Appendix 4.1-A

Additional Groundwater Corrective Action Program History

HOMESTAKE MINING COMPANY OF CALIFORNIA

GRANTS RECLAMATION PROJECT

GROUNDWATER CORRECTIVE ACTION PROGRAM

NOVEMBER 13, 2020

U.S. NUCLEAR REGULATORY COMMISSION LICENSE SUA-1471

STATE OF NEW MEXICO DP-200

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AA	Activated Alumina
ACL	alternate concentration limits
AEC	Atomic Energy Commission
APR	Annual Performance Report
^{o}C	Degrees centigrade
CAO	corrective action objectives
CAP	Corrective Action Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CGM	Conceptual geochemical model
CO	Confirmatory Order
COC	constituents of concern
DDM	Drain Down Model
DO	dissolved oxygen
DOE	Department of Energy
DOE-LM	Department of Energy Office of Legacy Management
DRP	Decommissioning and Reclamation Plan
EC	Electrocoagulation, engineering control
EIS	Environmental Impact Statement
EPA	United States Environmental Protection Agency
^{o}F	Degrees Fahrenheit
Fe	iron
ft	feet
ft amsl	feet above mean sea level
g	gram
GHB	general head boundaries
gpm	gallons per minute
GRA	general response action
GRP	Grants Reclamation Project
GWPS	groundwater protection standards
GWQB	Ground Water Quality Bureau
HDPE	high density polyethylene
HE	Hydro-Engineering, LLC
HFB	Hydraulic Flow Barrier
HMC	Homestake Mining Company of California
IC	institutional control
ISBT	in-situ biological treatment
IX	ion exchange

L	Liter
LC	license condition
LTP	large tailings pile
m	meter
mg/ft^3	milligrams per feet cubes
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MNA	monitored natural attenuation
NCP	National Contingency Plan
NEPA	National Environmental Protection Act
NESHAP	National Emission Standards For Hazardous Air Pollutants
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMEID	New Mexico Environmental Improvement Division
NMOSE	New Mexico Office of the State Engineer
NMSA	New Mexico Statutes and Authorities
NMSU	New Mexico State University
NOS	North Off-Site
NPL	National Priorities List
NPV	net present value
NRC	Nuclear Regulatory Commission
O&M	operations and maintenance
OS	On-Site
POC	point of compliance
ppm	parts per million
PRB	permeable reactive barrier
PRISM	Parameter-Elevation Regressions on Independent Slopes Model
PTT	post treatment tank
QAP	Quality Assurance Plan
RMSE	root mean squared error
RO	reverse osmosis
ROI	radius of influence
ROTP	Reverse Osmosis Treatment Plant
SAG	San Andres/Glorieta
SCM	surface complexation model
SCMM	surface complexation and mixing model
SI	saturation index
SMC	San Mateo Creek
SOS	South Off-Site
STP	small tailings pile

TDS	total dissolved solids
tpd	tons per day
TPP	tripolyphosphate
USEPA	United States Environmental Protection Agency
UMTRCA	Uranium Mill Tailings Radiation Control Act
USGS	United States Geological Survey
XRD	X-ray diffraction

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6 GROUNDWATER REMEDIATION

HMC has investigated and used a variety of groundwater remediation approaches and technologies since 1977 to restore groundwater quality in areas impacted by seepage from the LTP and other facilities at the GRP. The program to restore groundwater impacted by seepage from the facilities at the site has included six major operational components: (1) source control, (2) plume control, (3) reverse osmosis (RO) treatment, (4) zeolite treatment, (5) evaporation, and (6) land treatment. The first two operational components involve extraction from or injection of water into the tailings or underlying aquifers to remove contaminants or otherwise control the movement of contaminants. The last four operational components are related to the treatment, disposal, and/or utilization of water that has been extracted. Source control involved tailings dewatering and flushing of the soluble contaminant mass in the tailings pore water with unimpacted to slightly impacted water with low constituent concentrations to enhance the removal of COC mass by dewatering wells while reducing the COC concentrations in the LTP. The flushing of the LTP had the additional benefit of hydraulically pushing seepage water near or below the base of the LTP to the underlying alluvial groundwater where it was subsequently captured, removed, treated, and re-injected. The plume control program includes collection and injection operations that aid in the creation and maintenance of a hydraulic barrier downgradient of the LTP to inhibit the flow of contaminated groundwater away from the LTP beyond the hydraulic barrier. The plume control program also includes collection and injection operations distributed within the GRP area to capture, contain and restore groundwater that has been impacted by seepage from the LTP or the STP. The groundwater remediation history of the Site is discussed first in this section, followed by presentation of the existing remediation system and the treatment system water balance. The section concludes with a discussion of additional remedial technologies previously evaluated or tested at the Site.

6.1 REMEDIATION HISTORY

The original plume control program consisted of freshwater injection in selected locations with simultaneous collection of groundwater within seepage-impacted areas. The collection water was discharged to the mill processing stream until milling at the Site ceased. Thereafter, the collection water was evaporated until water treatment systems were developed to treat and thereby allow reuse of the collected groundwater. Water treatment processes employed at the GRP include RO, land application and zeolite treatment. The LTP dewatering well collection and injection of unimpacted or mildly impacted water to flush the LTP have been used for source control. The following listing summarizes the groundwater restoration processes and methods and the general sequence of their use at the GRP.

- Original groundwater restoration operations: Groundwater collection and injection wells were operated with collection water discharged to the mill processing stream. Injection operations began in 1977 and collection began in 1978. Groundwater injection was started just north of Broadview Acres to stop impacted water from flowing into this area; groundwater collection was started the next year 4,000 feet upgradient.

- Post-milling groundwater restoration operations: Groundwater collection and injection wells were operated with collection water discharged to evaporation ponds. The milling operations originally stopped in 1981 but additional milling was done from 1988 through 1990.
- Initial source control operations: Dewatering wells were installed in the LTP in 1995 and operated with discharge to evaporation ponds. Dewatering well operations in the LTP ended in 2017. Water collected by the toe drains installed around the LTP was also discharged to evaporation ponds beginning in 1992. The collection from the toe drains is expected to continue until discharge rates are too small for continued sump pump operation.
- Collection for reinjection operations: Collection from Alluvial Aquifer wells southeast of the STP for reinjection near the LTP began in 1995 and continued through July 2016.
- Initial groundwater collection treatment operations: After completion of the RO treatment plant in 1999, On-Site collection water was treated with RO and the produced water was used for injection. The RO brine discharged to the evaporation ponds. Also beginning in 1999, mildly impacted Off-Site groundwater was collected and used to irrigate land application areas. The land application irrigation program continued through 2012.
- Enhanced source control operations: A combination of dewatering and flushing injection wells was operated in the LTP beginning in 2000 to flush the tailings and enhance dewatering collection. The dewatering collection water was discharged to the evaporation ponds. Pumping ended in 2017 and flushing injection was discontinued in 2015.
- Expanded groundwater collection treatment operations: Zeolite treatment systems were installed, and the RO plant capacity was expanded. A 300 gpm zeolite system was completed in 2013 and the larger 1200 gpm zeolite system was constructed in 2015. The zeolite system has been used to treat seepage-impacted groundwater for reuse as injection water since 2016. Modifications and expansion of the RO plant were done in 2014 and 2015. Collected groundwater is treated with RO or zeolite and the treated water is used for injection. The RO brine, zeolite regeneration water and other waste waters are discharged to the evaporation ponds.

The following subsections discuss the history of the collection and injection operations, evaporation, tailings dewatering, tailings flushing, RO treatment, land application and zeolite treatment at the Site.

6.1.1 Alluvial Aquifer Groundwater Collection and Injection

After the EPA sampled several Broadview and Murray Acres subdivision wells in early 1975 and found elevated concentrations of selenium, HMC conducted a hydrological assessment (Hoffman, 1976) which included installation of more than 40 wells. This assessment resulted in the New Mexico Environmental Improvement Division (now NMED) and HMC entering into an agreement on August 18, 1976 which specified that HMC would design and construct a system to contain the seepage from the tailings pile. HMC designed a collection and injection system using a numerical groundwater flow model (Hoffman, 1977). Injection of fresh water just north of Broadview Acres started in June 1977 and operation of

groundwater collection wells adjacent to the tailings pile started in July 1978. **Figure 6-1** shows the locations of the Alluvial Aquifer collection and injection areas utilized from 1977 through 1981. This figure shows the general location of the six initial injection wells in the Alluvial Aquifer just north of Broadview Acres which were placed into operation in 1977. This figure also shows the general location of the initial collection wells used to collect Alluvial Aquifer groundwater adjacent to the LTP. and two small areas of collection in and adjacent to Murray Acres which started collection in 1980.

Figure 6-2 shows the Alluvial Aquifer collection and injection operational areas from 1982 through 1992 and the area where nine additional injection wells were added to the east of the original injection wells just north of Broadview Acres. The nine additional injection wells were added in 1982. This figure also shows that the general location of the Alluvial Aquifer collection wells near the LTP was similar to the location of the pre-1982 collection wells with the addition of a few wells on the west side of the LTP. The line of freshwater injection wells north of Murray Acres was added in 1983 and the area of these wells is shown on **Figure 6-2** while some additional collection east of Murray Acres was added in 1990.

The additions to the Alluvial Aquifer collection and injection wells in 1993 and 1994 included an additional line of injection wells southwest and southeast of the STP, and collection from the K area wells southwest of the STP (**Figure 6-3**). **Figure 6-4** shows the general location of the K area wells and other series of wells including the L, C, S, B, and D area wells. Some series of wells with a common letter preface in the well name have also been referred to as lines. Upgradient collection of Alluvial Aquifer groundwater north of the LTP was started in 1993 with this water being discharged to the drainage in the non-saturated portion of the alluvium to the west.

Figure 6-4 shows the areas of alluvial collection and injection operations from 1995 through 1999. Additional wells were added to the K area on the southwest side of the STP and the L area of collection to the southeast of the STP was added. The groundwater extracted from these two lines of collection wells was reinjected into the Alluvial Aquifer near the LTP where resident COC concentrations were higher to aid in the initial restoration of the higher concentrations. This enabled the collection of this groundwater without the need for disposal thereby allowing the evaporation ponds to be utilized for disposal of other collection water. Additions to the On-site collection were made during this period and the Murray Acres injection system was also expanded. The expansion in collection included additional wells in the S area, the K area and the B & D area. In addition, injection or reinjection wells were added on the south and east sides of the STP and on the northeast side of the LTP.

Figure 6-5 and **Figure 6-6** present the general location of the Alluvial Aquifer collection and injection wells for 2000-2004 and 2005-2009, respectively. The main addition to the Alluvial Aquifer collection system during these two periods is the collection of Alluvial Aquifer groundwater to feed the RO plant and the collection of groundwater for land application irrigation. The areas of Alluvial Aquifer groundwater collection that supplied the RO plant were fairly similar for both of these two periods after the addition of the K line of the alluvial collection wells on top of the STP on the south side of EP1. The common water supply to the South Irrigation system connected the Alluvial Aquifer collection wells in Sections 32 and 33 (T12N, R10W) to the Section 3 (T11N, R10W) and Felice Acres collection wells with all of the South

collection water being applied to only one of the Section 33 (T12N, R10W) or Section 34 (T12N, R10W) irrigation fields at one time. Because the section numbers referenced above are unique in the GRP area, the township and range notations are only included for the first reference to a particular section. Additional irrigation supply wells were added in Felice Acres for the 2005-2009 period. **Figure 6-6** shows where fresh water was injected in the South Off-site area to help maintain the irrigation well production.

