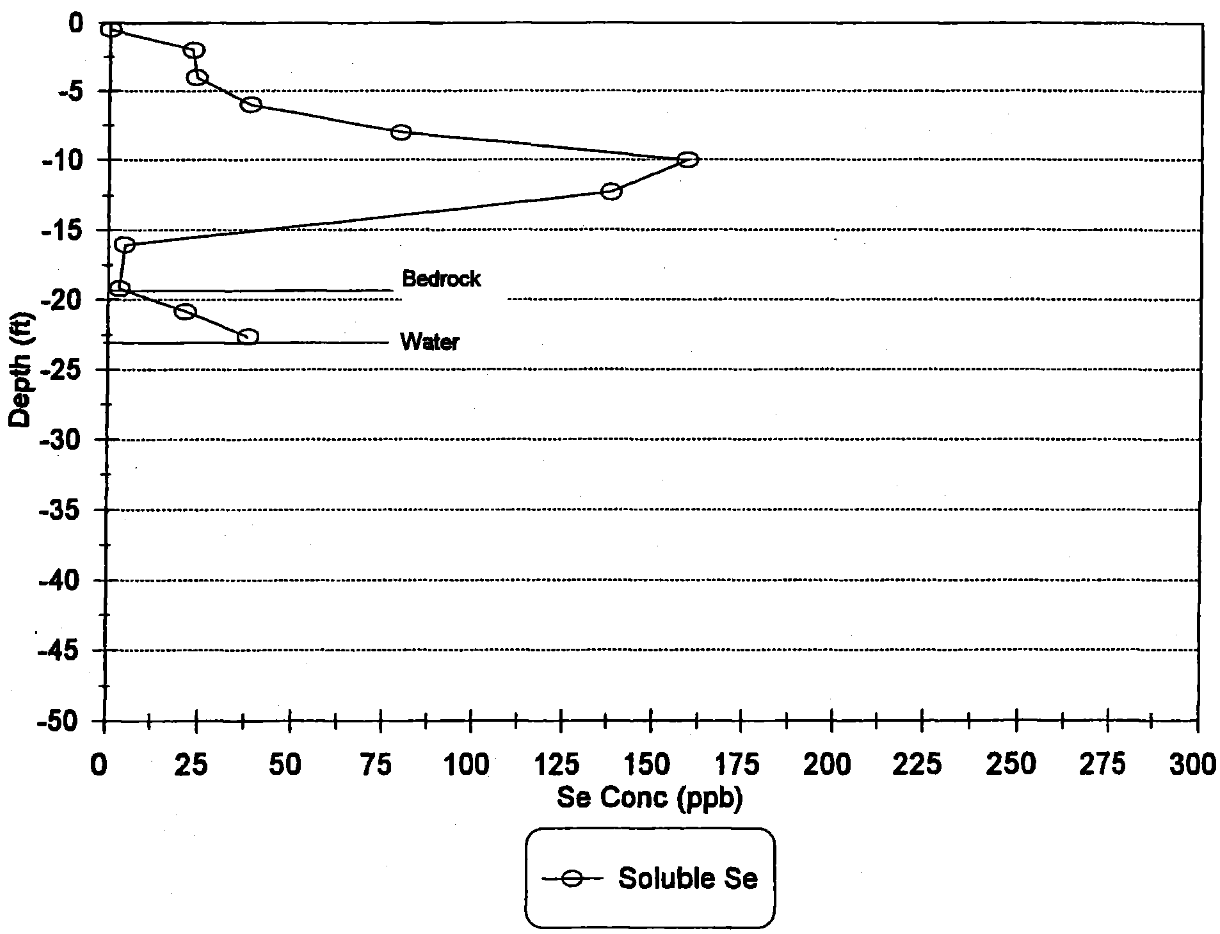
APPENDIX B

DETAILED WATER QUALITY DATA

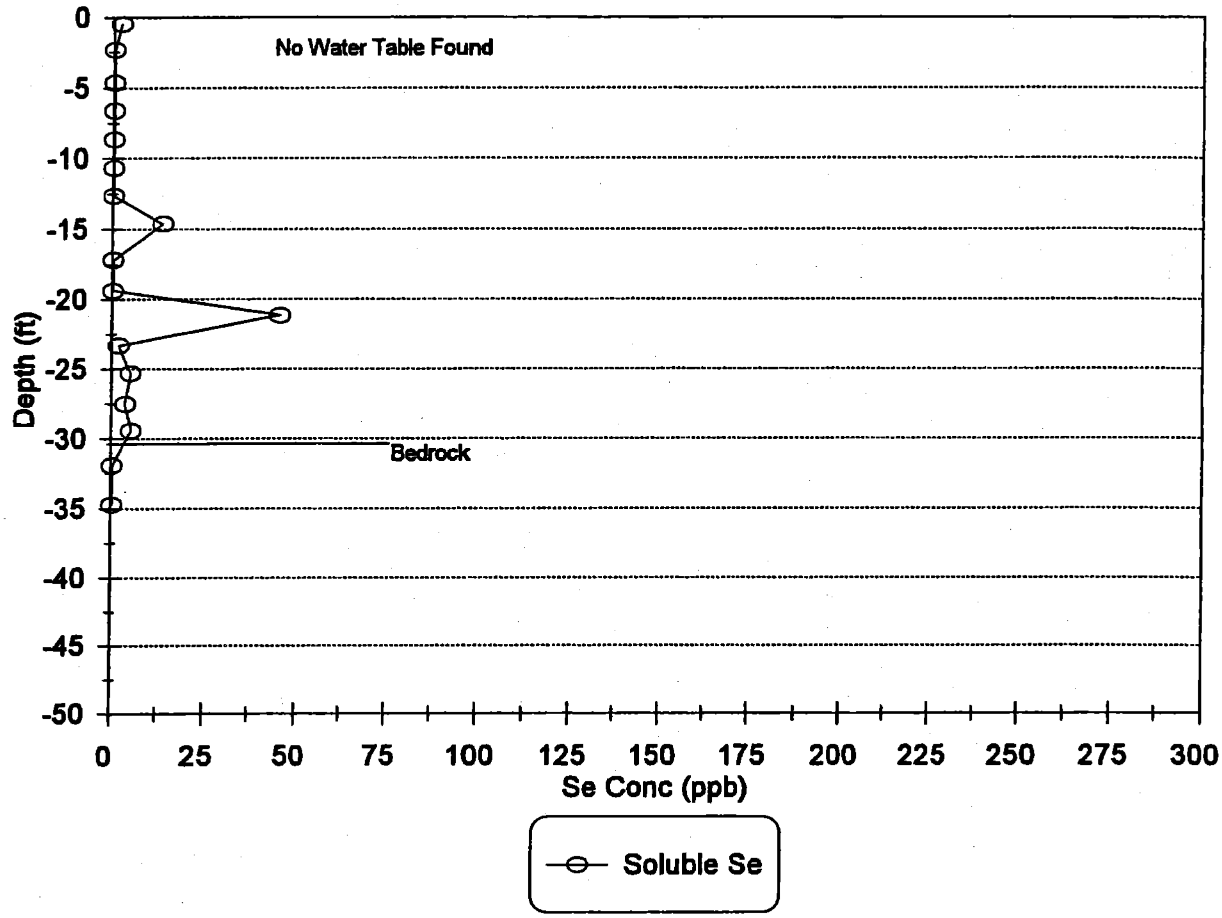
DH-01-35-I (14 years)