The North Irrigation System was located in Section 28 (T12N, R10W) and started irrigation in 2002 with the supply wells located in the western portion of this field and extending to the southwest slightly more than a quarter of a mile. Fresh water injection downgradient of this collection and upgradient of the Section 32/33 collection was done to aid the restoration in these areas. The North irrigation center pivot was expanded to 100 acres in 2005 which resulted in the use of additional irrigation supply wells to the east of the North land application irrigation area. An expanded area of freshwater injection to the north of the irrigation supply wells was also added during this period to increase the irrigation supply well production and aid restoration of the groundwater.

Figure 6-7 shows the locations of the last three years (2010-2012) of operation of the land application irrigation program when an additional restriction on the quality of water applied to the fields was imposed by NMED. Water from San Andres well 943 (**Figure 6-7**) was added to the South irrigation supply wells to produce water with an average uranium concentration less than 0.16 mg/l, while water from San Andres well 951R (**Figure 6-7**) was added to the North supply to meet this average uranium concentration limit. The area (and rate) of Off-site groundwater collection during 2013 through 2015 without the irrigation program was very limited as shown in **Figure 6-8**. This water was injected into the LTP as part of the tailings flushing program during this period.

The locations of the On-site collection and injection operations was similar for 2010-2012 and 2013-2015. Collection for reinjection was also conducted during both of these time periods. Upgradient Alluvial Aquifer groundwater collection ended in 2013 and therefore is not shown on the **Figure 6-8**. The significant differences in the Off-Site collection shown in **Figure 6-7** and **Figure 6-8** reflect the cessation of collection for irrigation after 2012. Through 2012, there were large areas of Off-Site collection in Sections 27, 28, 32, 33, 34, 35 and 3 to supply the irrigation (**Figure 6-7**). From 2013 through 2015, the Off-Site collection was reduced to smaller areas in Sections 28, 34 and 35 (**Figure 6-8**) to supply water for the tailings flushing and testing of the zeolite treatment.

Figure 6-9 shows the 2016-2018 Alluvial Aquifer groundwater collection and injection locations. Alluvial RO collection supply wells were added in the southwestern portion of the LTP area and between the LTP and evaporation ponds during this time period. The collection area southeast of the STP that is primarily in the Northeast quarter of Section 35 (T12N, R10W) is designated as the L area and collection from these wells was switched to the RO feed as shown in **Figure 6-9**. The Alluvial Aquifer groundwater collection system in the South Off-site area was mainly in the Felice Acres area and northeast corner of Section 3, but also included a small area in central Section 3 during the last portion of this time period. The South and North Off-site collection water was treated through the zeolite systems to meet the Site uranium standard and enable the re-use of this water for injection supply. Treated water injection locations are

shown on **Figure 6-9** for both the South and North Off-site areas. The North Off-site alluvial collection locations are shown in the western- and central portion of Section 28 where Alluvial Aquifer restoration is occurring.

Groundwater collection for the reinjection program operated for approximately seven months during 2016 but was discontinued after July 2016 due to concerns raised by the NRC. The Confirmatory Order (CO) issued by the NRC in March 2017 (NRC, 2017) required that HMC provide an analysis of the collection for reinjection program and its impacts on restoration progress. This analysis was reported in Hydro-Engineering L.L.C. (2017a). The conclusions of this analysis were that the collection for reinjection was successful in preventing the expansion of the L area contaminant plume without detracting from restoration efforts within the hydraulic control area near the LTP, and, the transfer of relatively small quantities of COCs into the hydraulic control area by reinjection did not significantly delay restoration progress near the LTP. The collection for reinjection is not depicted on **Figure 6-9** because the L area groundwater collection was treated through the RO plant after July of 2016.

6.1.2 Chinle Aquifer Groundwater Collection and Injection

The Chinle Aquifer collection and injection well systems are discussed in this section. **Figure 6-10** shows the locations of collection and injection wells used in the Upper, Middle, and Lower Chinle Aquifers from 1984 through 1999. This figure shows the locations of the West and East Faults with the subcrop for the Upper Chinle Aquifer shown in dark blue, the subcrop for the Middle Chinle Aquifer shown in red and the Lower Chinle Aquifer subcrop, which is located in Section 3, shown in light blue. The subcrop for the Upper Chinle Aquifer is an important contact with the Alluvial Aquifer because it extends below the alluvium beneath the western portion of the LTP. This creates a fairly direct pathway by which seepage-impacted Alluvial Aquifer groundwater in the immediate area of the LTP can enter the Upper Chinle Aquifer. In contrast, seepage-impacted Alluvial Aquifer groundwater must flow a significant distance from the immediate LTP area before reaching a subcrop where it can enter the Middle or Lower Chinle Aquifers. Each of the Chinle Aquifers extends down dip to the east and northeast of their respective subcrops.

The initial injection in the Upper Chinle Aquifer occurred in well CW5 which is located just north of Broadview Acres with injection starting in 1984. Upper Chinle well CW4R is located just west of the STP and groundwater collection only occurred in 1995. **Figure 6-10** also shows the location of well CE2 just south of the Collection Ponds. Groundwater collection from well CE2 started in 1999 and has continued through the present. Upper Chinle well CW13 is located east of the East Fault and east of Broadview Acres and injection into this well started in 1996. **Figure 6-10** also shows the location of Middle Chinle well CW14 north of the northwest corner of Broadview Acres which has been used for injection since 1997.

Figure 6-11 shows the continuing use of Upper Chinle injection well CW5 north of central Broadview Acres during the period between 2000 and 2012. Injection into Upper Chinle well CW25, which is located just east of the northeastern portion of Murray Acres, started in 2000 while the injection into Upper Chinle wells 944, east of Highway 605, and CW4R, west of the STP, was initiated in 2002 and 2003, respectively.

Collection from Upper Chinle wells CE5, CE6, CE11 and CE12, which are located southwest of Evaporation Pond 2 (EP2) and the Collection Ponds (**Figure 6-11**), was started in 2006 while this figure also shows the continuing collection from Upper Chinle well CE2 which is located just south of the Collection Ponds. Collection from Upper Chinle well CE7, which is located just north of the Collection Ponds, was started in 2010. Collection from Upper Chinle well CW3 located northeast of the LTP was done as a source of water for the tailings flushing program from 2001 into early 2007. Upper Chinle collection wells 929 and 934 are located east of Highway 605 and were also used as a source of tailings flushing water starting in 2002 and 2001, respectively. Felice Acres area Upper Chinle well CW53 was pumped for irrigation supply from 2006 through 2011. Upper Chinle collection well CW18 located east of Highway 605 and Felice Acres was used as a source of freshwater injection starting in 2002 and continuing through 2004.

Figure 6-11 also shows the location of Middle Chinle well CW14 north of the northwest corner of Broadview Acres where injection continues. Middle Chinle wells CW1 and CW2 north of the LTP were pumped from 2001 through 2012 as a source of tailings flushing water. Collection of Middle Chinle groundwater started in Felice Acres with the start of the land application irrigation program in 2000. Middle Chinle collection wells CW44 and 498 and well CW45 in southern Felice Acres were used from 2000-2009 and 2004-2009, respectively. Middle Chinle collection wells 482 and 483 in northern Felice Acres were used from 2005-2012 while collection well 493 was used from 2008-2012. Middle Chinle collection well CW28 east of Highway 605 and east of Felice Acres was used as a source of freshwater injection for alluvial wells 848 and 868 starting in 2002 and continuing through 2006.

Figure 6-11 also shows the location of four Lower Chinle collection wells located in Section 3 which were used in the land application irrigation program which started in 2000. Lower Chinle collection well 653 was used through 2009. Lower Chinle collection well 538 was used 2004-2009, while wells CW29 and CW42 were pumped from 2005-2009 and 2007-2009, respectively.

Figure 6-12 shows the collection and injection wells used in 2013 through 2015 in the Upper, Middle and Lower Chinle Aquifers. Upper Chinle injection wells 944, CW4R, CW5, CW13 and CW25 were used during this three-year period. Upper Chinle collection wells CE2, CE5, CE6, CE7, CE11 and CE12 near the Collection Ponds were also used for the three-year period shown on the figure, while Upper Chinle collection well 929 was used only in 2013. Felice Acres-area Upper Chinle well CW53 was only pumped as a source of water for flushing injection into the tailings during 2014.

Figure 6-12 also shows the location of Middle Chinle well CW14 north of the northwest corner of Broadview Acres where continuation of injection into the Middle Chinle occurred during 2013-2015. Middle Chinle wells CW1 and CW2 north of the LTP were only pumped during 2013 for use as a source of tailings flushing water. Collection of Middle Chinle water continued in Felice Acres with wells 482 and 483 being used in 2013 and 2015 while collection wells 498, CW44 and CW45 in southern Felice Acres were used in 2013 and 2014. Felice Acres collection well Y7 was also used during 2014 and 2015. Collection of Middle Chinle groundwater from five R series wells in the northeast corner of Section 3 also occurred during some of this three-year period. **Figure 6-12** also shows the location of Lower Chinle collection well CW29 in Section 3 which was used in 2013 as a source of water for the tailings flushing program.

The locations of the collection and injection wells used in 2016 through 2018 in the Upper, Middle and Lower Chinle aquifers are presented on **Figure 6-13**. Upper Chinle injection wells 944, CW4R, CW5, CW13 and CW25 were continually used during this three-year period. Upper Chinle collection wells CE2, CE5, CE6, CE7, CE11 and CE12 are located near the Collection Ponds and were also used for the three-year period, while Upper Chinle collection CE19 (located just south of the wells listed above) and collection wells CE15 and CE15A, which are located north of Broadview Acres, were only used in 2017 and 2018. A series of wells prefaced with a B in the well name are located along the southern toe of the LTP and are collectively referred to as the B wells. Similarly, a series of wells prefaced with a T in the well name are located on top of the LTP and are collectively referred to as the T wells. Five B collection wells near the Upper Chinle subcrop just south of the LTP and five T wells near the subcrop on top of the LTP were also operated to collect Upper Chinle water during 2017 and 2018.

Figure 6-13 also shows the location of Middle Chinle well CW14 north of the northwest corner of Broadview Acres and well CW30 west of Felice Acres where continued injection into the Middle Chinle occurred. Injection into Middle Chinle well CW77, which is located just west of well CW30, occurred during 2017 and 2018. As noted in the preceding paragraph, a series of wells prefaced with a letter of the alphabet in the well name is collectively referred to by that letter for many wells in the GRP. Examples of this in the South Off-site area are the R wells in Section 3 and the Y wells in southern Felice Acres. Injection of treated water into five wells in southern Felice Acres and three R wells in the northeast corner of Section 3 occurred over the three-year period presented on **Figure 6-13**. Middle Chinle collection from four Y wells in southern Felice Acres was done during this three-year period while well CW45 was pumped during 2018. Collection of Middle Chinle groundwater from six R wells in the northeast corner of Section 3 also occurred during 2016-2018.

Figure 6-13 shows the location of Middle Chinle collection well CW62 west of the West Fault and three Middle Chinle injection wells to the south of well CW62 that were used during 2016-2018. Lower Chinle collection well R68 in Section 3 was used during 2018 as a feed to the zeolite treatment system.

6.1.3 Evaporation

Evaporation was used to dispose of water at the GRP starting in 1986 with the construction of the West and East Collection Ponds which were lined with a single asphalt liner. These two ponds were used to dispose of brine during the final years of the mill operation and were used as part of the evaporation system after 1990. **Figure 6-14** shows the locations of the Collection Ponds relative to the LTP and STP. Evaporation Pond 1 (EP1) was constructed in 1990 with a single asphalt liner similar to the Collection Ponds. EP1 occupies the northern two thirds of the STP and was constructed by excavating tailings to form pond dikes (**Figure 6-14**). Evaporation Pond 2 (EP2) was constructed in 1996 between the STP and the East Collection Pond with two high density polyethylene (HDPE) liners with leak detection. The third evaporation pond, EP3, is shown on **Figure 6-14** and is located approximately one-third mile north of the northwest corner of the LTP. EP3 consists of two cells and, like EP2, is double-lined with HDPE and a leak detection system. EP1 and both of the collection ponds are slated to be re-lined with two HDPE liners and leak detection systems in 2020.

6.1.4 Tailings Dewatering

The first phase of the tailings dewatering program was the installation of a series of toe drains around the perimeter of the LTP in 1992 to intercept perched zone (alluvial sand generally 10 feet below the base of the tailings) groundwater seeping from the tailings into the alluvium. The perched zone is not naturally saturated but contained seepage from the tailings in the immediate area of the LTP. The locations of the toe drains around the perimeter of the LTP and their seven associated sumps are shown on **Figure 6-15**. The perimeter drainage system also includes a second pipe drain designated as a French drain (**Figure 6-15**) that is located along a similar alignment as the toe drain system. The toe drain and French drain pipe systems are connected to common sumps and are typically referred to as the toe drains because there is no separation of discharge from the two pipe drain systems. Two additional sumps tied to the old tailings decant towers (East and West reclaim sumps) are also shown on this figure. **Figure 6-16** shows the cumulative volume of tailings water, 413 million gallons, removed by the toe drains through 2018 which is an average collection rate of 29 gallons per minute (gpm) for the past 27 years. The peak collection rate of slightly greater than 50 gpm, occurred in 2003, 2004, 2008 and 2009 during the operation of the tailings flushing program. The average rate produced from the toe drains is declining with time as expected and was 8.8 gpm in 2018.

Tailings wells were installed in the Large Tailings Pile beginning in 1994, and numerous wells were added each year to develop the tailings dewatering program. The vertical well dewatering program started in 1995 with the dewatering wells completed in the tailings and perched zone. A vacuum was applied to the well head of the dewatering wells in the early years of the program to enhance the small well yields. The cumulative volume of tailings water pumped was 508 million gallons which is shown in **Figure 6-16**. Well dewatering did not occur in 2018. The tailings well dewatering rate averaged 42 gpm over a 23-year period (1995 through 2017). The water levels in the LTP have dropped dramatically since 2015 and this makes it unlikely that any additional vertical well dewatering is practical with the very small potential well yields. The peak dewatering rates of 104 and 105 gpm occurred in 2011 and 2012. The dewatering rates were restricted during a few years due to the limited evaporation pond storage available during those years. The dewatering wells continue to aid in the removal of tailings water from the LTP because they function as vertical drains between the tailings and the perched zone.

6.1.5 Tailings Flushing

Testing of tailings flushing was deemed necessary due to large COC concentrations in the tailings water and the lack of decline in constituent concentrations from dewatering alone. Testing of tailings flushing using both a sand tailings area and slime tailings area was conducted in 1999 and the flushing program was started in 2000 and ceased in mid-2015. **Figure 6-15** shows the location of the injection wells used in the flushing program along with the dewatering wells. The average tailings injection rate varied from 61 gpm in 2000 to a peak of 308 gpm in 2014. The tailings flushing injection rate into the LTP averaged 233 gpm over the 16-year period of operation of this program. The tailings dewatering and flushing programs dramatically reduced uranium and molybdenum concentrations in the LTP water from pre-flushing levels

of approximately 40 and 100 mg/L, respectively, to average concentrations in 2018 of 5.4 and 13.7 mg/L, respectively.

6.1.6 Reverse Osmosis (RO) Treatment

The reverse osmosis (RO) plant (**Figure 6-14**) was constructed in 1999 to treat collected groundwater and supply a produced water stream suitable for injection into groundwater (see **Figure 6-14** for location of the RO plant to the northwest of the West Collection pond). Pilot testing of the RO process was conducted in 1995 (HMC, 1998) and the results of the pilot test indicated RO was suitable for groundwater treatment. Information submitted to the NRC in support of the RO process also included an evaluation of the injection of RO produced water (Hydro-Engineering L.L.C., 1998). The approval of the use of RO treatment was subsequently granted in 1998 (NRC, 1998) as License Amendment 30. The original RO plant consisted of a 300 gpm low pressure RO which could be operated in series with a 75 gpm high pressure unit to treat the brine from the low-pressure unit. The RO plant utilized a lime/caustic pre-treatment and clarification unit with sand filters. Blowdown (sludge) from the pre-treatment unit discharged to the West Collection Pond.

The RO plant was expanded with the addition of a second 300 gpm low pressure unit that first operated in 2002. The pre-treatment processes for the second low pressure RO unit were common with the original RO units. The three RO units were designated as Low Pressure No. 1 (LPRO-1), High Pressure No. 1 (HPRO-1) and Low Pressure No. 2 (LPRO-2).

An expansion and upgrade of the RO plant was undertaken in 2014 and 2015 with the replacement of sand filtration by microfiltration units and the addition of a third low pressure unit (LPRO-3) with a capacity of 600 gpm. Additional upgrades/changes to the RO plant included addition of a second clarifier, addition of two equalization basins to the RO pre-treatment system, and addition of a post treatment tank (PTT). The PTT receives the RO produced water, the zeolite treated water and fresh water from the San Andres Aquifer prior to distribution to the injection system.

The RO plant was switched in mid-2015 from the use of sand filters to microfiltration. The installation of LPRO-3 occurred in late 2015 with testing in December of 2015. A second high-pressure unit (HPRO-2) with a capacity of 250 gpm was added in 2016. HPRO-2 was configured to treat the brine from the three low pressure units when they were all operating. As discussed above, the brine from LPRO-1 can serve as the feed for HPRO-1, so there are multiple combinations of low pressure and high-pressure RO units that can be operated giving a current RO plant feed rate ranging from approximately 280 gpm to a maximum theoretical capacity of 1200 gpm. The high-pressure RO units were not configured to directly treat feed water to the plant, and do not increase the total feed rate to the RO plant. Rather, the high-pressure units accept brine streams from operating low-pressure units and can increase the quantity of product water from the plant while reducing the rate of brine production. The product water from all five RO units is discharged to the PTT while the final brine stream from the combination of operating units is discharged to the evaporation ponds. Other miscellaneous flows and blowdown from the RO plant are pumped to

the West Collection Pond for recycle to the RO plant. The RO plant inputs and output of RO product water for injection are listed **Table 6-1**.

Because the RO product water has much lower Total Dissolved Solids (TDS) and other constituent concentrations than the fresh water produced from the San Andres Aquifer, injection of RO product water or a mixture of RO product water and fresh or other treated water is generally more effective in aquifer restoration (Hydro-Engineering L.L.C., 1998). The observed aquifer restoration progress presented in APR reports continues to show that the treated water injection is more effective than the fresh water in reducing the uranium and molybdenum concentrations within the Alluvial Aquifer.

6.1.7 Land Application

A soil investigation (RIMCON and Hydro-Engineering, 1998) was conducted in the area of the GRP prior to selection of the land application irrigation areas. The sample results from the 1998 investigation and multiple samples collected from outside the land application area each year were used to establish background concentrations. An analysis of the potential risk of the land application program was conducted prior to the start of irrigation in 2000 (Environmental Restoration Group and Hydro-Engineering (ERG and HYDRO), 1999). The results of the land application irrigation program were analyzed and presented in irrigation reports (ERG and HYDRO, 2001, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012 and 2013).

The land application program consisted initially of a South irrigation system with 120 acres of flood irrigation in Section 34 and a 150-acre center pivot sprinkler system in Section 33. These two irrigation areas were supplied by the same pipeline and only one of the areas was irrigated at a time. **Figure 6-17** shows the location of the flood area in Section 34 and the center pivot on Section 33. The North irrigation system was started in 2002 in Section 28 with a 60-acre center pivot supplied by wells in Section 28 using a separate supply pipeline (**Figure 6-17**). **Table 6-2** presents the quantity of water applied to the irrigated areas, average feet of water applied to the fields and area irrigated for each year. The irrigated area acreage was increased in 2002 by the additional of 60 acres in the North center pivot. The addition of 24 acres of flood irrigation in Section 33 increased in irrigated area during 2004 while the North center pivot was expanded by 40 acres in 2005. The location of the 24-acre flood area in Section 33 south of Valle Verde subdivision is shown on **Figure 6-17**. **Table 6-2** shows that the yearly usage of water for irrigation varied from 201 to 1054 ac-ft of water with the depth of annual water application varying from 1.4 to 3.0 feet of water.

The average concentrations of uranium, selenium, TDS, sulfate, chloride and molybdenum in water for each year irrigation applied to the South fields are presented in **Table 6-3**. This table shows that the yearly average uranium concentrations applied to the South fields varied from 0.22 to 0.29 mg/L except for the last three years of application when the uranium concentration in the applied water was restricted to a maximum of 0.16 mg/L. The average yearly uranium concentration for the North irrigated area varied from 0.23 to 0.39 mg/L except for the last three years when the maximum concentration was restricted to 0.16 mg/L. The uranium concentration in the North irrigation water was generally higher than that for

the South irrigation water. The constituent concentrations for the water applied to the North Irrigation Field are provided in **Table 6-4**. The concentrations of other COCs (nitrate, vanadium, thorium-230, and radium 226 + radium 228) in the irrigation supply water were below the corresponding Site standards and levels of concern.

COC concentrations in soil were measured prior to the use of irrigation in an area and each year during the operation of the land application irrigation system. This information is presented in the irrigation reports previously cited. Suction lysimeters were installed in 2009 to obtain soil moisture samples in the irrigation areas for measurement of COC concentrations in the water. Lysimeters were installed in 3, 5, 3 and 1 locations in the Section 28 center pivot, Section 33 center pivot, Section 34 flood area and Section 33 flood area, respectively. **Figure 6-17** shows the location of these lysimeter installations. The results are reported in the irrigation reports previously cited. Most of these lysimeters produced water samples that were useful to evaluate the COC concentrations in soil moisture and the movement of these constituents in the soil profile. However, as are common, drier soil conditions resulted in some lysimeters not producing samples. The soil moisture chemistry data from the lysimeter water samples were used to evaluate COC migration in the soil profile as a result of irrigation. The last two attempts to sample the lysimeters, during the first quarter of 2016 and in October 2017 after the monsoon season, did not produce any samples. The likelihood of successful sampling from the suction lysimeters has greatly diminished as the soil profile dried out following the termination of the land application irrigation program.

Soil moisture instruments were installed prior to the 2012 irrigation season to measure soil moisture content in the upper portion of the soil profile. **Figure 6-17** shows where the soil moisture instruments were added adjacent to lysimeters LY34-3 and LY28-2. The termination of the land application irrigation program after the 2012 season resulted in gradual drying of the soil profile in the irrigation areas. With the passing of more than six years since the last irrigation, the soil moisture content in the irrigation areas is relatively stable and does not reflect any residual effects from land application irrigation.

6.1.8 Zeolite System Treatment

Testing of zeolite to remove uranium from the GRP area groundwater was initially conducted using bench scale tests in 2007. Favorable results from the bench scale testing led to expansion to a 5 gpm capacity pilot scale test using two plastic water tanks filled with zeolite (RIMCON, 2009). The pilot testing was further expanded with the construction and operation of a 50 gpm zeolite system consisting of two HDPE lined zeolite cells on top of the LTP (RIMCON and Hydro-Engineering, 2012).

A zeolite system consisting of three HDPE lined cells with a design capacity of 300 gpm was constructed adjacent to the two lined cells used in the 50 gpm system (see **Figure 6-14** for location on the LTP). The 300 gpm zeolite system (abbreviated as 300Z) was designed and installed in 2012 and 2013 (RIMCON and Hydro-Engineering, 2012) and was developed for treatment testing purposes as well as operation as a full-scale treatment system. The 300Z was tested with supply of both On-site and Off-site groundwater (RIMCON, 2013). The 300Z was used successfully to reduce uranium concentrations in the supply water

to levels that met Site groundwater standards, which made it suitable for treatment of Off-site groundwater where uranium was the only constituent exceeding its groundwater standard.