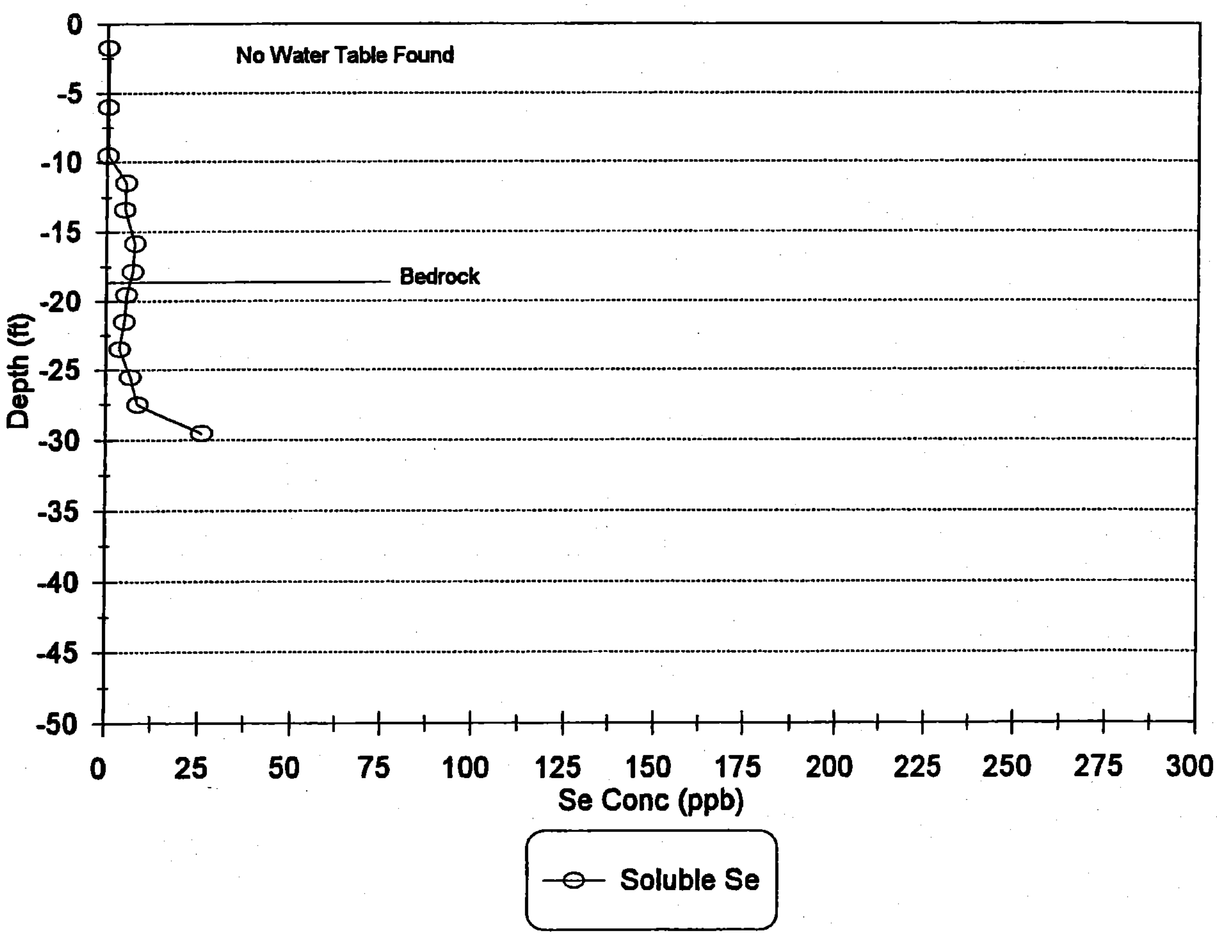
DH-01-35-O

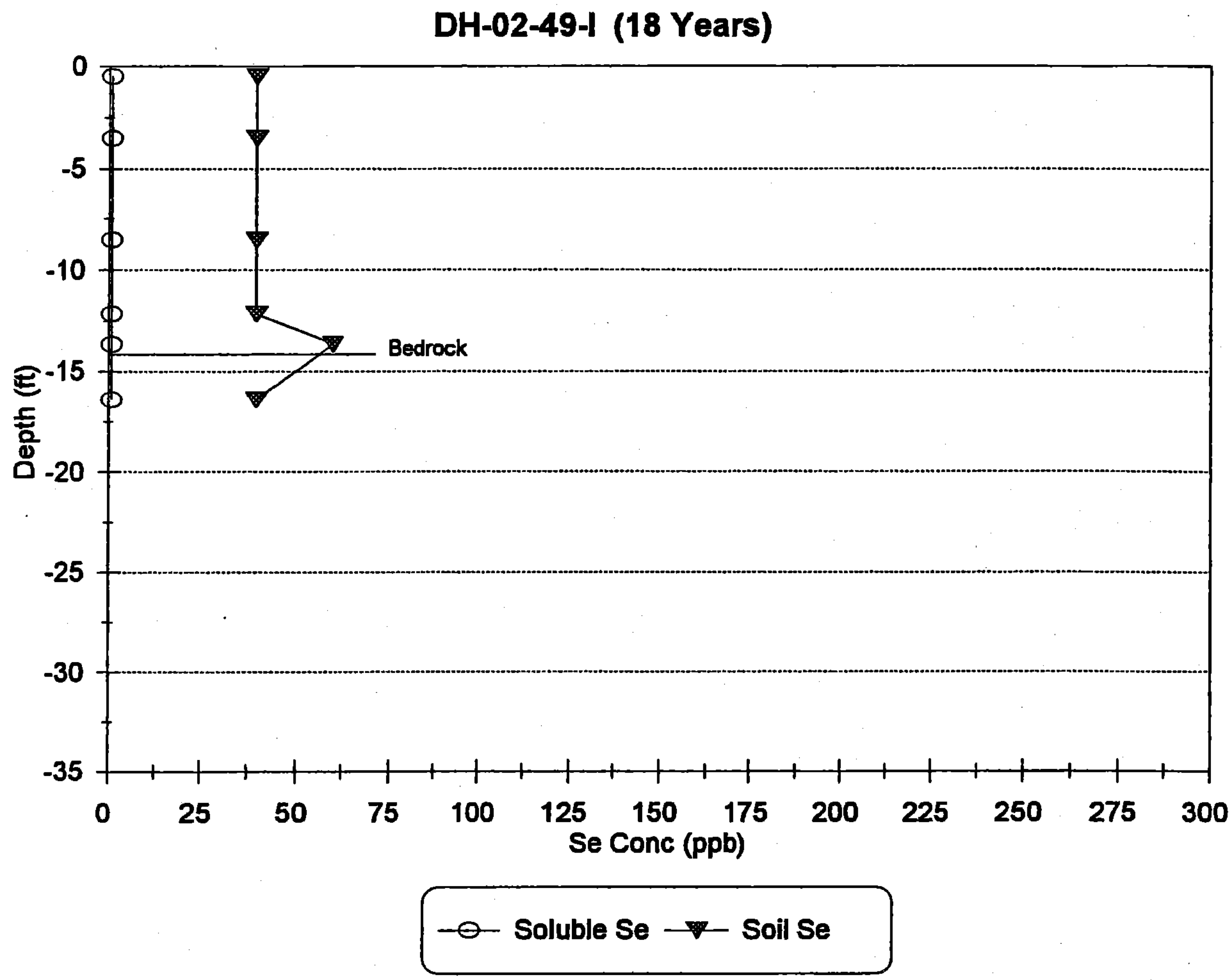


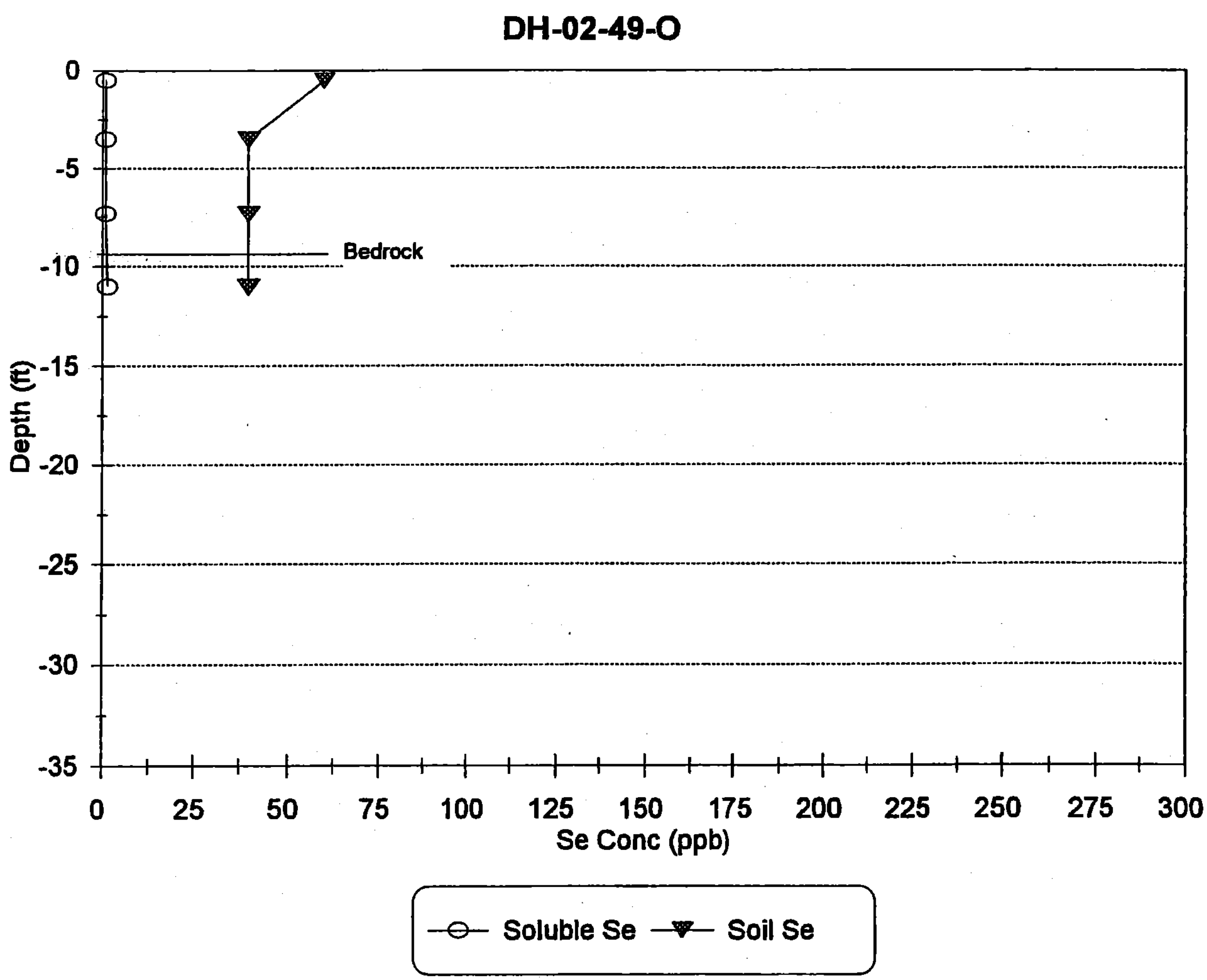
DH-01-41-I (14 years)