The 1200 gpm zeolite system (abbreviated as 1200Z) was installed in 2015 in the southeast corner of the top of LTP as shown on **Figure 6-14** (Hydro-Engineering, 2015). The 1200Z system consists of four trains with three cells and a treatment capacity of 300 gpm for each train (Hydro-Engineering L.L.C, 2017b). The water quality results from treating the Off-site groundwater with the zeolite process have been documented in Section 2 of the 2016, 2017 and 2018 APRs.

The zeolite beds have been used since 2016 to remove the uranium from the Off-site collection water because uranium is the only site constituent that exceeds the Site uranium standard in the Off-site collection wells. The effective continuous zeolite treatment capacity is estimated to be 1,050 gpm from the combination of the 300Z and 1200Z systems when the time required to regenerate the zeolite beds is considered. The 300Z and 1200Z systems produce treated water that is piped to the PTT where it is mixed with RO product water and fresh water prior to injecting it back into the groundwater. **Table 6-5** lists the inputs to the 1200Z and 300Z treatment systems and the rates of treated and regeneration water for 2016 through 2018. The table shows that the average treated water rate has varied from 233 to 267 gpm.

The North and South Off-site restoration areas (**Figure 2-4**) supply the water for the zeolite treatment because the COC concentrations in the Off-site groundwater meet the site standards with the exception of uranium. The well location figures in **Section 6.2** show which wells are presently being used to supply the zeolite treatment process systems from the North and South Off-site collection wells. The Off-site maps from the 2016, 2017 and 2018 APR reports show which wells have been used for both groundwater collection and treated water injection during the last three years.

6.2 EXISTING REMEDIATION SYSTEM

This subsection presents the existing collection and injection wells used in the remediation system. The Alluvial Aquifer restoration program is first and followed by the presentation of the restoration program for the Chinle Aquifers.

6.2.1 Existing Alluvial Aquifer Collection and Injection

The Alluvial Aquifer collection and injection wells used in the existing remediation system are discussed in this section. Uranium concentration contours and hatch patterns showing areas of current and planned future restoration operation are displayed on **Figure 6-18** through **Figure 6-22** and indicate the general areas where the uranium concentration in the Alluvial Aquifer exceeded the Site standard in 2018. The following discussion of restoration activity uses uranium as the key indicator constituent for seepage impacts because it is the only constituent where concentrations exceed the Site standard in Off-site areas, and because the areas requiring restoration to meet Site standards for other COCs are generally similar to or contained within the areas requiring restoration to meet the uranium Site standard.

Figure 6-18 shows the areas where the restoration operations are occurring and where future restoration operations are planned with green and blue hatch patterns, respectively. These hatch patterns generally

enclose the active or planned areas of collection operations, but the active or planned injection operations may extend beyond the area in the hatch pattern. **Figure 6-18** also shows a bounding box to indicate the areas presented for the On-site map (**Figure 6-19**), the South Off-site map (**Figure 6-20**), the North Off-site map (**Figure 6-21**) and the L Area On-site map (**Figure 6-22**).

Figure 6-19 shows the existing On-site Alluvial Aquifer collection and injection wells with collection well operation on the west and south sides of the LTP and the southwest portion of the top of the LTP. Collection operations are also occurring on the west and south sides of EP1. This collection in combination with the injection downgradient of the collection wells results in a hydraulic control area where seepage-impacted Alluvial Aquifer groundwater is captured by the collection wells. Expansion of the collection area to the wells to the east and on top of the LTP is planned for the future as COC concentrations are reduced in the present operational restoration areas.

The existing South Off-site alluvial collection and injection wells are shown on **Figure 6-20** with collection and injection operations in and near the Middle Chinle subcrop in South Felice Acres in Section 35 and northeast Section 3. Because of the contact with the Middle Chinle subcrop, restoration of this area of the Alluvial Aquifer is critical to the restoration of the Middle Chinle Aquifer in the South Off-site area. A collection well is also operating in the northern portion of Felice Acres to capture seepage-impacted Alluvial Aquifer groundwater and reduce the relatively small uranium concentrations to below the Site standard. Two collection wells in the central portion of Section 3 are also in the existing South Off-site Alluvial Aquifer collection program to prevent continuing migration or expansion of the uranium plume in this area.

Figure 6-21 shows the existing North Off-site alluvial collection and injection wells with the present North Off-site operations occurring on the western (downgradient) end of the North plume. The blue hatch pattern shows where future operations in the North Off-site area will be conducted and this remediation will progress from the western side of the plume to the east.

The L Area On-site alluvial restoration area, which is located to the southeast of the STP, is presented in **Figure 6-22**. This figure shows the location of wells used in the ongoing restoration in the L area along Highway 605 and that uranium concentrations exceed the Site standard over a significant area but exceed 0.5 mg/L in only a small portion of this area.

6.2.2 Existing Chinle Aquifer Collection and Injection

The Chinle Aquifer collection and injection wells used in the existing remediation system are presented in this subsection. Uranium concentration contours and hatch patterns indicating exceedance of the uranium Site standard are shown on figures in this subsection. The concentration contours and hatch patterns indicate where continuing and/or additional restoration is needed to reduce uranium concentration to below the Site standards. Like the discussion in the preceding sections for the Alluvial Aquifer, uranium is the primary COC and the following discussion of restoration activity uses uranium as the key indicator constituent for evaluating seepage impacts as well as restoration progress. The concentration of other COCs may exceed their Site standards in the On-site area, but the areas where Site

standards are exceeded for other COCs are generally similar to or contained within the areas requiring restoration to meet the uranium Site standard. The Chinle wells will be discussed separately for the Upper, Middle and Lower Chinle Aquifers.

The Upper Chinle Aquifer collection is mainly near its subcrop area near the LTP as shown in **Figure 6-23**. Upper Chinle Aquifer groundwater is being extracted from well CE15 which is located north of Broadview Acres (**Figure 6-23**). Injection into Upper Chinle Aquifer well CW5 is occurring and injection into well CE15A is planned to drive the Upper Chinle groundwater toward the collection wells north of these injection wells. Injection into wells located just north of Broadview acres (**Figure 6-23**) is also expected to increase the gradient to the south and cause the Upper Chinle groundwater with elevated uranium concentrations in the middle of Felice Acres to move into the alluvium through the Chinle subcrop contact in South Felice Acres.

Figure 6-24 shows the Upper Chinle Aquifer wells near the LTP and Collection Ponds with active collection near the Chinle subcrop and in four wells (CE5, CE6, CE11 and CE19) located southwest of EP2. The operation of collection wells located within and directly adjacent to the subcrop benefits both the Upper Chinle Aquifer and the Alluvial Aquifer as it captures and removes seepage-impacted groundwater from both aquifers. Selected wells in the Upper Chinle subcrop area are completed in both the alluvium and Upper Chinle sandstone because the aquifers are hydraulically connected at the subcrop. As restoration progresses near the subcrop, additional Upper Chinle Aquifer wells located along the subcrop and in the plume area extending to the east of the subcrop (**Figure 6-24**) are planned to be operated.

The locations of the Middle Chinle Aquifer collection and injection wells used in the existing remediation system are presented on **Figure 6-25** and **Figure 6-26** along with the 2018 uranium concentration contours and patterns indicating areas where the Site standards are exceeded. **Figure 6-25** shows the existing Middle Chinle Aquifer wells west of the West Fault with only one operating collection well, CW62, and three operating injection wells in 2018. Collection from well CW62 is expected to be effective in restoring this area with continual pumping. The collection and injection wells in the South Off-site area are shown on **Figure 6-26** with five operating collection wells (Y1, Y7, Y13, Y23 and CW45) in South Felice Acres and six operating collection wells (R1, R2, R3, R4, R5 and R11) in the northeast corner of Section 3. Groundwater collection in these areas is expected to reduce the uranium concentrations to levels below the Site standards with a few additional years of operation.

Collection from the Lower Chinle Aquifer for the existing remediation system is shown on **Figure 6-27** with one Lower Chinle well (R68) being pumped during 2018. Additional collection from the Lower Chinle Aquifer is expected to be undertaken but significant expansion in the Lower Chinle Aquifer collection will likely be delayed until the Alluvial Aquifer in the Middle Chinle subcrop area and the Middle Chinle Aquifer are restored. The planned sequencing of the restoration including the delay of expanded Lower Chinle Aquifer collection is based upon the priority assigned to Alluvial Aquifer and Middle Chinle Aquifer collection, the efficient utilization of zeolite treatment capacity, and the improved effectiveness of overall restoration when the Alluvial Aquifer above the Chinle subcrops is restored.

6.3 TREATMENT WATER BALANCE

Collected groundwater was initially pumped to the mill process water ponds resulting from tailings discharge on the LTP and decanted to the mill until milling ended in 1990. Because the water was processed through the mill ion exchange (IX) process, uranium was removed from the collected groundwater during the operation of the mill. Collected water was discharged to the evaporation ponds after mill operation ceased. RO treatment of the collected On-Site groundwater began in 2000 and is planned to continue until groundwater restoration is complete. Zeolite system treatment of the Off-Site water with discharge to the PTT began in 2016 and is planned to continue until Off-Site groundwater restoration is complete. **Table 6-6** presents the rates and volumes of feed, treated, and disposed water for the RO, zeolite and evaporation ponds for 2016 through 2018.

The 2012 operational flow sheet is presented on **Figure 6-28** to show the water balance during the final year of land application and prior to the operation of the zeolite treatment systems. The hydrogeologic units undergoing restoration in 2012 included the Alluvial Aquifer, the Upper Chinle Aquifer, the Middle Chinle Aquifer and the Lower Chinle Aquifer. Water treatment occurring in 2012 was limited to RO treatment of On-Site collection water.

The tailings dewatering and flushing programs were active during 2012 and **Figure 6-28** shows an average 128 gpm (105 gpm of well dewatering and 23 gpm toe drain collection) of tailings water being discharged to the evaporation ponds and an average of 264 gpm of flushing injection into the LTP. The average seepage rate from the LTP was estimated to be 154 gpm with a 17 gpm decline in water storage in the LTP observed during 2012. The flushing injection water was supplied by groundwater collection from the Alluvial, Upper Chinle and Middle Chinle Aquifers.

RO treatment was being used to treat the majority of the On-site groundwater collection with an average input of 267 gpm from the Alluvial Aquifer and 11 gpm from the Upper Chinle aquifer during 2012 which resulted in an average of 182 gpm of RO product water being injected into the Alluvial Aquifer.

Figure 6-28 shows the last year of land application irrigation with a yearly average irrigation supply rate of 188 gpm being applied to the irrigated fields. The majority of the irrigation supply was from the Alluvial Aquifer (average of 113 gpm) with only an average 10 gpm supplied from the three Chinle aquifers. The irrigation supply was supplemented by an average 65 gpm pumped from the San Andres Aquifer in order to meet the restriction of a maximum uranium concentration in the irrigation supply of 0.16 mg/L as previously described. Irrigation of the land application areas occurred from 2000 through 2012 with a total of 9,551 acre-feet of water applied over the 13-year period (**Table 6-2**). This equates to an average irrigation supply rate of approximately 455 gpm during the land application program.

Discharge of water to the evaporation ponds for disposal occurred at an average rate of 201 gpm in 2012 while the calculated average evaporation rate for the year was 221 gpm (**Figure 6-28**). Other inputs to the evaporation ponds include an average precipitation contribution of 34 gpm.

Figure 6-28 shows that an average 1222 gpm of fresh water was pumped from the San Andres Aquifer with the majority of this water injected into the Alluvial Aquifer. All of the San Andres water injected into

the Upper Chinle Aquifer was On-site while the average of 30 gpm of San Andres water injection into the Middle Chinle Aquifer occurred in both the On-site and South Off-site areas. Additionally, **Figure 6-28** shows that an average 28.5 gpm was collected from the Alluvial Aquifer (in the L Area wells) for reinjection within the Hydraulic Control Area between the STP and LTP.

Figure 6-29 shows the water balance for 2018 with the operation of the RO and zeolite treatment systems and the utilization of the PTT to mix the RO product, zeolite treated water and fresh water prior to being injected into the groundwater for hydraulic control. The configuration with RO and zeolite treatment processes with supplemental fresh water provided by the San Andres aquifer shown in **Figure 6-28** has been in place since 2016. Between 2012 and 2016, the zeolite treatment process was developed and tested with water supplied from both the On-site and Off-site areas. The RO plant was also upgraded and expanded in 2014 and 2015 including the installation of the PTT. During 2018, the water treatment rates were in part limited by a reduction in the available evaporation capacity resulting from reduced utilization of EP-1 to allow repair of the EP-1 liner planned for 2020.

As indicated in **Figure 6-29**, the RO had an average input rate of 492 gpm with an average 350 gpm of RO product water produced in 2018. The average input to the zeolite cells was 296 gpm with an average 267 gpm of this water being discharged to the PTT for mixing with the RO product and fresh water. The PTT discharged a combined average of 745 gpm (678 gpm, 21 gpm and 46 gpm respectively to the Alluvial, Upper Chinle and Middle Chinle Aquifers) of treated water for injection into groundwater.

The tailings flushing and dewatering ceased in 2015 and 2017, respectively, and therefore the only pumping from the LTP during 2018 was an average of 8.8 gpm from the toe drains. The change in water level elevations in the LTP indicated that the change in tailings water storage within the LTP for the year was a decline equivalent to an average rate of 29 gpm. This water balance indicates the average seepage rate from the LTP was 20 gpm in 2018. The input of water to the evaporation ponds averaged 177 gpm in 2018 including 28 gpm of precipitation on the ponds. A decline in storage of 23 gpm for the year yields an estimate of an average 200 gpm for evaporation during the year based on the evaporation pond water balance.

The rate of pumping from the San Andres Aquifer has declined in the last three years with the diversion of 468 ac-ft (average of 232 gpm) pumped from San Andres wells in 2018. **Figure 6-30** shows that the usage of San Andres Aquifer water (the F.W. Injection bar in the figure) has declined from a typical usage volume of 2000 ac-ft per year before 2016 to less than 500 ac-ft per year in 2018. The water right permit issued by the New Mexico Office of the State Engineer limits maximum withdrawal from the San Andres Aquifer to 500 ac-ft per year starting in 2018.

Figure 6-30 also portrays the transition in water treatment and management processes and the relative rates of water withdrawal since 2002. The irrigation (land application) program was conducted from 2000 through 2012 with the majority of the irrigation water produced from Alluvial Aquifer wells in the Off-site area. From 2002 through 2009, the irrigation supply constituted 25 to 30 percent of the total diversion. During this same time period, the On-site collection was approximately 10 to 15 percent of the total diversion. After irrigation ended in 2012 and prior to the zeolite water treatment initiated in 2016, the

Off-site collection was limited to water supplied for tailings flushing injection or testing of zeolite treatment. The On-site collection rates were also reduced during this three-year transition period while the RO system was being expanded and upgraded. Starting in 2016, the On-site collection rates were increased as a result of the increased RO capacity. The Off-site collection rates were also increased as the zeolite treatment systems were utilized for treatment of this Off-site groundwater. The rate of freshwater collection from the San Andres Aquifer declined since 2016 with a maximum diversion of 500 ac-ft per year starting in 2018. The gradual decline in total diversion (**Figure 6-30**) from 2016 to 2018 is attributed to necessary repairs and maintenance for the RO and zeolite systems, and the reduction in evaporation capacity prior to the planned repair of EP-1.

6.4 ADDITIONAL REMEDIAL TECHNOLOGIES EVALUATED

In addition to the groundwater remediation technologies that were extensively used or are currently being used at the Site (Sections 6.1 and 6.2), the effectiveness and implementability of several remedial technologies were evaluated through bench and pilot-scale testing. The tested technologies included in situ groundwater treatment technologies (tripolyphosphate and bioremediation) and ex situ treatment technologies (electrocoagulation, ion exchange, activated alumina, and deep well injection). A summary of the technology evaluations including the technical approach and results and conclusions from studies is presented here to document the technology evaluations and support the screening and evaluation of technologies and remedial alternatives in **Section 8**.

6.4.1 Tripolyphosphate

Tripolyphosphate (TPP) injection is a remediation approach that includes injection of a TPP solution to create an in-situ treatment zone such as a permeable reactive barrier (PRB) that removes uranium from groundwater. The technology works by forming phosphate minerals (autunite and apatite) in the aquifer. Autunite directly sequesters aqueous uranium in the oxidized form. In addition, excess phosphorous results in apatite mineral formation, providing a long-term source of treatment capacity for uranium migrating into the treatment zones.

Separate field-scale pilot TPP injection studies were completed at the Site: one within the LTP; one limited pilot injection test in the Alluvial Aquifer east of the LTP; a pilot and an expanded TPP injection test within the Alluvial Aquifer downgradient (southwest) of the LTP. These pilot tests are described below.

Between 2010 and 2012, an in situ TPP pilot study was completed in the LTP with the following objectives:

- Precipitate stable phosphate minerals in the treatment zone that would remain stable and do not dissolve when pore water geochemistry returns to pre-injection conditions;
- Immobilize and remove uranium from pore water in the LTP; and
- Minimize mobilization of molybdenum and selenium from tailings solids as a result of the TPP solution injection.

Results from the field-scale study in the LTP indicated the following:

- Phosphate and calcium amendment solutions were dissolved, delivered and distributed in the subsurface;
- Uranium was immobilized from pore water with removal ranging up to 81% where geochemical conditions (pH adjustment) and phosphate concentrations were sustained long enough for precipitation to occur;
- Geochemical and hydrogeological conditions in the LTP were shown to be complex and different than the Alluvial Aquifer and presented complications to treatment performance including high reactivity of the tailings solids, high buffering capacity of tailings solids and pore water, low permeability that limited solution delivery to fine-grained materials, and continuous influx of untreated water with poor water quality;
- Monitoring and adjustment of pH by adding acid (e.g. sulfuric acid) was required to create and maintain the appropriate geochemical conditions in LTP pore water;
- Required pH adjustment caused off-gassing and heat generation that did not appear to affect performance; and
- No significant mobilization of molybdenum or selenium to pore water occurred in the TPP treatment zone.

A field-scale TPP pilot study was initiated in the Alluvial Aquifer between 2013 and 2014 through injections of TPP into the Alluvial Aquifer in limited areas east and southwest of the LTP. Post-injection performance monitoring indicated that injection of TPP removed and immobilized dissolved uranium through in situ precipitation. In addition, formation of apatite in the treatment zone likely maintained uranium immobilization for at least one year.

The TPP pilot study was expanded in the Alluvial Aquifer west of the LTP between 2015 and 2016 by installation of a 750-foot long PRB using 34 injection wells and seven extraction wells near the southwest corner (downgradient) of the LTP. To install the PRB, TPP solutions were injected into the upper and lower portions of the Alluvial Aquifer over a period of 6 weeks. Although injection well fouling and loss of injectability were observed, periodic flushing with unamended groundwater was able to maintain sufficient injectability to install the PRB.

Results from the field-scale study based on 9 months of performance monitoring indicated the following:

- Significant uranium removal from groundwater (up to 86%) was observed within some areas of the PRB. When inconsistent or limited performance was observed, performance monitoring locations were outside the radius of influence (ROI) of the PRB injection wells or were near the northern and southern ends of the PRB where variable groundwater flow directions were observed;
- Within the PRB where white solids (most likely amorphous calcium tripolyphosphate) were observed in the injection wells, uranium removal from groundwater was greatest and ranged up to 93%;

- Adsorbed arsenic was displaced from alluvial soil by the TPP solution; and, arsenic concentrations in groundwater increased above baseline conditions within the ROI of the injections wells in the PRB. Arsenic concentrations in groundwater outside the PRB remained near baseline concentrations;
- Variations in groundwater flow conditions influenced the distribution of orthophosphate in the Alluvial Aquifer and limited the performance evaluation to wells closest to the PRB; and
- Significant reductions in concentrations of other COCs in alluvial groundwater (e.g. molybdenum, vanadium, and selenium) were not observed during the study.

In summary, the complex geochemical and heterogeneous tailings solids conditions within the LTP limited the performance of TPP and could be expected to severely limit the feasibility of applying TPP full-scale directly within the LTP. In the Alluvial Aquifer, the field-scale study indicates that in situ treatment of uranium using TPP or some other injectable apatite-forming solution is feasible, and a full-scale design would need to include detailed evaluation of the ability to effectively deliver and distribute the solution and establish the required extent of the PRB to treat the mass flux of uranium in groundwater.

6.4.2 Bioremediation

An in-situ bioremediation process for treating COCs in groundwater at the Site was tested which included subsurface injection of a readily degradable organic carbon substrate to create an anaerobic in situ reactive treatment zone. Under anaerobic conditions, indigenous microbes use nitrate and sulfate as electron acceptors. The anaerobic conditions reduce the oxidation states of uranium, molybdenum, and selenium, which can be removed from groundwater through the creation of low solubility metal/nonmetal precipitates.

An In-Situ Biological Treatment (ISBT) field-scale pilot study was initiated in 2000 to evaluate the ability of anaerobic biological treatment to decrease sulfate and nitrate and immobilize uranium, molybdenum, and selenium in situ. Prior to the study, sulfate reduction was occurring naturally as evidenced by hydrogen sulfide in groundwater indicating that sulfate reducing bacteria are indigenous in groundwater and biostimulation of sulfate reducing bacteria could be feasible.

Prior to the field study, a bench-scale study evaluated nutrient mixes and organic carbon sources including glucose, acetate, methanol, a glucose-methanol blend, molasses, and lactose to stimulate microbial growth, create anaerobic conditions, achieve groundwater cleanup goals, and limit the potential for biological well fouling. Based on the results of the bench-scale study, methanol at a concentration of 25 mg/L was selected as the carbon source for the field-scale study.

For the field-scale study, two ISBT systems were constructed at an East site consisting of a cluster of 8 wells and a West site consisting of 10 wells. Baseline data showed the two sites represented different concentrations of COCs and hydrogeologic conditions where the East site had a relatively low hydraulic conductivity and the West site had a relatively high hydraulic conductivity.

Following delivery of the methanol, significant reduction in uranium, molybdenum, and selenium were observed, but the ability to achieve alluvial groundwater standards for uranium and molybdenum was not consistent within the performance monitoring networks at both study sites. The quantity of carbon substrate delivered was adequate to complete nitrate reduction and start sulfate reduction, but not enough to complete sulfate reduction and sustain the reducing conditions to achieve the required reduction in COCs throughout the study areas. Uniform and adequate delivery of the carbon substrate was limited heterogeneity within the Alluvial Aquifer and issues with the delivery systems.

In summary, ISBT and injection of a soluble and readily degradable carbon substrate can quickly create the reducing conditions required to remove the COCs from groundwater. However, ISBT would be difficult to implement across a large treatment area and would likely require continuous or periodic delivery of carbon substrates to maintain the appropriate geochemical conditions. The stability of sulfide and precipitates that remove COCs is uncertain if redox conditions return to background.