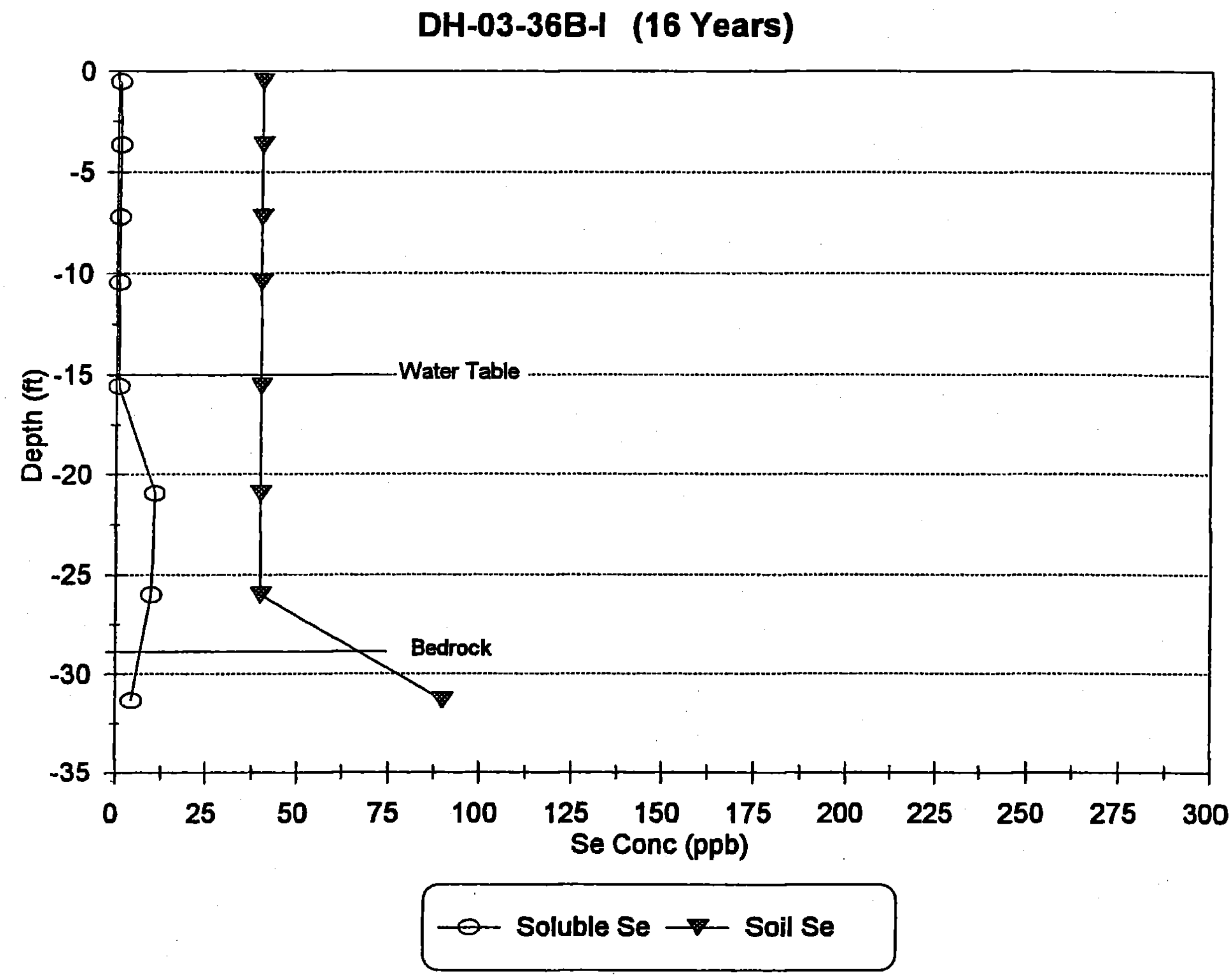


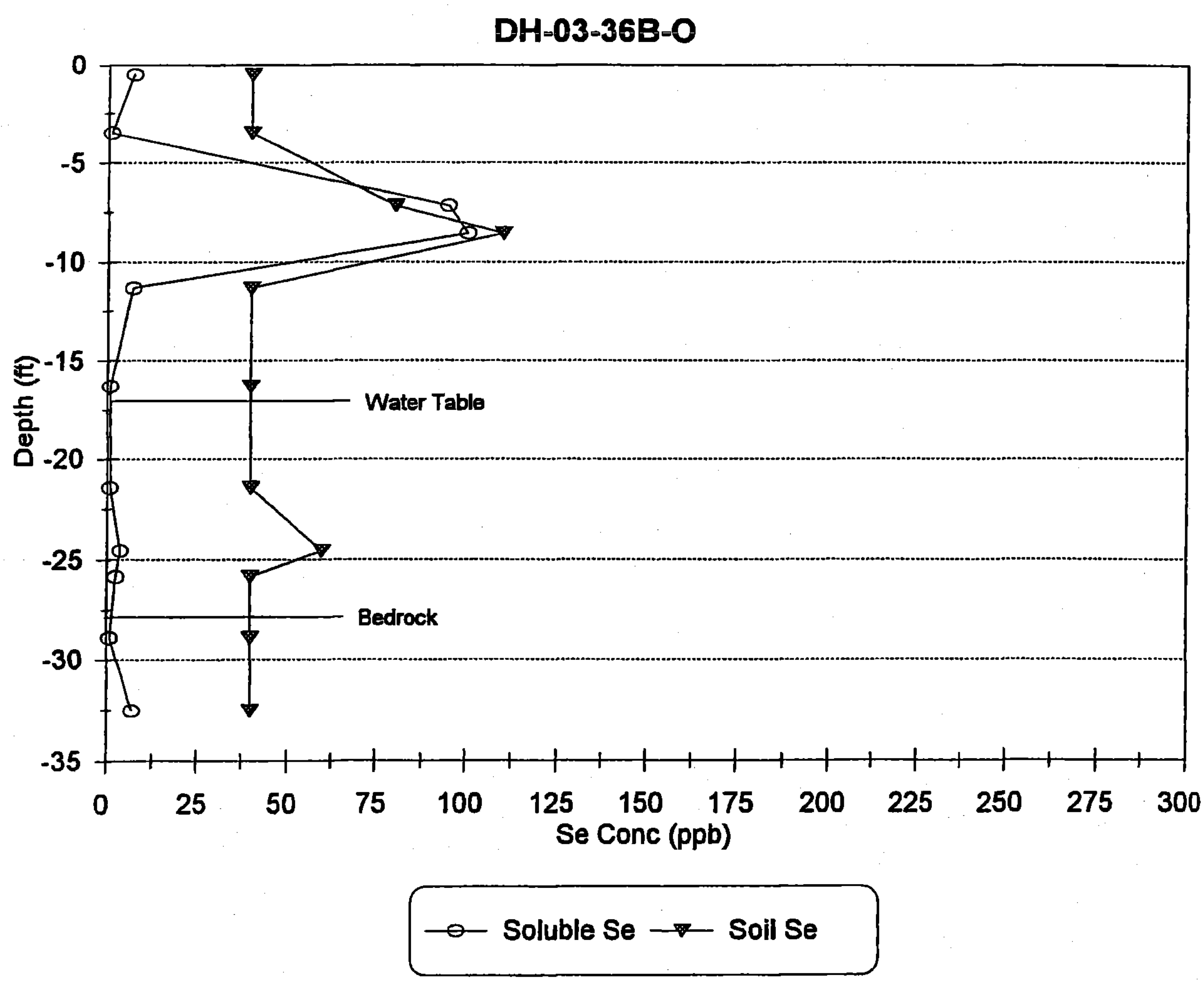
DH-01-41-O



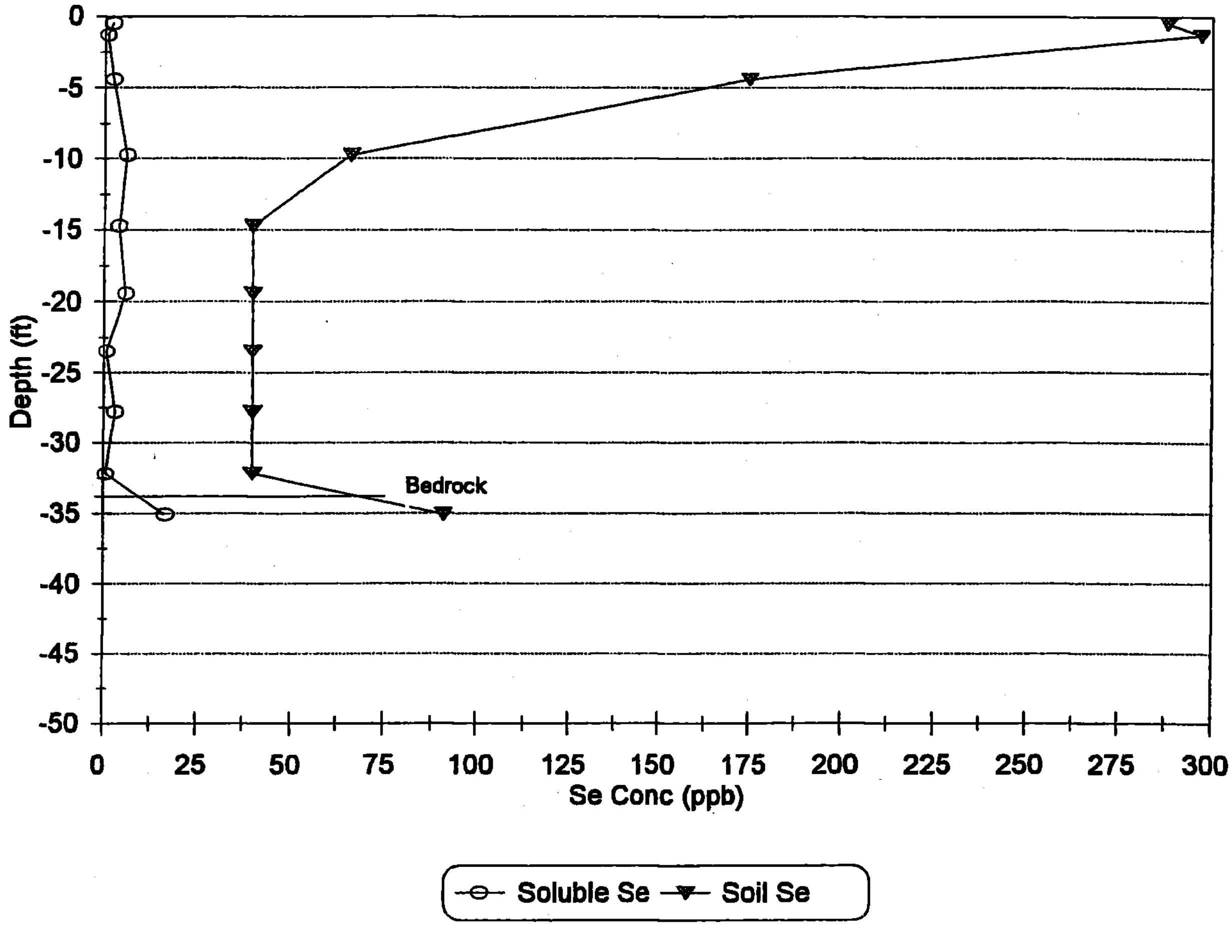

DH-02-49-I (18 Years)
Bedrock
Depth (ft)
0
-5
-10
-15
-20
-25
-30
-35
0 25 50 75 100 125 150 175 200 225 250 275 300
Se Conc (ppb)
Soluble Se
Soil Se


DH-02-49-O
Bedrock
Depth (ft)
0
-5
-10
-15
-20
-25
-30
-35
0 25 50 75 100 125 150 175 200 225 250 275 300
Se Conc (ppb)
Soluble Se
Soil Se

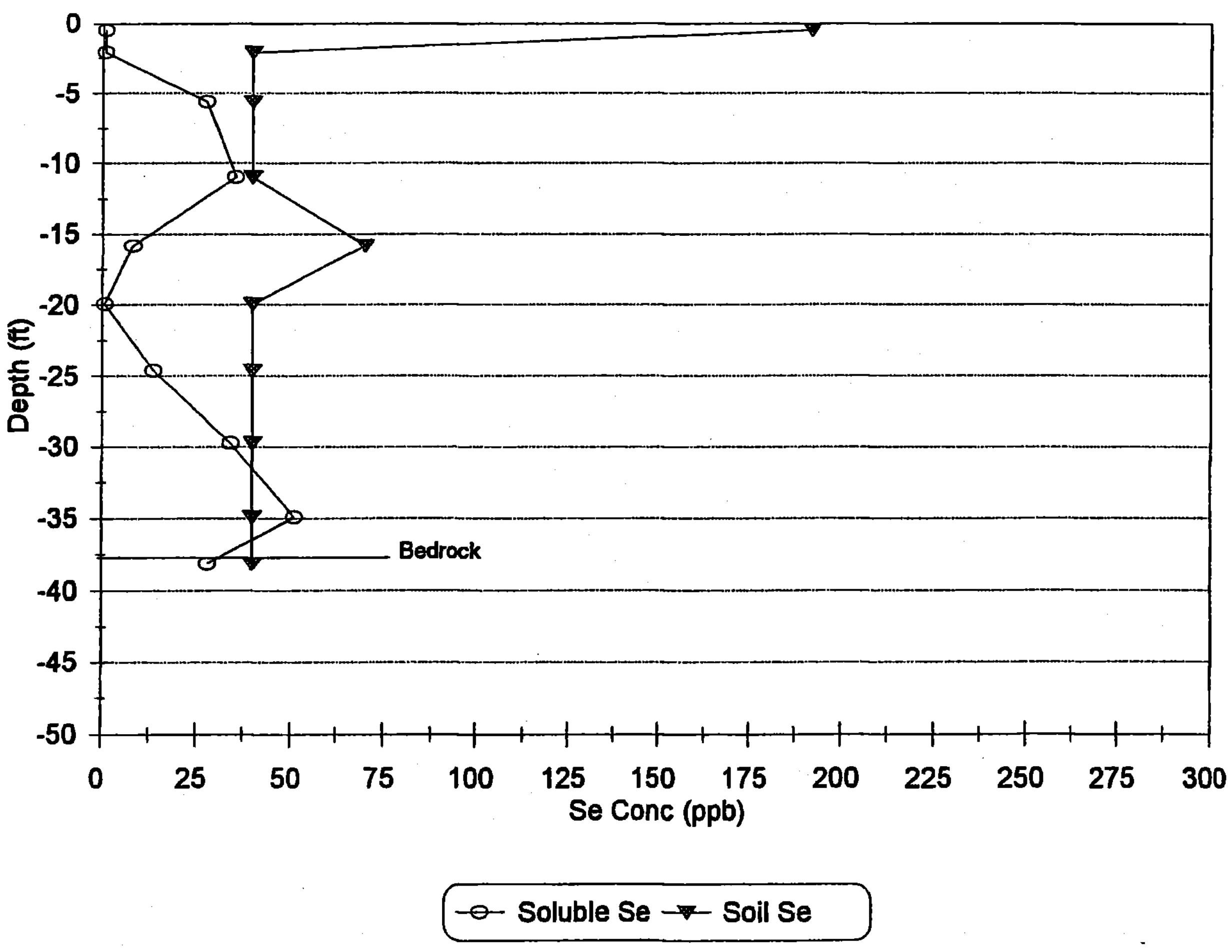

DH-03-36B-I (16 Years)
Depth (ft)
0
-5
-10
-15
-20
-25
-30
-35
Water Table
Bedrock
0
25
50
75
100
125
150
175
200
225
250
275
300
Se Conc (ppb)
Soluble Se
Soil Se


DH-03-36B-O
Depth (ft)
0
-5
-10
-15
-20
-25
-30
-35
Water Table
Bedrock
0
25
50
75
100
125
150
175
200
225
250
275
300
Se Conc (ppb)
Soluble Se
Soil Se

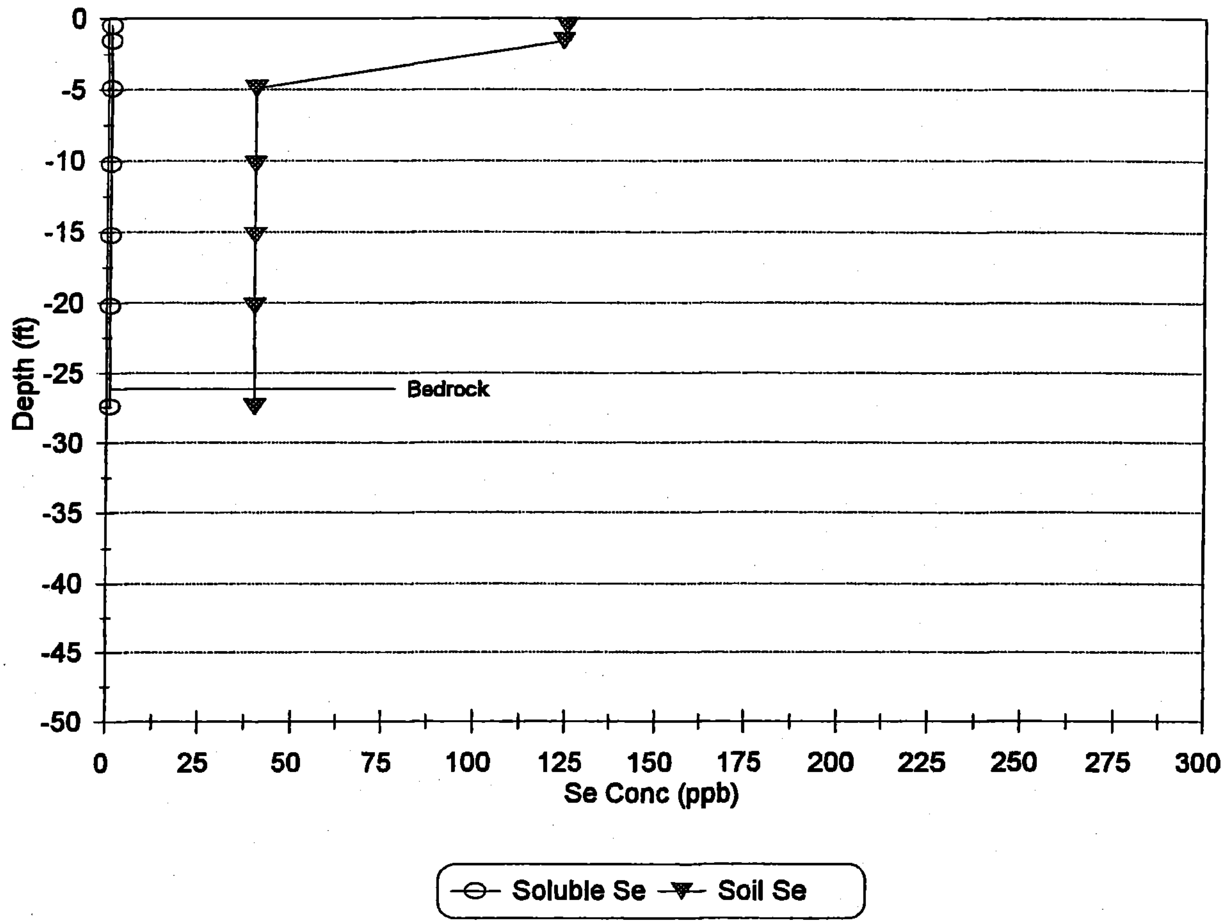
DH-04-11B-I (14 Years)



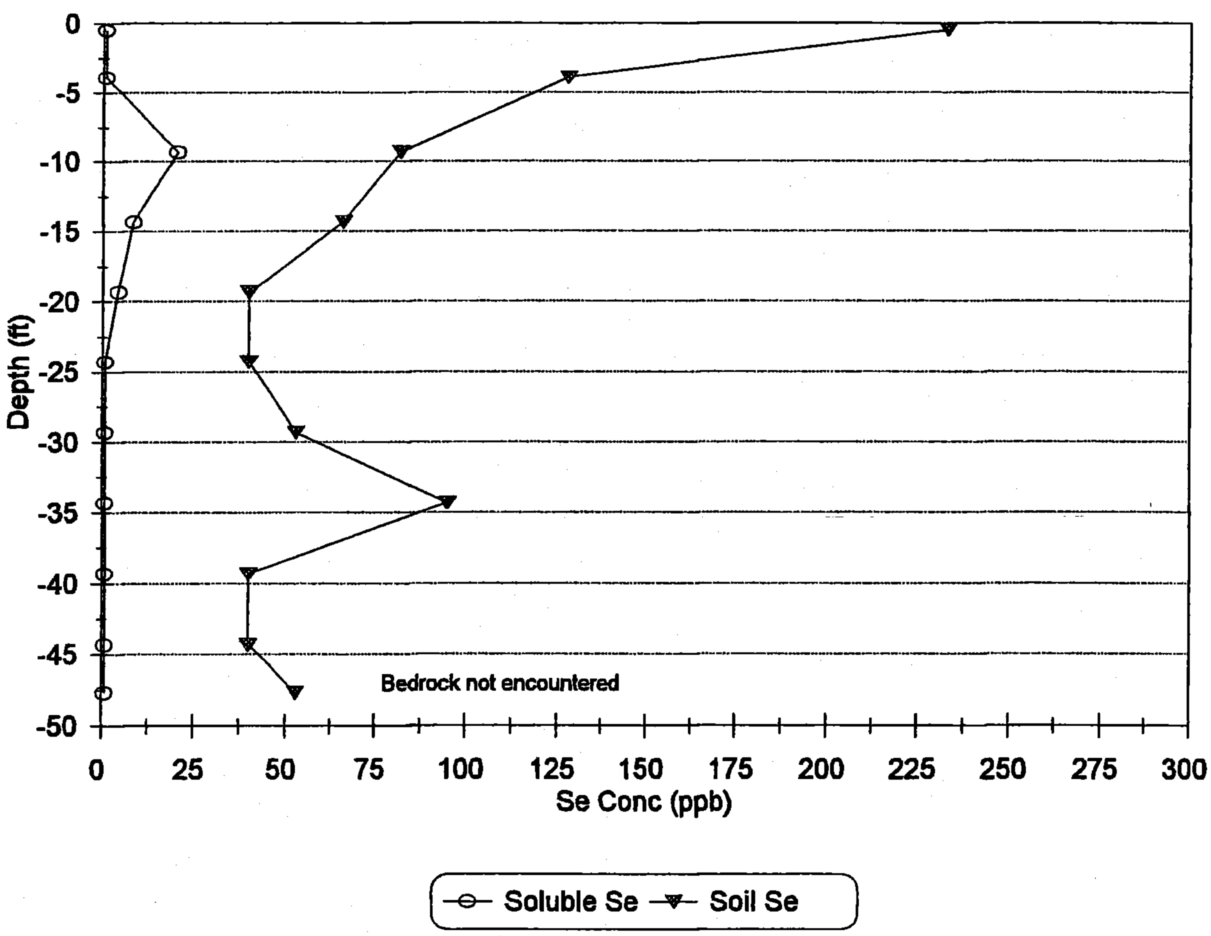
DH-04-11B-O



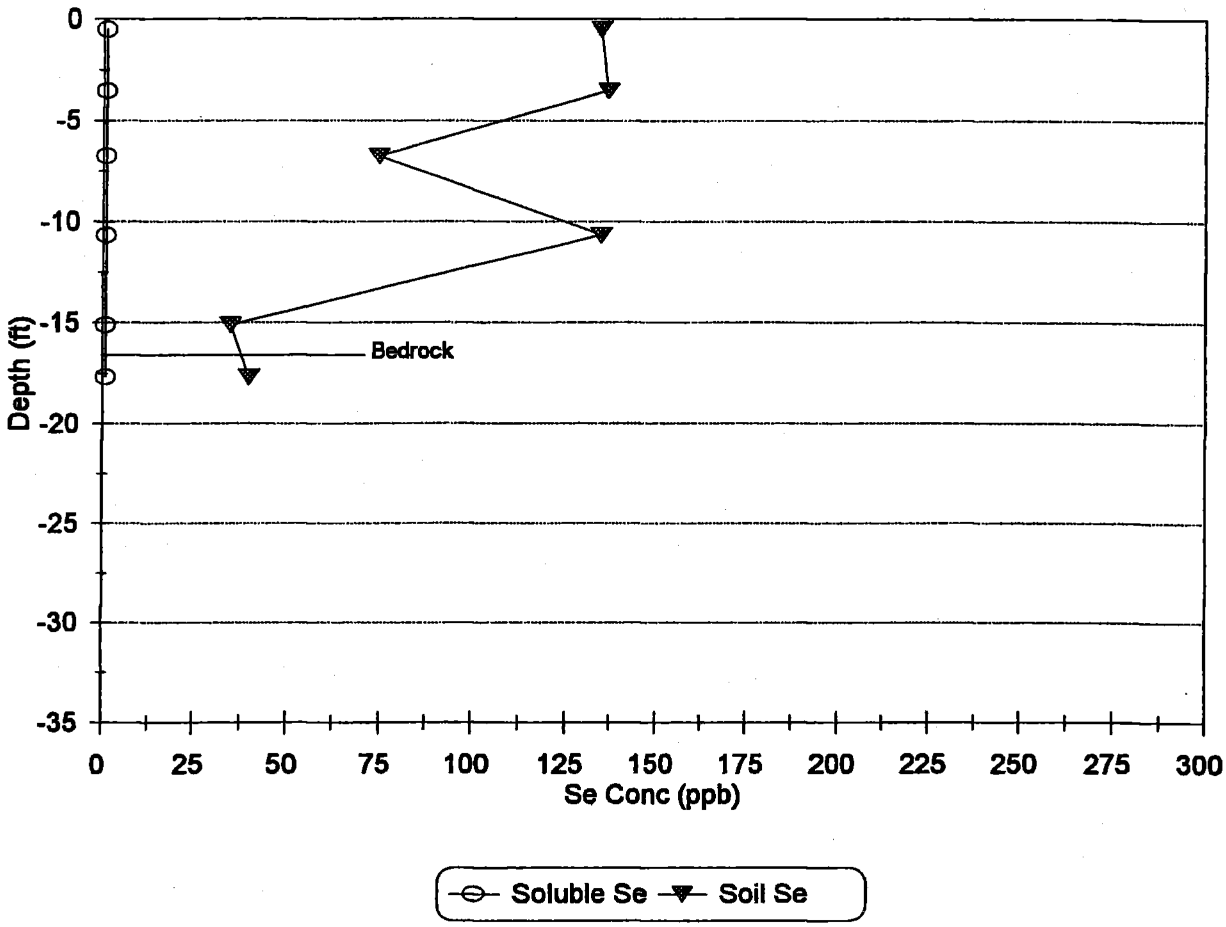
DH-05-34B-I (13 Years)