6.4.3 Electrocoagulation (EC)

Electrocoagulation (EC) is an ex situ water treatment method that applies an electrical current through a treatment vessel via an anode and cathode, which removes dissolved multivalent metals such as uranium from the water by corrosion of an anode that produces coagulant particles, and electrically destabilized agglomeration of destabilized metals as flocs. The most common anodes are iron and aluminum that produce multivalent ions, which favor coagulation (Nariyan et al. 2017). During the electrocoagulation process with an iron anode, iron is released as poly-oxyhydroxide and oxide complexes, which act as coagulants that react with uranium to form uranium oxide solids that are removed as flocs.

A bench-scale study of EC performance on water samples from the Site was performed by Gerber Pumps International, Inc. and summarized in a proposal from Powell Water Systems, Inc. dated November 9, 2011. The results and conclusions from the study showed that uranium, molybdenum, and selenium can be significantly removed by EC from site water. Iron anodes were more effective than aluminum anodes and were recommended for a full-scale system.

In 2012, Baroid Industrial Drilling Products completed a bench-scale evaluation of CleanWave® electrocoagulation treatment process and recommended a two-step treatment process that included ultrafiltration following EC to meet the site treatment targets. A field-scale demonstration of CleanWave® was recommended and implemented in September and October 2013. The 100-gpm capacity treatment system included the following process steps to achieve treatment targets:

Untreated water was aerated in a source tank (dissolved oxygen > 5 mg/L) to oxidize water and provide optimal redox conditions for uranium and molybdenum removal.

- The CleanWave® EC unit used iron plate anodes and operated at 200 amps and 80 volts to produce the required flocculent production rate.
- pH adjustment followed the EC unit to maintain optimal pH (< 4) conditions for co-precipitation and removal of molybdenum.

- Multiple 18,000-gallon weir tanks provided residence time for particle settling and solids separation from the treated water. Following pH-controlled removal of molybdenum in the first weir tank, disodium phosphate (DSP) was added to flocculate uranium in the second weir tank.
- Ultrafiltration (UF) with a nominal pore diameter of 0.03 micrometers was required to remove suspended micro-flocs.

The average uranium and molybdenum influent concentrations during the study were 3.0 mg/L and 2.2 mg/L, respectively. The average uranium effluent concentration was 0.027 mg/L indicating the treatment train removed 99% of the uranium. The average molybdenum effluent concentration was 0.86 mg/L indicating the treatment train removed 61% of the molybdenum. Although the planned and implemented iron dosage decreased molybdenum concentrations to less than the target of 0.10 mg/L in the bench study when pH was less than 4, molybdenum in micro-flocs was not adequately removed in the first weir tank, was carried over to the DSP weir tank, and solubilized when the pH increased in the second weir tank after DSP addition. Additional treatment steps were recommended to improve molybdenum removal including increasing the iron dosage, using a circular clarifier with sludge recycling and floc mixing, and an additional UF treatment step prior to DSP addition.

In summary, the study indicated that EC can achieve the treatment targets for uranium but is not effective as configured at removing molybdenum to the required target. Following the EC-initiated coagulation reaction, separate removal steps are required to remove uranium and molybdenum.

6.4.4 Ion Exchange (IX)

IX is a common water treatment process where IX resins remove dissolved ions from water. IX resins can be regenerated with salt solutions (e.g. sodium chloride) that displace the targeted ions (e.g. uranium and molybdenum). In 1994, bench-scale treatability testing was performed to polish effluent from RO treated water with total dissolved solids (TDS) concentrations less than 100 mg/L. The study indicated that IX resins could achieve polishing treatment objectives for molybdenum and uranium for at least 10,000 to 20,000 IX resin bed volumes, respectively, because of the high quality of the RO treated water.

During the EC field demonstration in 2013 (**Section 6.4.3**), a chloride-based anion exchange treatment unit (three resin vessels in series) was used to remove molybdenum from the UF permeate (treated water). Regeneration of the IX resin was completed with 3 bed volumes of a 1% sodium chloride solution. The observed order of adsorption affinity for the IX resin was uranium, sulfate, molybdenum, selenium, and chloride. As the IX resin reached sorption capacity, molybdenum was released by the resin because of the sorption preference for sulfate.

In summary, IX resin systems can be designed to target effective removal of dissolved ions including uranium, molybdenum, and selenium from water. However, treatment efficiency and effectiveness limits application of IX as a polishing step following other water treatment options that significantly remove suspended and dissolved solids. Thus, IX as a standalone treatment option is not a feasible option for groundwater at the Site.

6.4.5 Activated Alumina (AA)

Activated Alumina (AA) is a highly porous aluminum oxide solid with a very high surface area to weight ratio that is used in treatment vessels to remove dissolved ions from water in a process similar to the IX treatment process. Spent AA is typically regenerated with a caustic solution (1% NaOH) to remove the adsorbed ions followed by water and a weak acid solution (sulfuric acid) to neutralize residual caustic solution and reactivate the alumina.

In 1994, bench-scale treatability testing was performed to polish effluent from RO- treated water with TDS concentrations less than 100 mg/L. The study indicated that AA could achieve polishing treatment objectives for molybdenum and uranium for at least 600 bed volumes before uranium breakthrough.

In summary, AA systems can be designed to target effective removal of uranium and molybdenum from water as a polishing step following other water treatment options that significantly remove suspended and dissolved solids. However, the bench study also showed that IX resins have a significantly higher sorption capacity than AA and are easier to regenerate. Thus, IX resin treatment is likely more cost effective than AA if a polishing treatment step is needed.

6.4.6 Deep Well Injection

A feasibility study of using deep well injection to dispose water at the Site was completed in 1994. The study concluded that the most favorable injection zone from the standpoint of formation capacity would be the Permian Meseta Blanca Sandstone, which would likely achieve gravity injection rates ranging from 200 to 300 gpm and pressure injection rates ranging from 300 to 500 gpm. An aquitard (Permian Middle and Lower San Ysidro) above the injection zone would protect the overlying Permian San Andres/Glorieta aquifer, which is a source of municipal water supply.

Regulatory approval to install and operate deep well injection requires that the quality of the groundwater in the receiving formation is poor (TDS is greater than 10,000 mg/L) or that the injected water not negatively affect the water quality of the receiving formation if TDS is less than 10,000 mg/L. Since the estimated TDS of groundwater quality in the Meseta Blanca Sandstone is less than 10,000 mg/L, regulatory approval is not expected to be feasible because untreated water from the Site would contain uranium and molybdenum that could negatively impact the quality of water in the Meseta Blanca Sandstone.

In summary, deep well injection of untreated water is not expected to be feasible because of regulatory concerns and required permitting. Disposal of treated water by deep well injection may be feasible but would require further evaluation and monitoring of water quality at depths approximately 2,100 feet below the ground surface at the Site.

Table 6-1. Reverse Osmosis (RO) Plant Performance 2000-2018

Year	Input (gpm)		Output (gpm)	
	Collection Wells	Tailings Collection	RO Injection	Brine
2000	274	0	204	70
2001	276	5	222	59
2002	383	5	288	100
2003	338	4	266	76
2004	293	12.2	249	64
2005	250	6.4	198	49
2006	257	2.1	184	48
2007	262	0	204	55
2008	264	3.1	194	60
2009	251	0.3	171	60
2010	240	0	166	59
2011	257	1.4	170	58
2012	267	0	182	50
2013	236	0	148	47
2014	235	0	165	47
2015	228	0	112	52
2016	584	8	449	141
2017	497	3	407	108
2018	445	0.5	350	85

Table 6-2. Land Application Areas Water Usage 2000-2012

YEAR	WATER USAGE (AC-FT)	IRRIGATED AREA (AC)	FEET OF WATER APPLIED	AREA IRRIGATED
2000	715	270	2.65	Sections 33 and 34
2001	695	270	2.57	Sections 33 and 34
2002	995	330	3.02	Sections 28, 33 and 34
2003	949	330	2.88	Sections 28, 33 and 34
2004	1028	354	2.90	Sections 28, 33 and 34
2005	1034	394	2.62	Sections 28, 33 and 34
2006	837	370	2.26	Sections 28, 33 and 34
2007	789	370	2.13	Sections 28, 33 and 34
2008	1054	394	2.68	Sections 28, 33 and 34
2009	731	394	1.86	Sections 28, 33 and 34
2010	201	120	1.68	Section 34
2011	213	100	2.13	Section 28
2012	310	220	1.41	Section 28 and 34

Table 6-3. Constituent Concentrations in Water Applied to South Irrigation Field

Constituent Concentrations Applied to the South Irrigation Fields						
	Constituent (mg/L)					
Year	**Uranium**	**Selenium**	**TDS**	**Sulfate**	**Chloride**	**Molybdenum**
2000	0.27	0.12	1549	624	107	<0.03
2001	0.28	0.11	1620	693	120	<0.03
2001	0.26	0.1	1570	642	113	0.04
2002	0.23	0.1	1564	705	126	<0.03
2003	0.22	0.08	1600	732	----	----
2004	0.26	0.09	1553	679	131	<0.03
2005	0.27	0.06	1546	732	162	<0.03
2006	0.29	0.07	1650	716	151	0.04
2007	0.28	0.06	1584	666	134	<0.03
2008	0.24	0.05	1550	702	137	<0.03
2009	0.24	0.05	1673	709	161	<0.03
2010	0.14	0.05	1711	739	167	<0.03
2011	No South Irrigation					
2012	0.12	0.04	1690	689	161	<0.03

Table 6-4. Constituent Concentrations in Water Applied to North Irrigation Field

	Constituent Concentrations Applied to the North Irrigation Field					
	Constituent (mg/L)					
Year	**Uranium**	**Selenium**	**TDS**	**Sulfate**	**Chloride**	**Molybdenum**
2002	0.23	0.08	2070	881	----	----
2003	0.24	<0.005	2070	936	184	<0.03
2004	0.27	0.07	2115	919	185	<0.03
2005	0.35	0.08	2109	927	180	0.04
2006	0.35	0.08	1986	882	175	0.04
2007	0.36	0.08	2122	921	171	0.04
2008	0.36	0.07	1917	927	133	0.04
2009	0.39	0.07	2029	894	174	0.05
2010	No North Irrigation					
2011	0.14	0.03	1409	608	121	<0.03
2012	0.14	0.036	1846	756	189	<0.03

Table 6-5. Zeolite Treatment System Performance 2016-2018

Year	Input (gpm)		Output (gpm)	
	1200 Zeolite	300 Zeolite	Zeolite Treated Water	Regeneration
2016	152	115	233	34
2017	247	56	253	50
2018	259	37	267	29

Table 6-6. Major Treatment and Disposal Flows and Volumes 2016-2018

Major Treatment and Disposal Flows and Volumes During 2016-2018							
		Feed/Input Rate		Treated Water Discharge		Evap/Disposal Discharge	
Treatment/Disposal System	Year	Rate (gpm)	Volume (gallons)	Rate (gpm)	Volume (gallons)	Rate (gpm)	Volume (gallons)
Reverse Osmosis	2016	632	338,550,000	449	240,520,000	146	78,210,000
	2017	553	289,703,000	407	213,438,000	108	56,504,000
	2018	491	253,070,000	350	180,430,000	85	43,820,000
Zeolite	2016	257	137,670,000	233	124,810,000	22	11,780,000
	2017	279	146,083,000	229	124,085,000	50	25,998,000
	2018	296	152,500,000	267	137,640,000	23	11,860,000
Evaporation Ponds	2016	243	130,170,000	--	--	173	92,670,000
	2017	188	98,752,000	--	--	225	117,936,000
	2018	149	76,967,000	--	--	200	103,104,000
Collection Ponds	2016	40	21,430,000	--	--	30	16,070,000
	2017	53	27,883,000	--	--	23	11,846,000
	2018	62	31,960,000	--	--	33	17,010,000