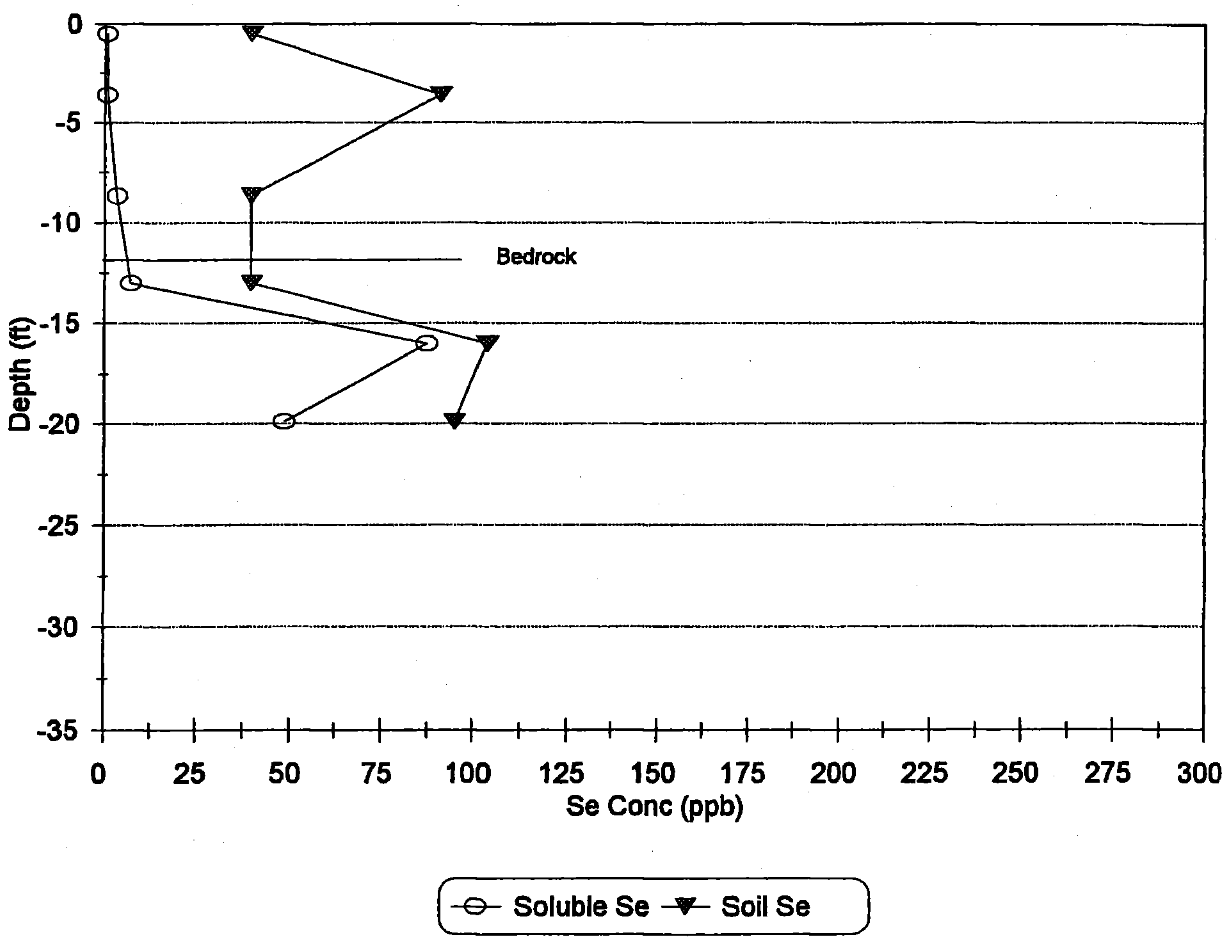
DH-05-43B-O

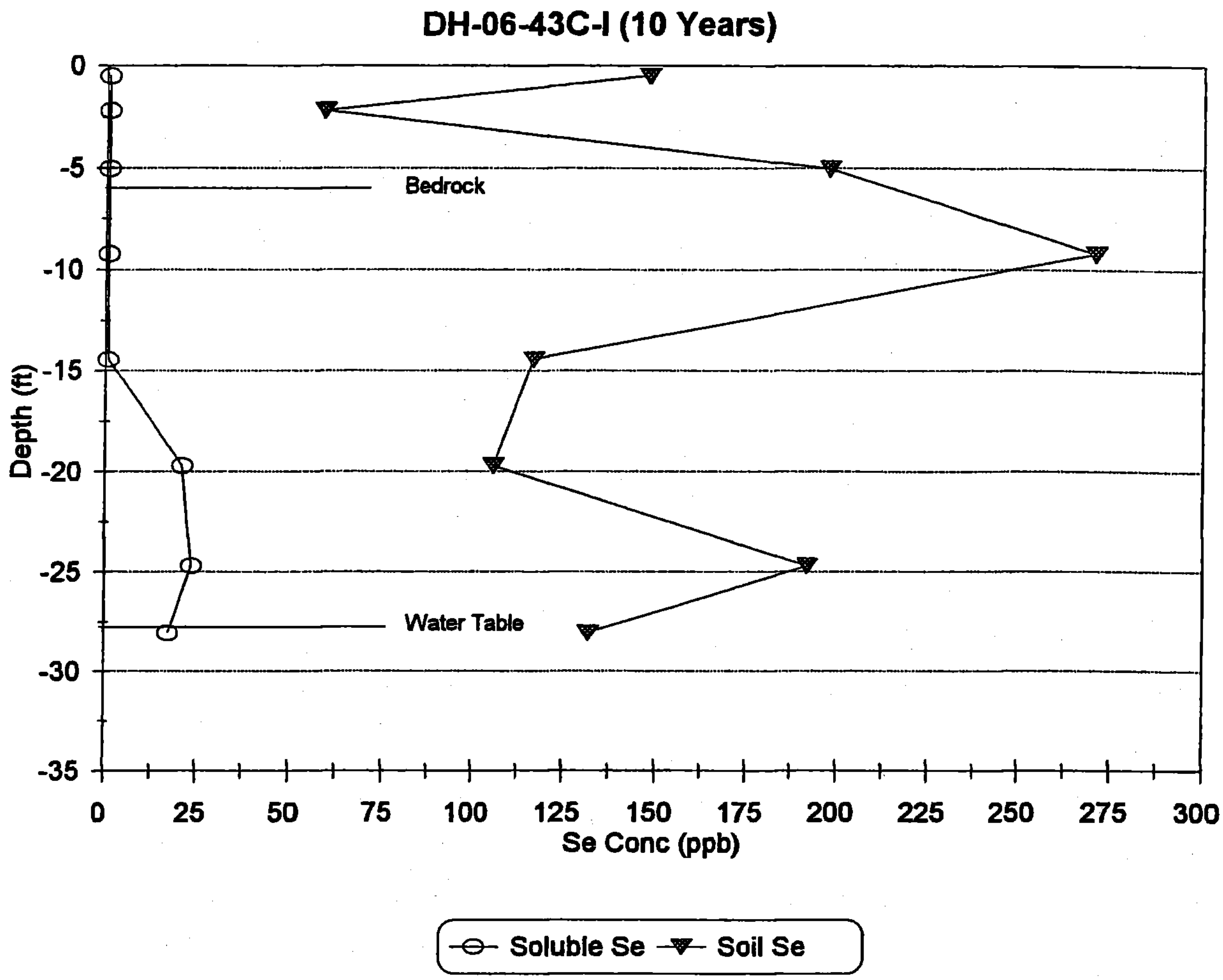


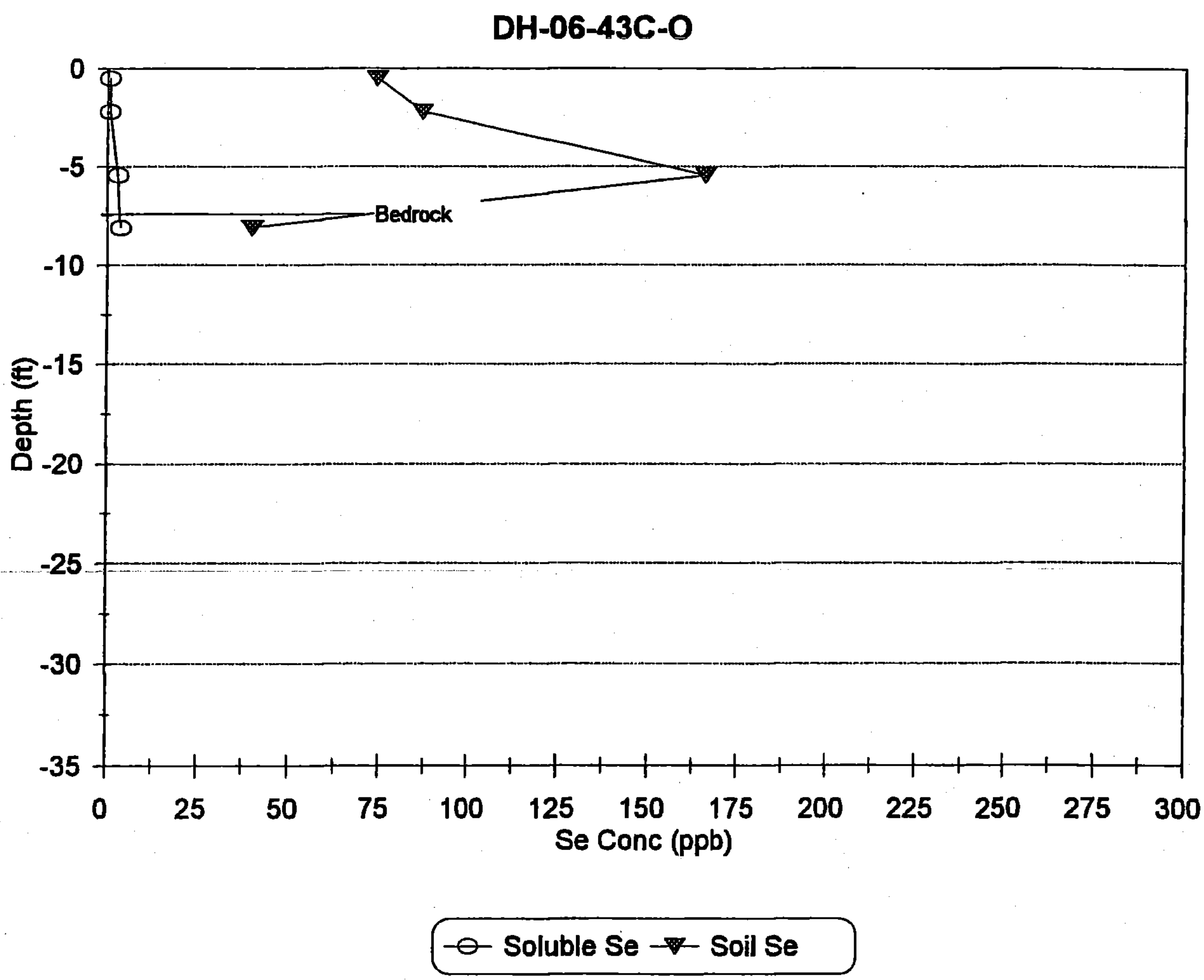
DH-06-19A-I (8 Years)

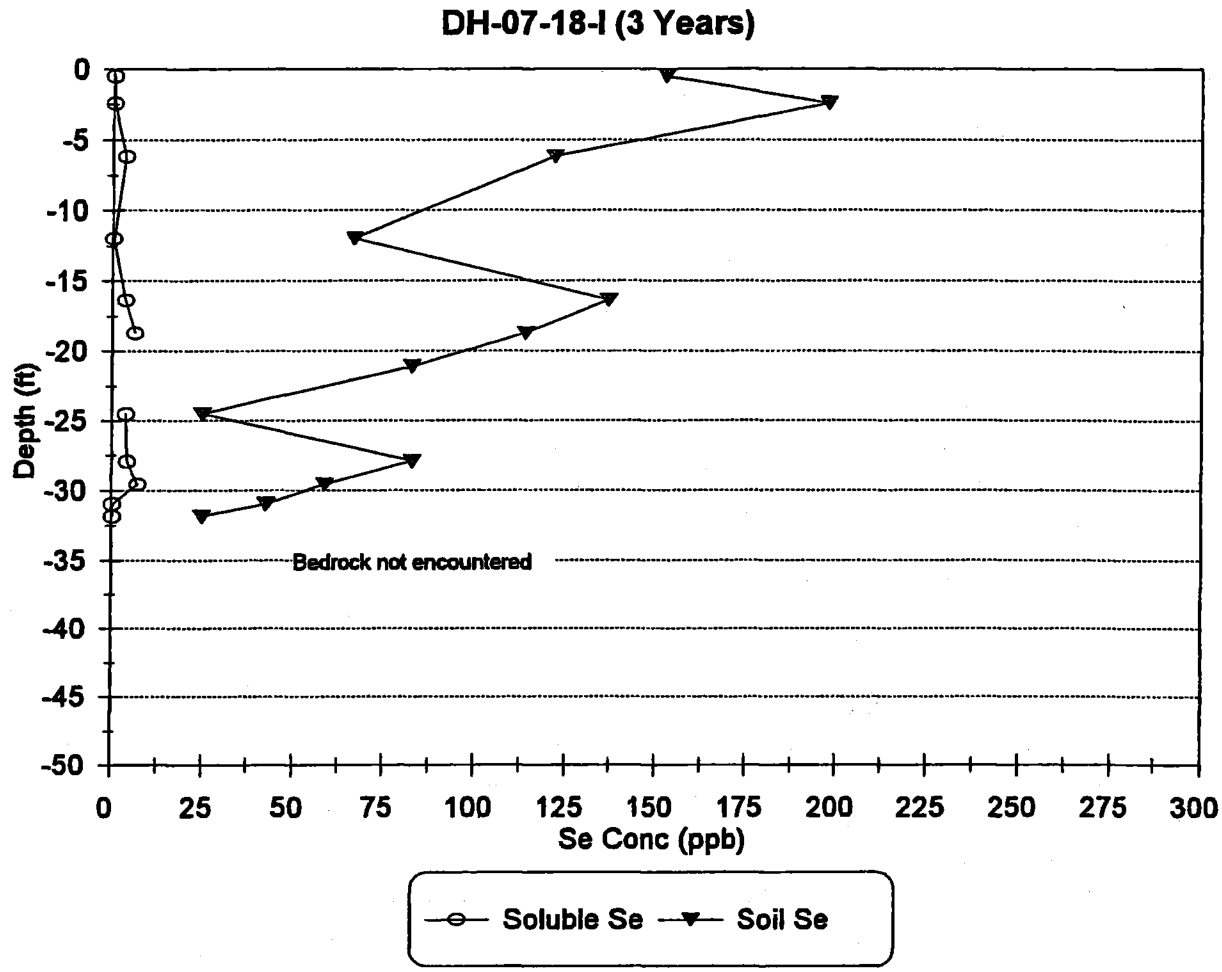


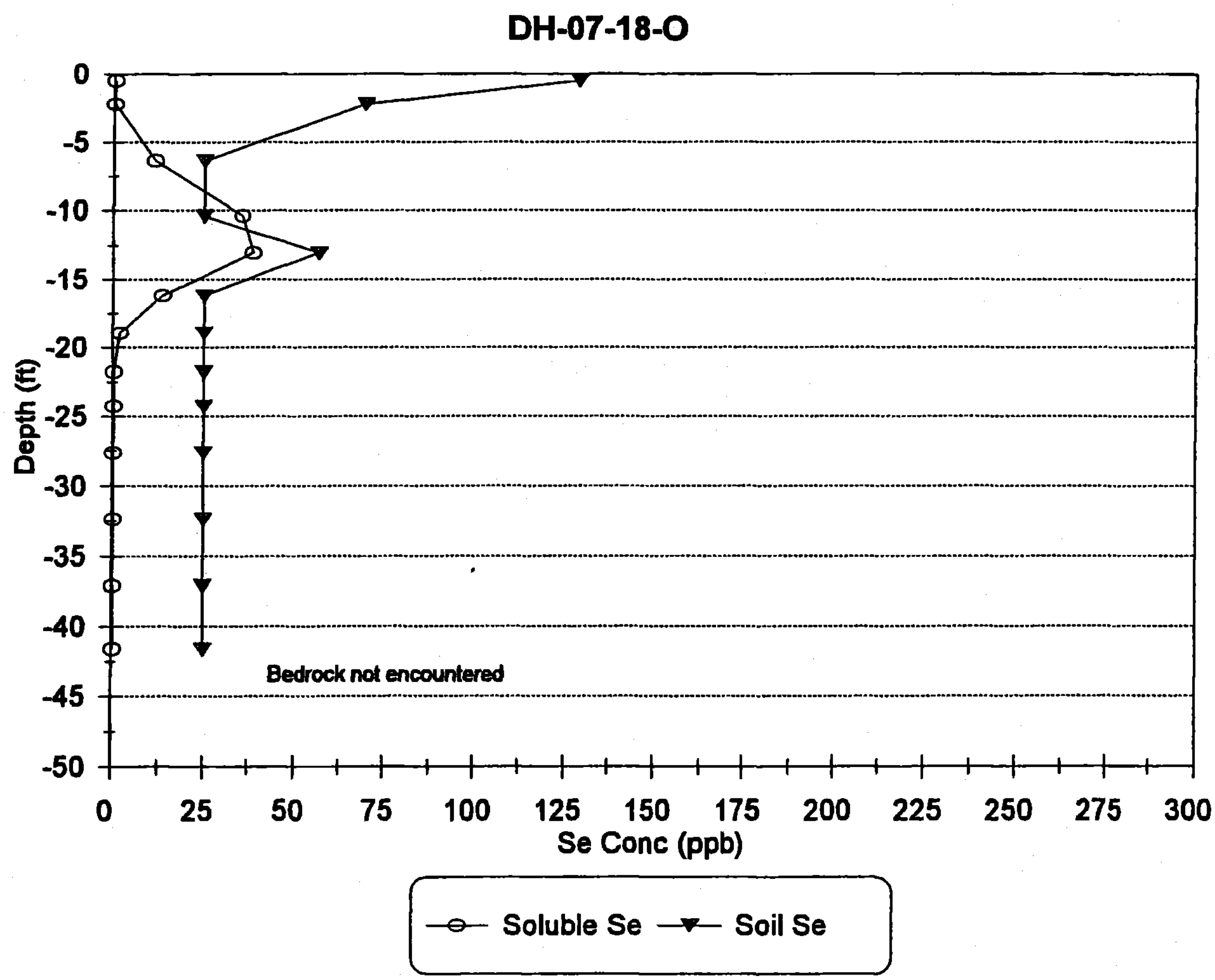
DH-06-19A-O

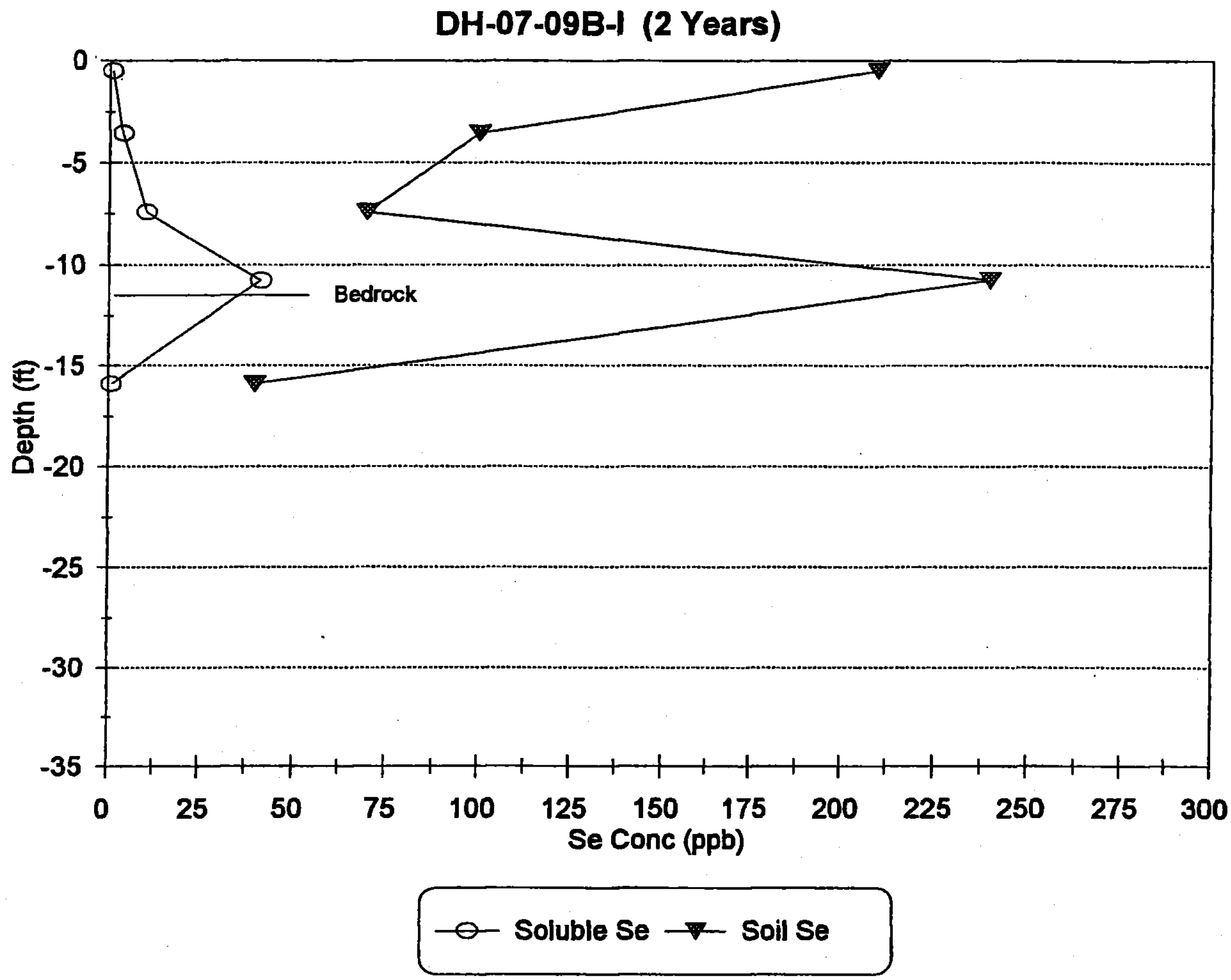



DH-06-43C-I (10 Years)
Depth (ft)
0
-5
-10
-15
-20
-25
-30
-35
Bedrock
Water Table
0 25 50 75 100 125 150 175 200 225 250 275 300
Se Conc (ppb)
Soluble Se
Soil Se

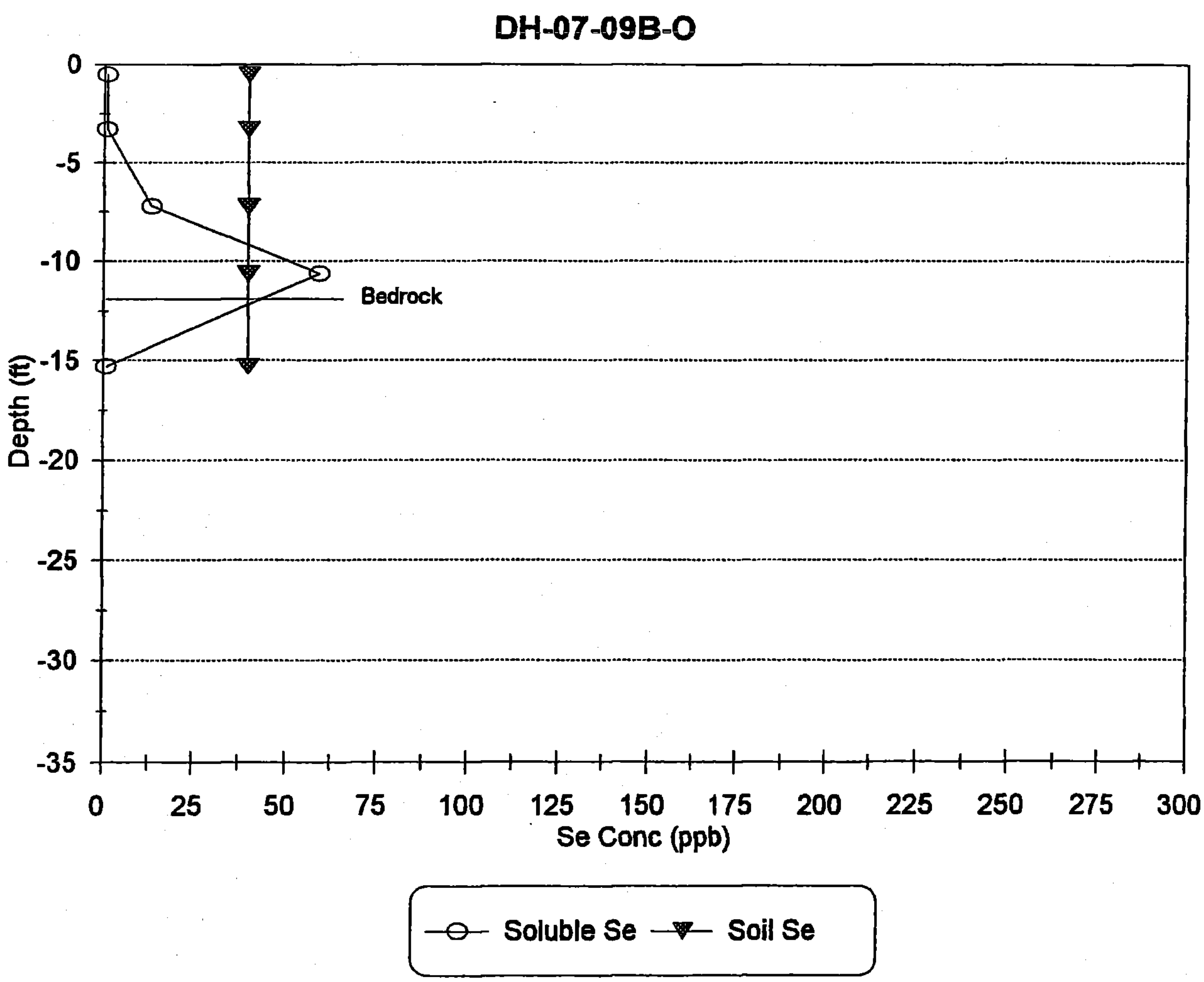

DH-06-43C-O
Depth (ft)
0
-5
-10
-15
-20
-25
-30
-35
Bedrock
0 25 50 75 100 125 150 175 200 225 250 275 300
Se Conc (ppb)
Soluble Se
Soil Se


DH-07-18-I (3 Years)
Depth (ft)
Se Conc (ppb)
Bedrock not encountered
Soluble Se
Soil Se