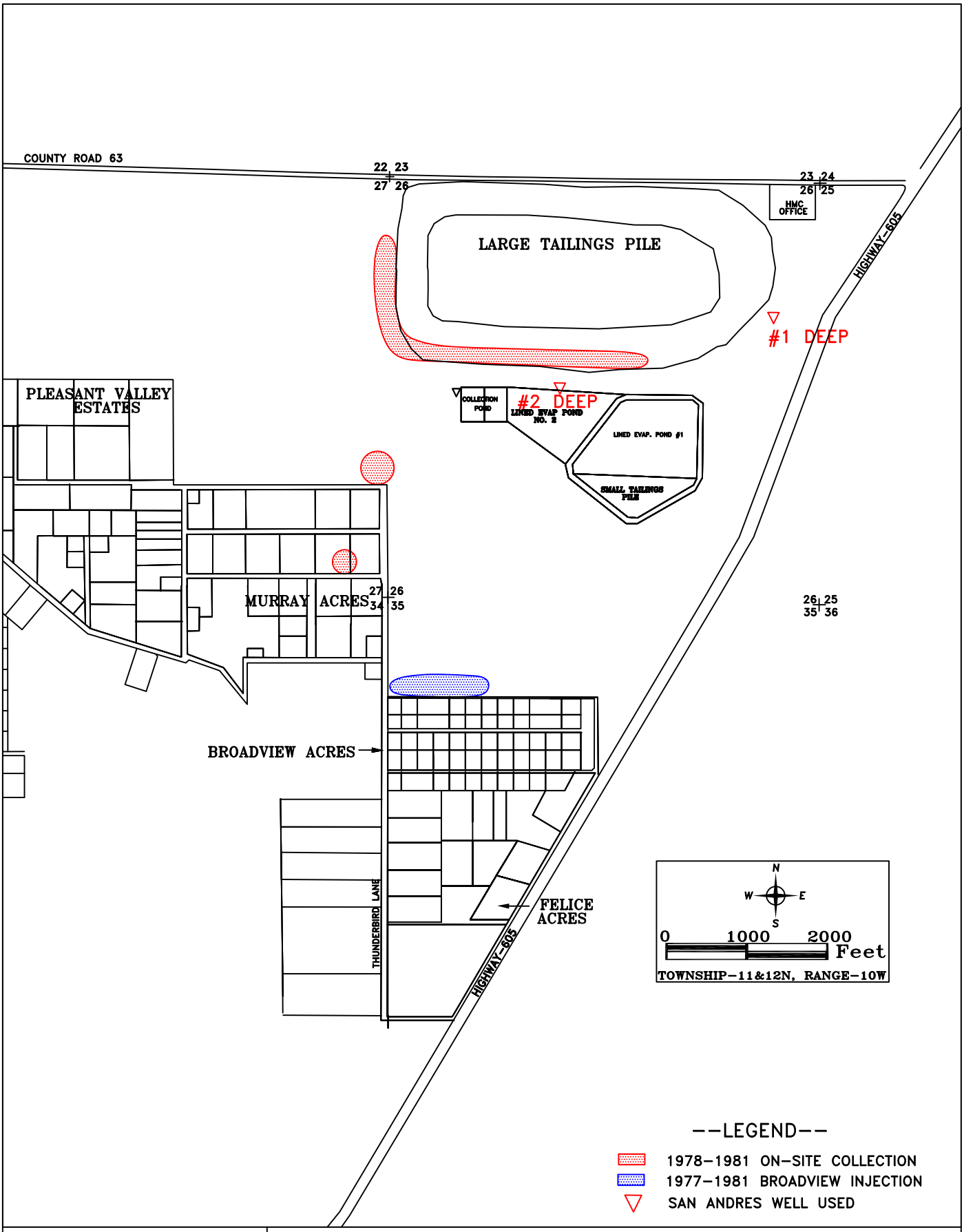

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FIGURE 6-1
ALLUVIAL OPERATION LOCATIONS,
1977-1981

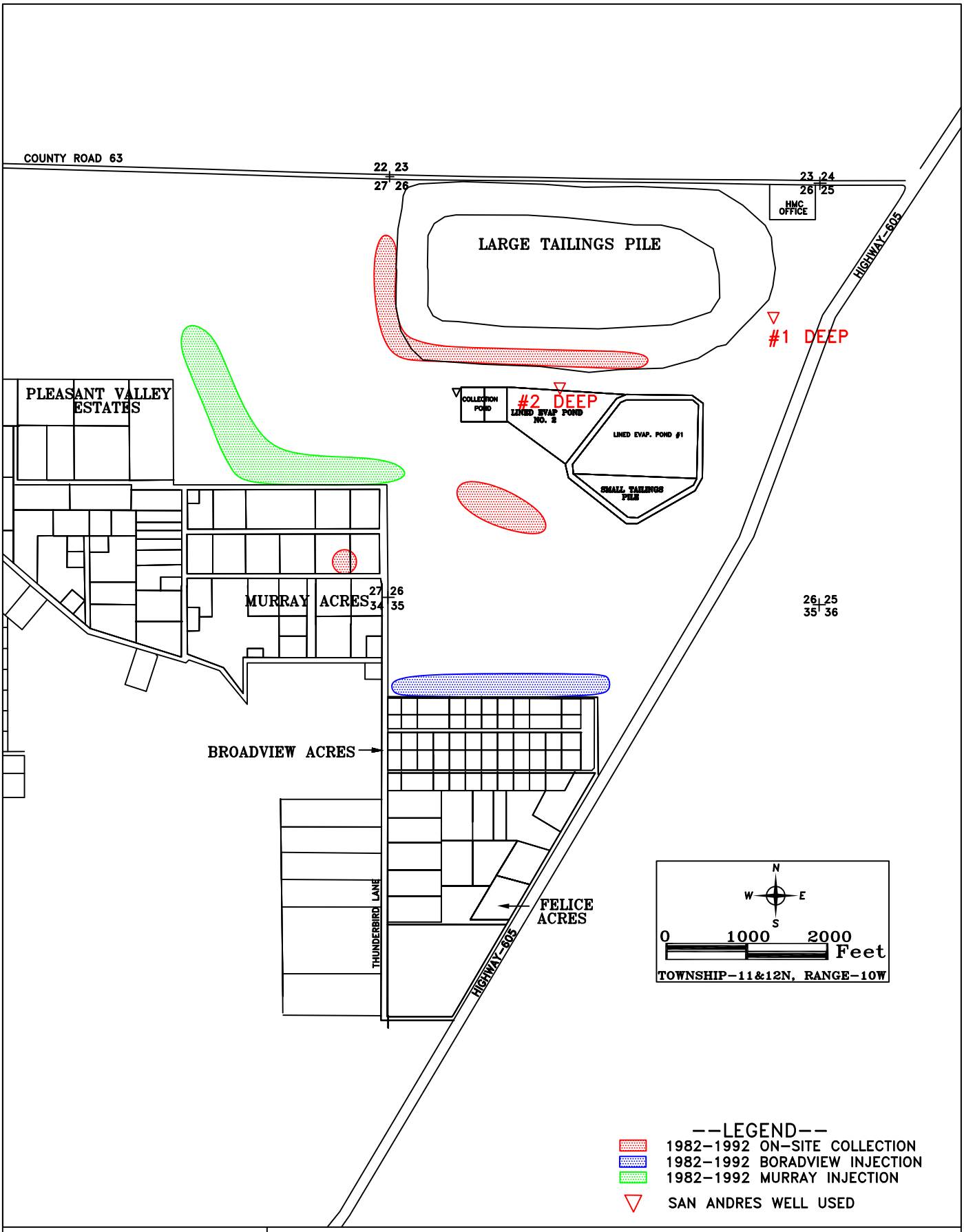

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FIGURE 6-2
ALLUVIAL OPERATION LOCATIONS,
1982-1992

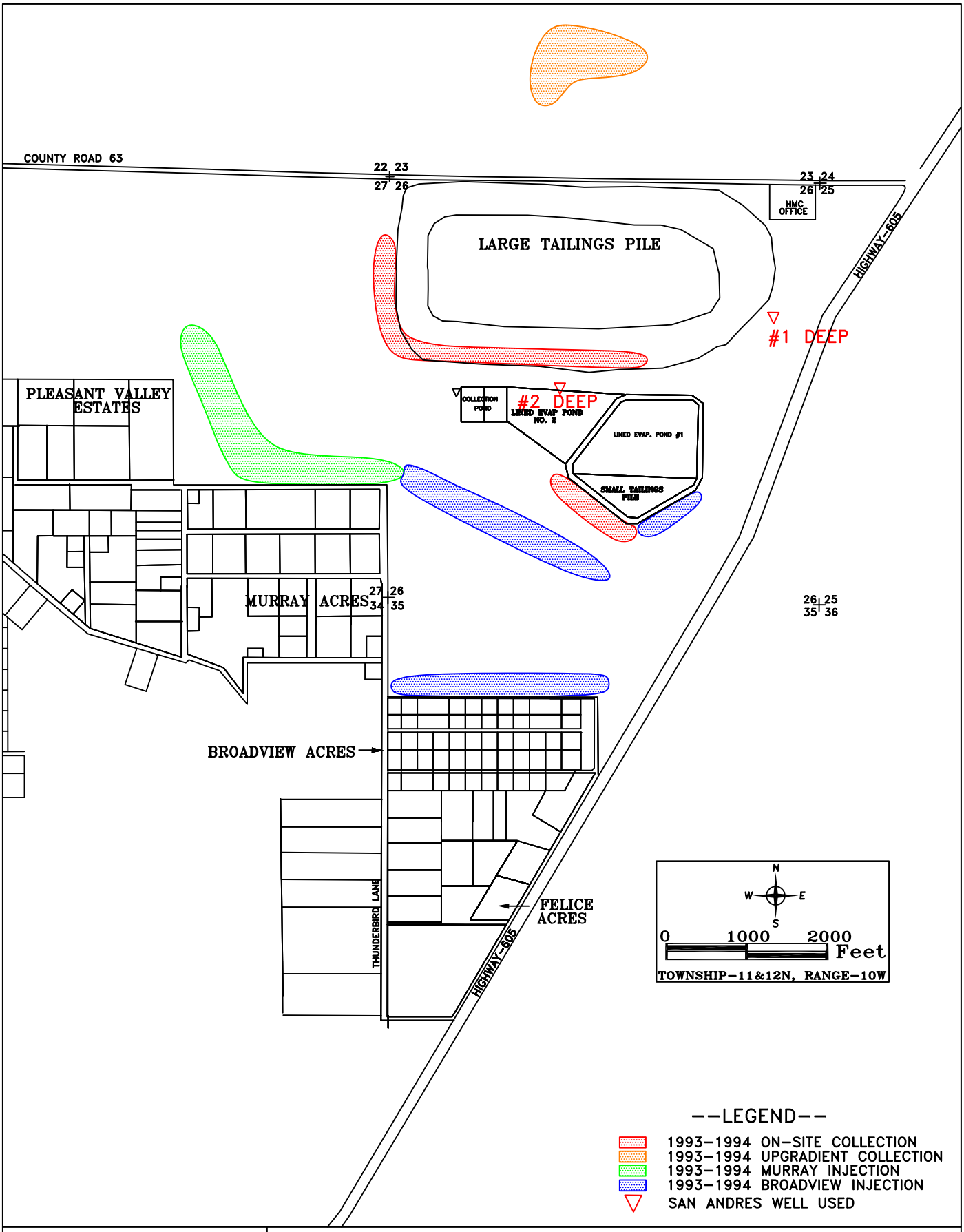

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FIGURE 6-3
ALLUVIAL OPERATION LOCATIONS,
1993-1994