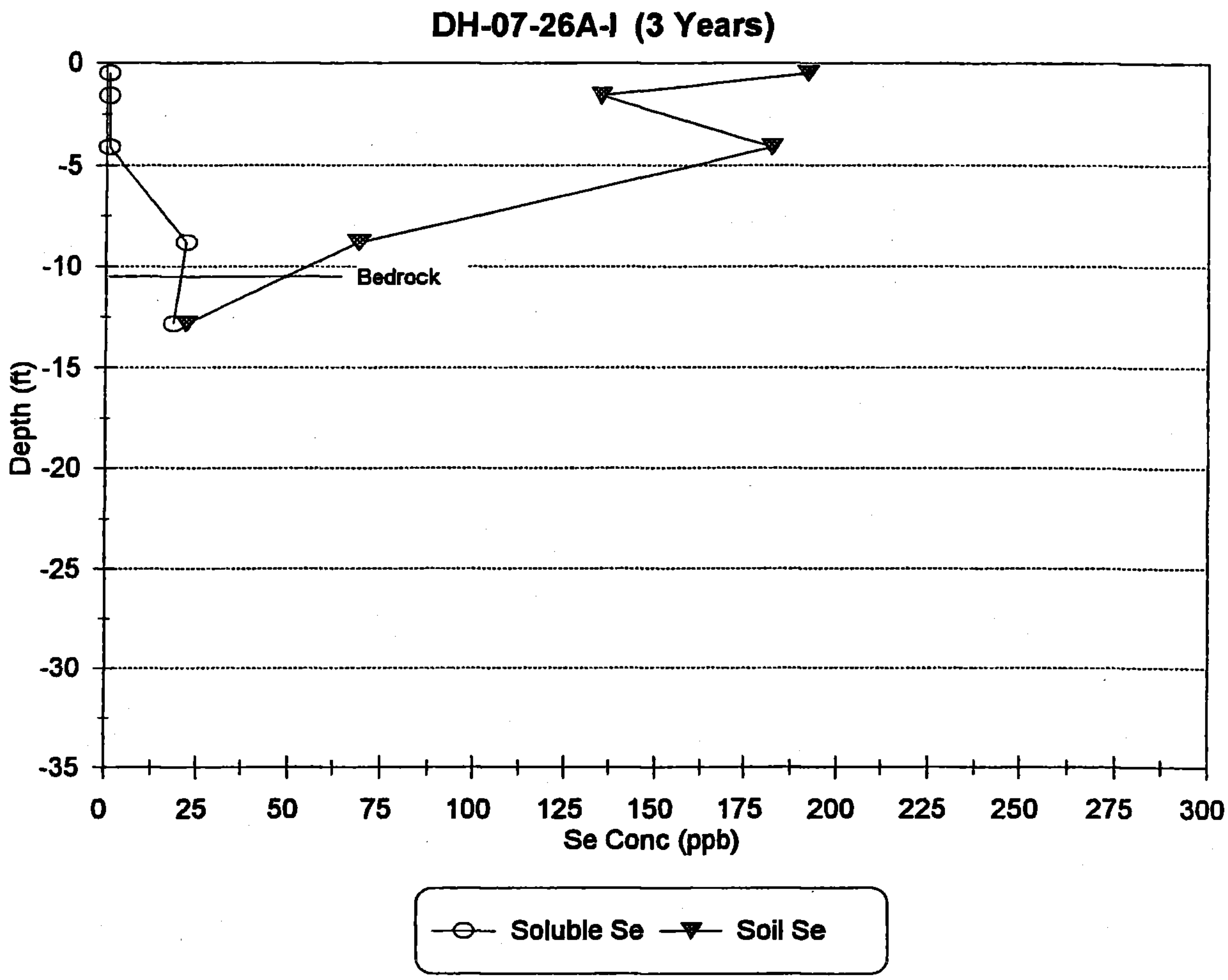

DH-07-18-O
Depth (ft)
Se Conc (ppb)
Bedrock not encountered
Soluble Se
Soil Se

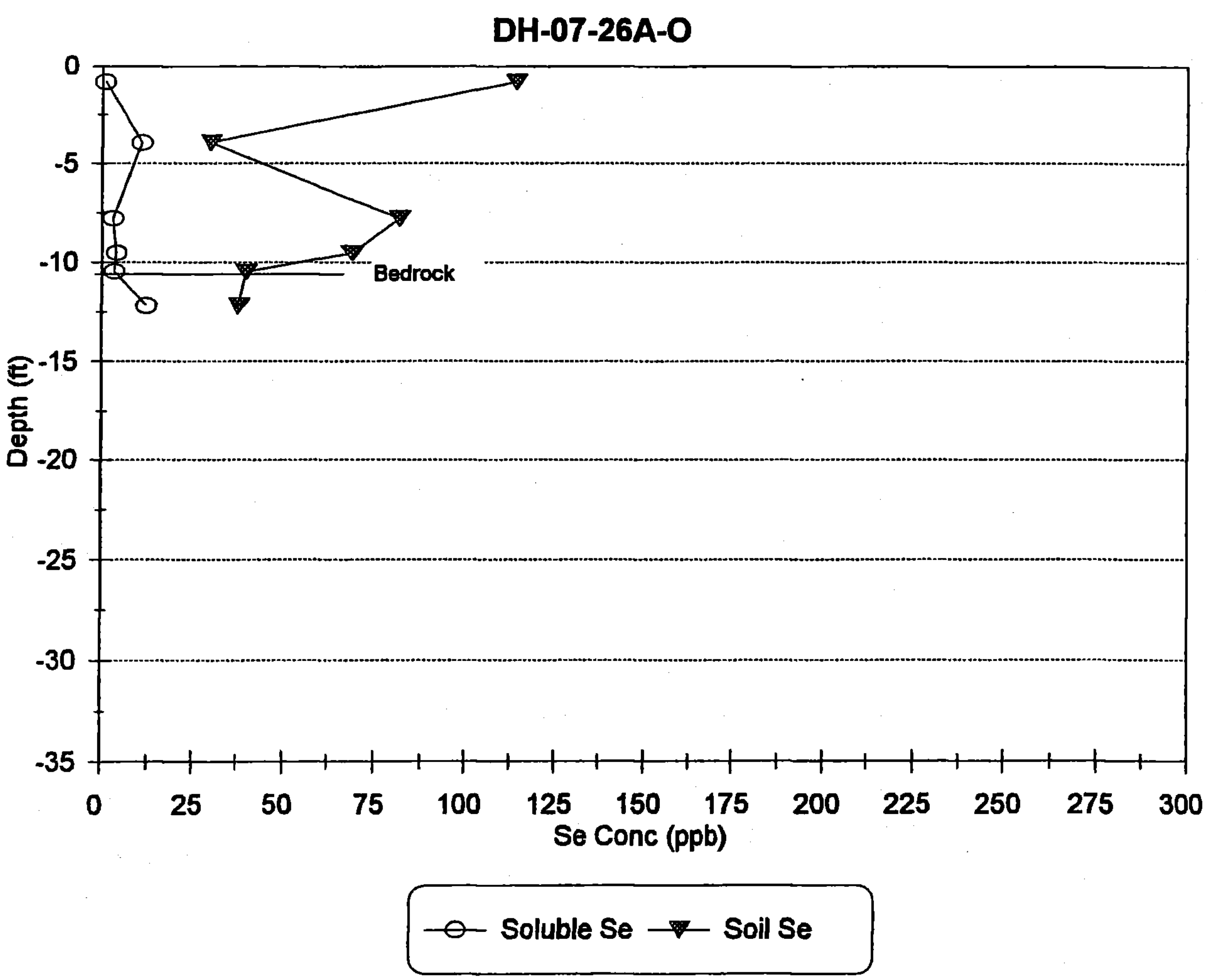


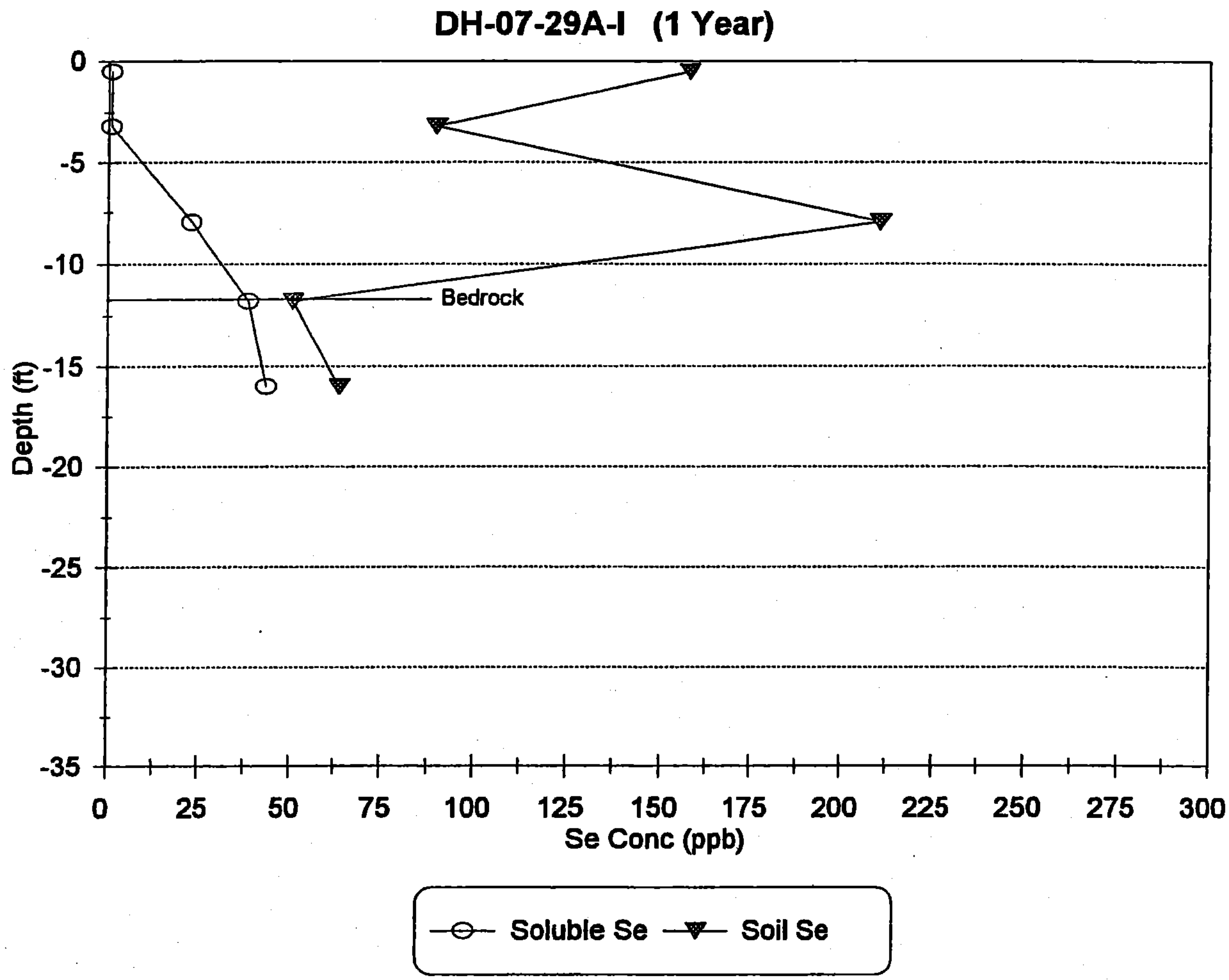
DH-07-09B-I (2 Years)
Depth (ft)
0
-5
-10
-15
-20
-25
-30
-35
Bedrock
0 25 50 75 100 125 150 175 200 225 250 275 300
Se Conc (ppb)
Soluble Se
Soil Se



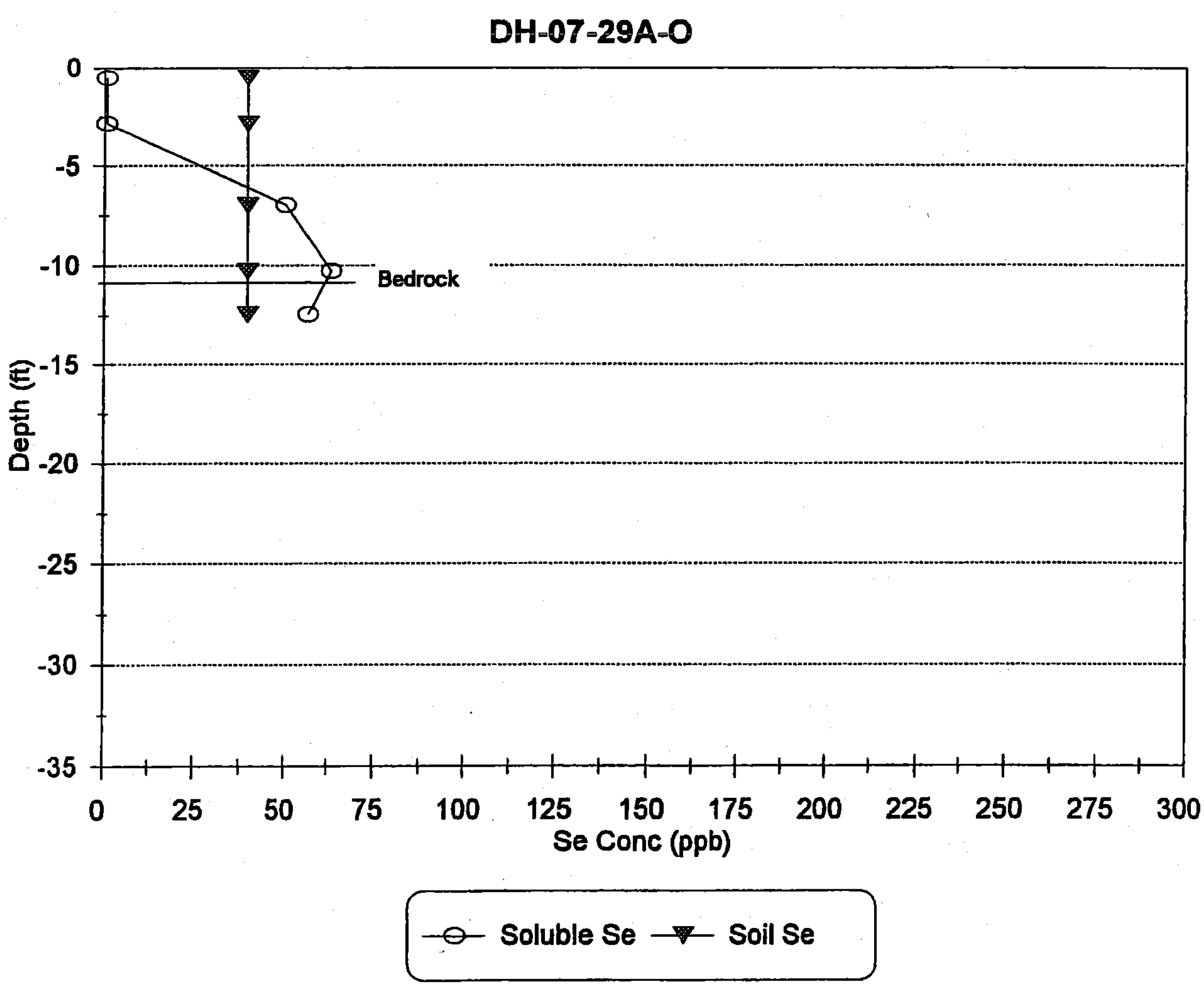
DH-07-09B-O
Depth (ft)
0
-5
-10
-15
-20
-25
-30
-35
Bedrock
0 25 50 75 100 125 150 175 200 225 250 275 300
Se Conc (ppb)
Soluble Se
Soil Se


DH-07-26A-I (3 Years)
Depth (ft)
0
-5
-10
-15
-20
-25
-30
-35
Bedrock
0 25 50 75 100 125 150 175 200 225 250 275 300
Se Conc (ppb)
Soluble Se
Soil Se

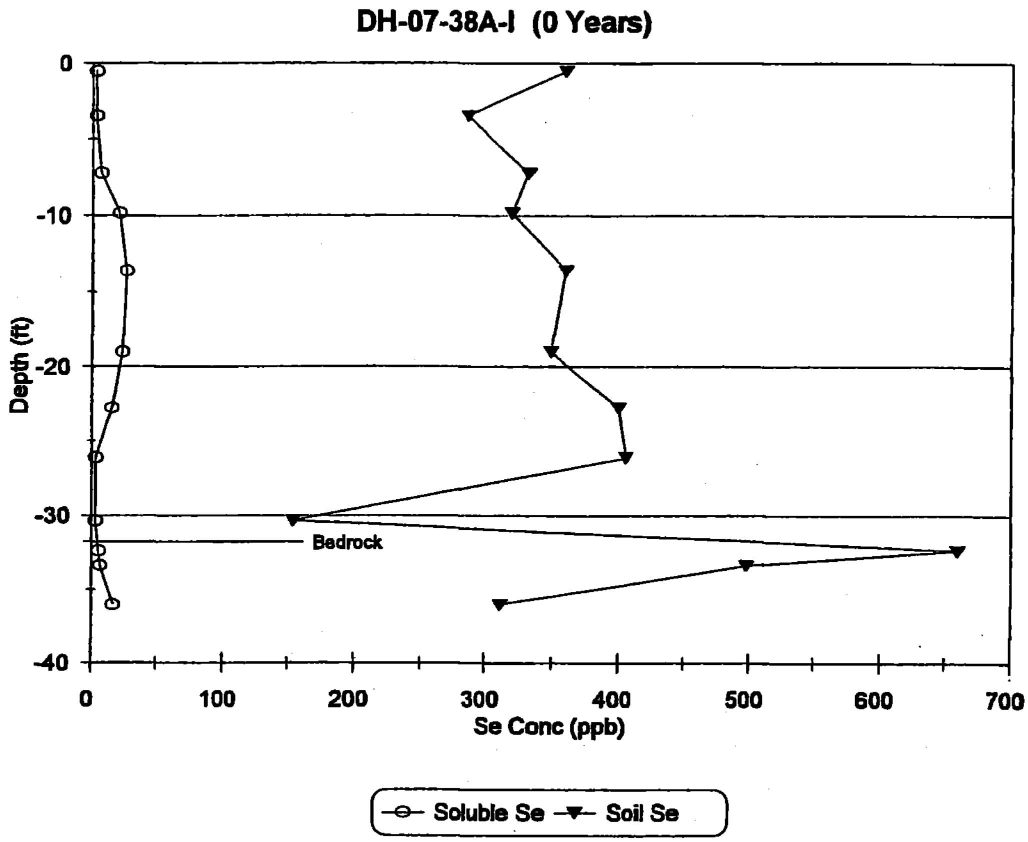

DH-07-26A-O
Depth (ft)
0
-5
-10
-15
-20
-25
-30
-35
Bedrock
0 25 50 75 100 125 150 175 200 225 250 275 300
Se Conc (ppb)
Soluble Se
Soil Se

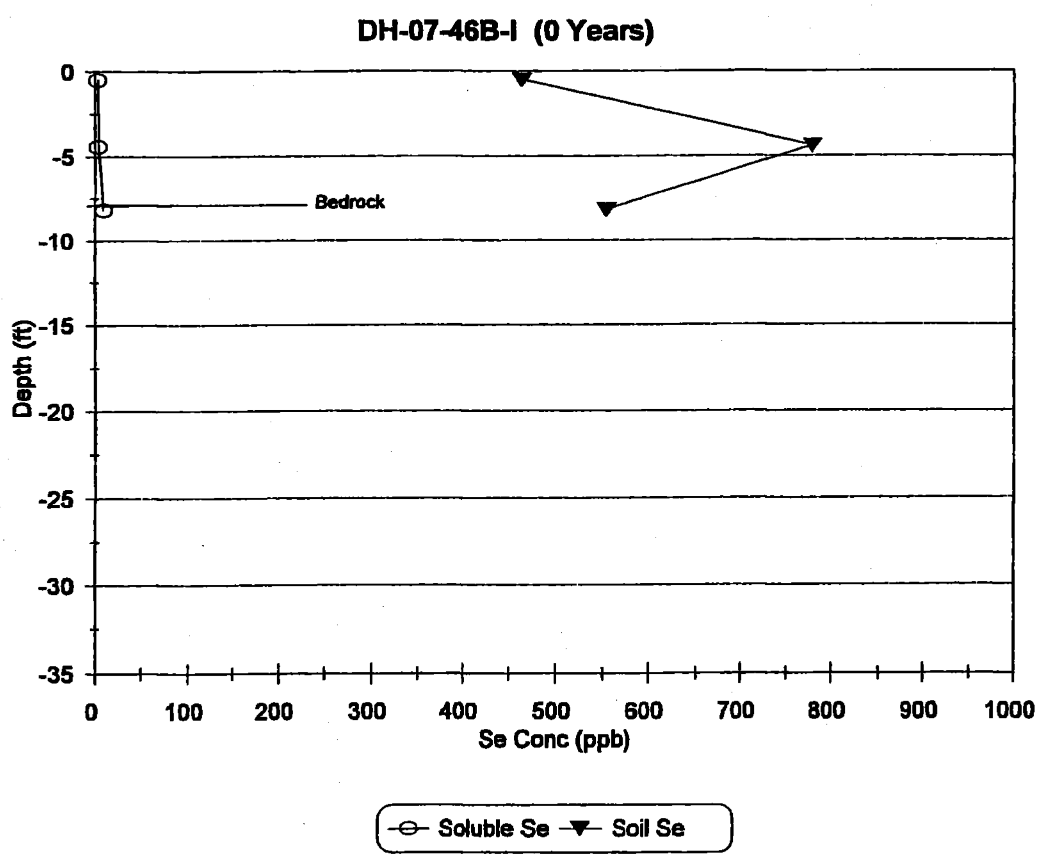


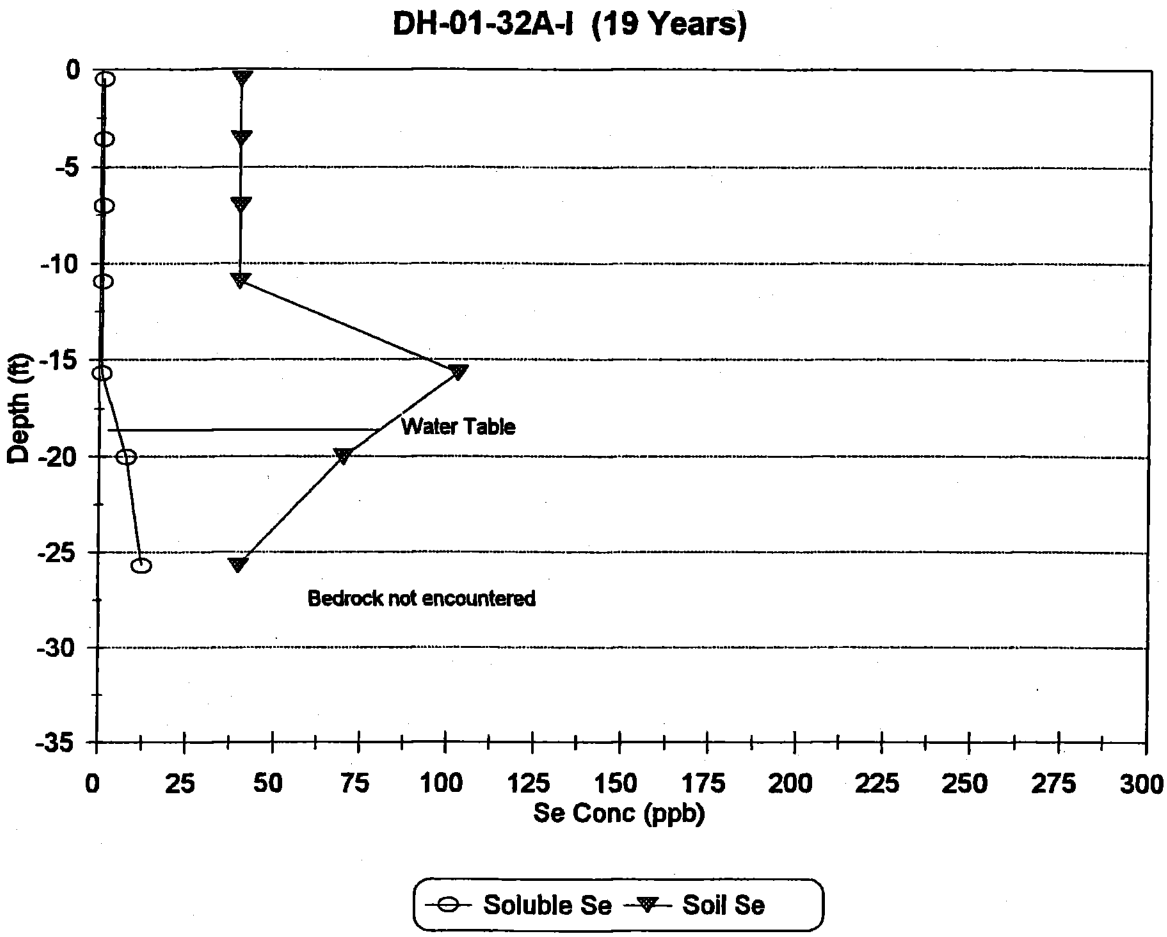
DH-07-29A-I (1 Year)
0
-5
-10
-15
-20
-25
-30
-35
Depth (ft)
Bedrock
0 25 50 75 100 125 150 175 200 225 250 275 300
Se Conc (ppb)
Soluble Se
Soil Se

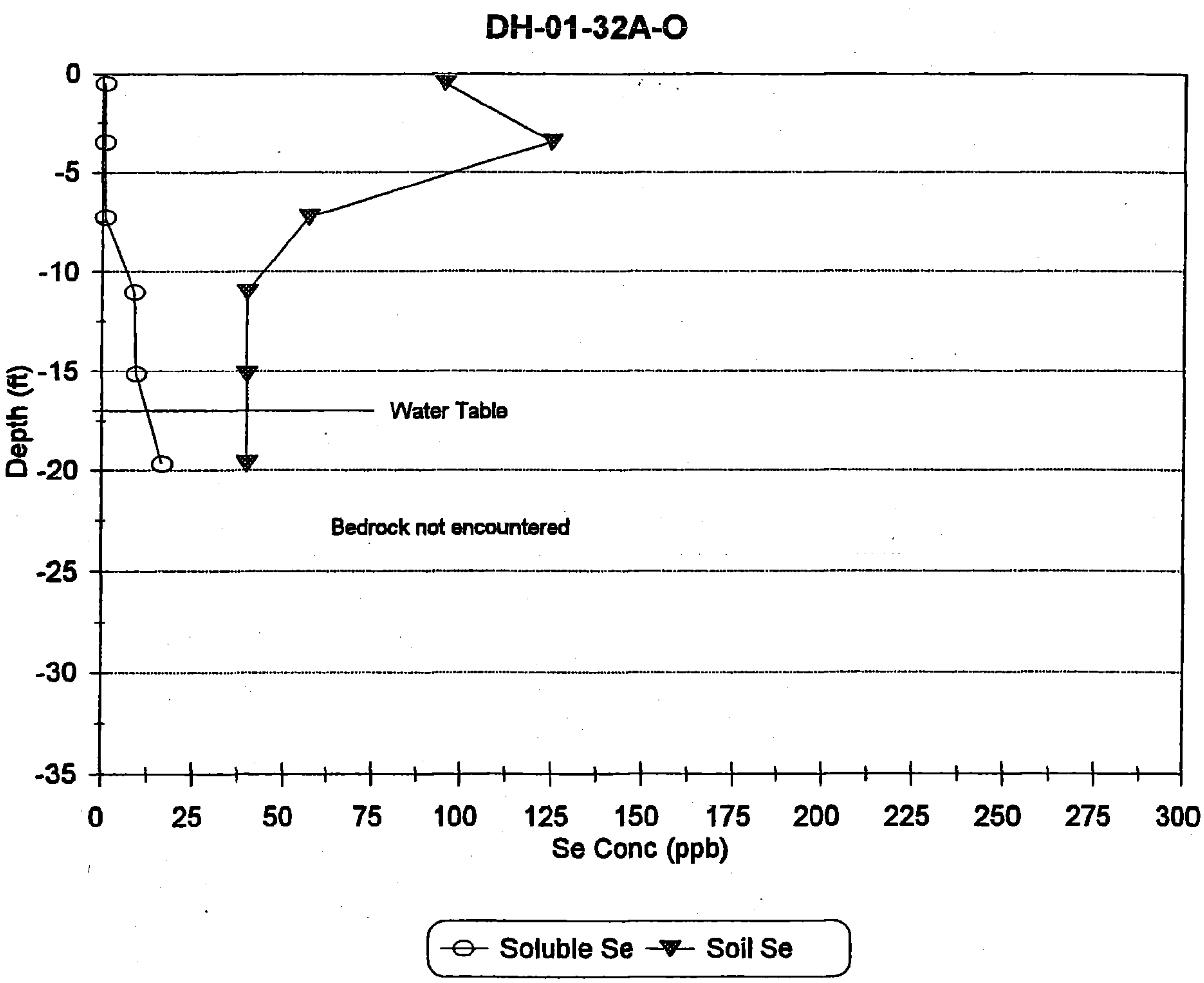


DH-07-29A-O
0
-5
-10
-15
-20
-25
-30
-35
Depth (ft)
Bedrock
0 25 50 75 100 125 150 175 200 225 250 275 300
Se Conc (ppb)
Soluble Se
Soil Se


DH-07-38A-I (0 Years)
Depth (ft)
0
-10
-20
-30
-40
Bedrock
0
100
200
300
400
500
600
700
Se Conc (ppb)
Soluble Se
Soil Se


DH-07-46B-I (0 Years)
Depth (ft)
0
-5
-10
-15
-20
-25
-30
-35
Bedrock
0
100
200
300
400
500
600
700
800
900
1000
Se Conc (ppb)
Soluble Se
Soil Se


DH-01-32A-I (19 Years)
Depth (ft)
Se Conc (ppb)
0
-5
-10
-15
-20
-25
-30
-35
0
25
50
75
100
125
150
175
200
225
250
275
300
Water Table
Bedrock not encountered
Soluble Se
Soil Se


DH-01-32A-O
Depth (ft)
Se Conc (ppb)
0
-5
-10
-15
-20
-25
-30
-35
0
25
50
75
100
125
150
175
200
225
250
275
300
Water Table
Bedrock not encountered
Soluble Se
Soil Se