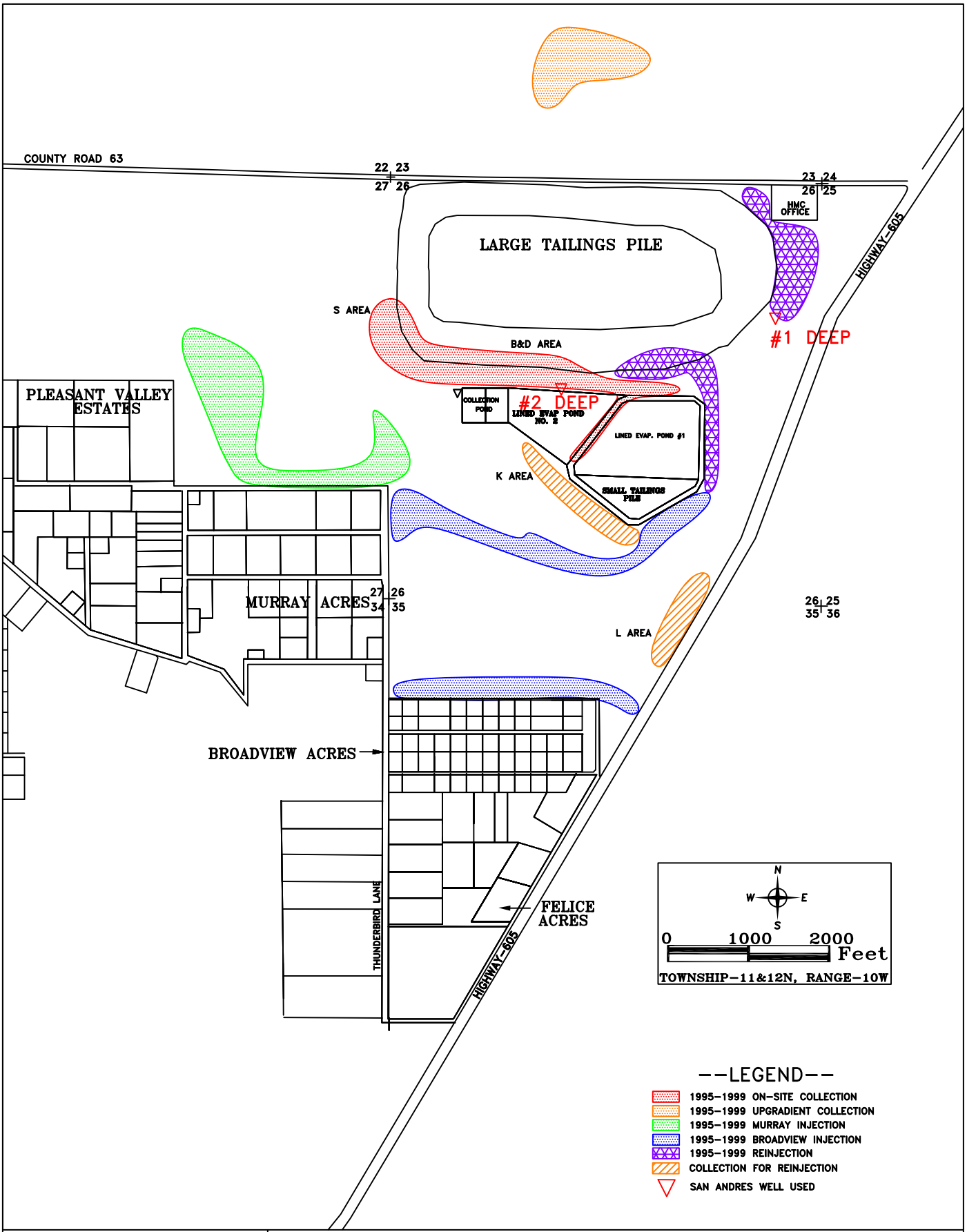

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FIGURE 6-4
ALLUVIAL OPERATION LOCATIONS,
1995-1999

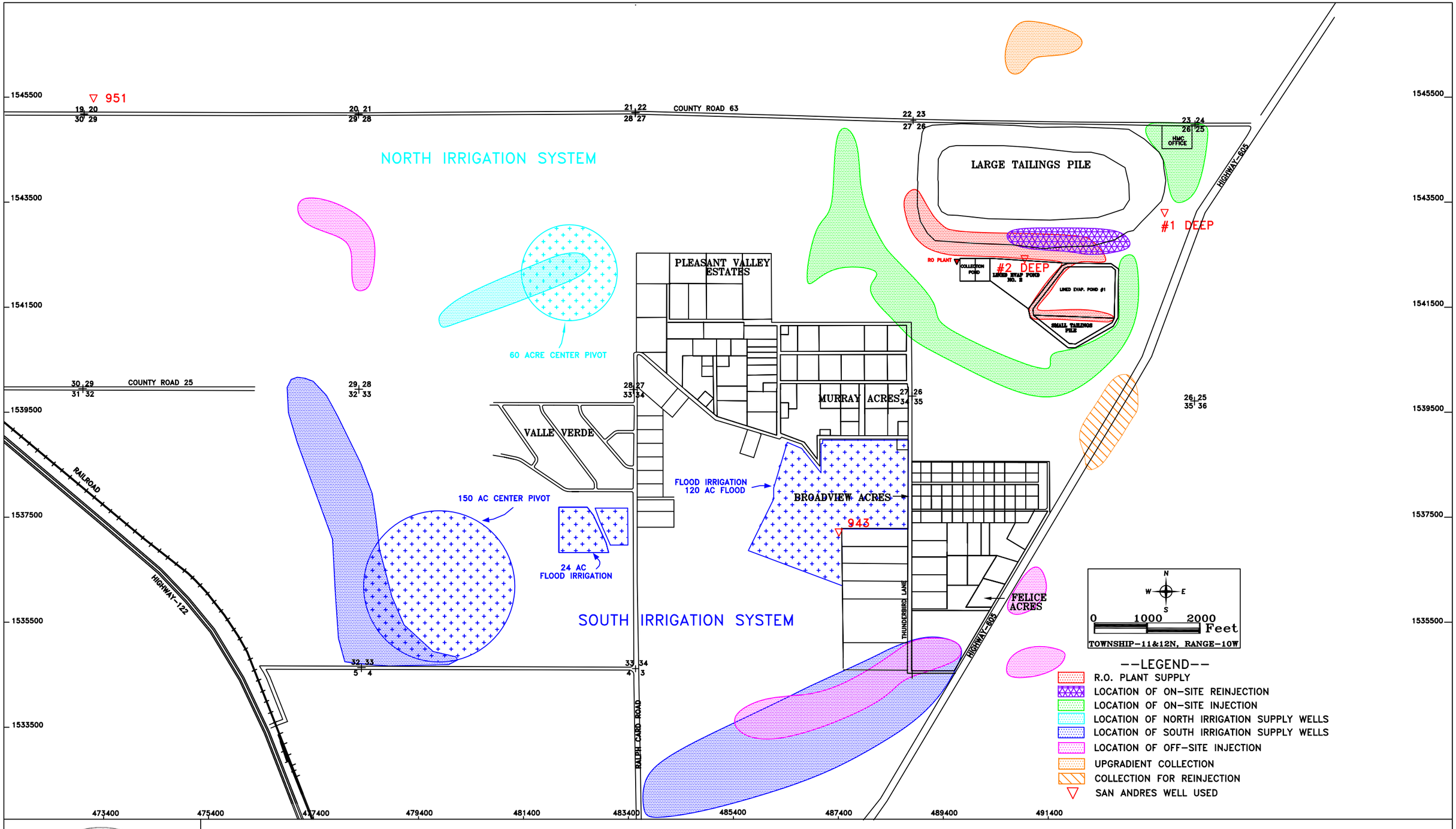

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FIGURE 6-5
ALLUVIAL OPERATION LOCATIONS,
2000-2004

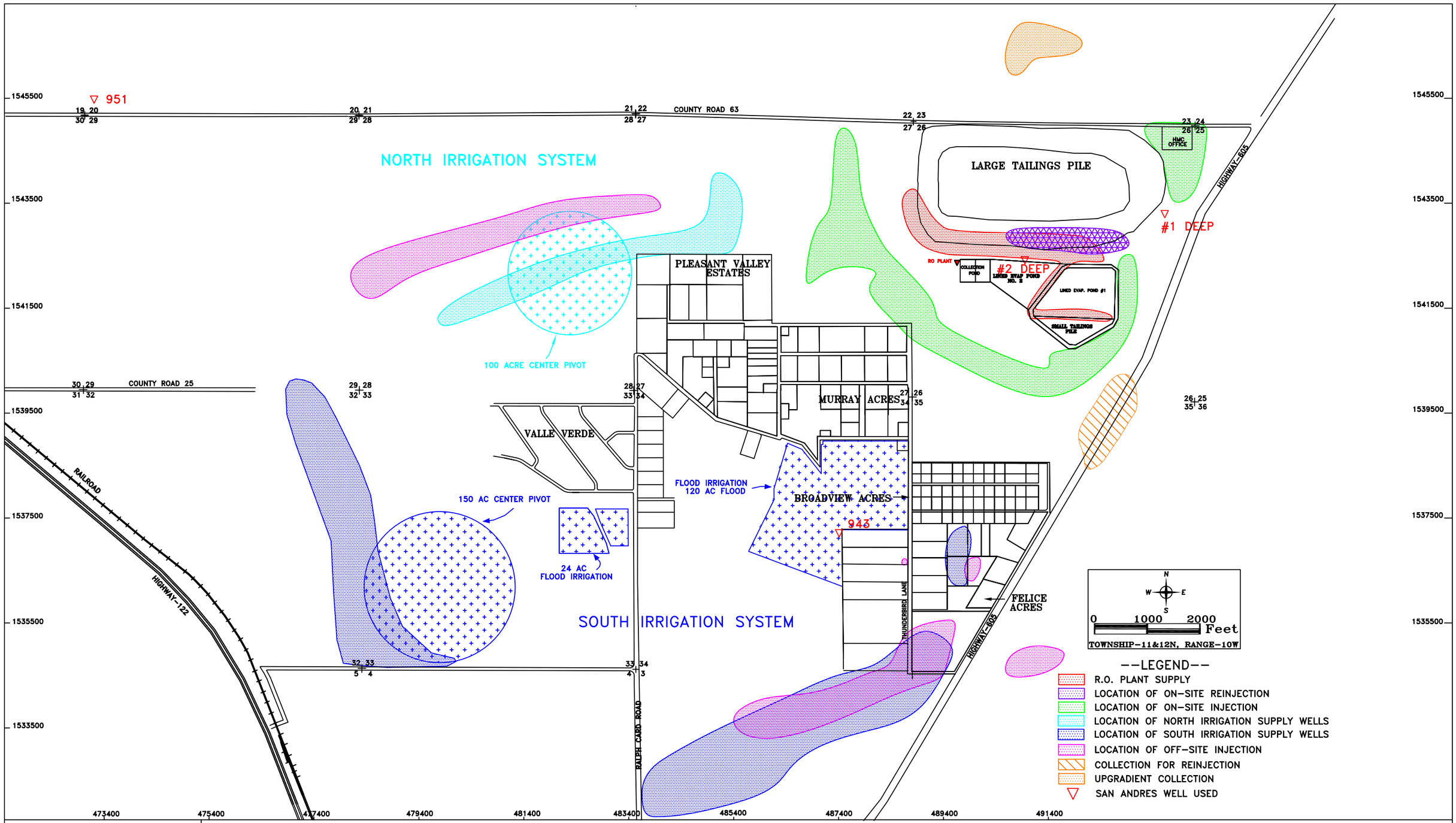

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FIGURE 6-6
ALLUVIAL OPERATION LOCATIONS,
2005-2009

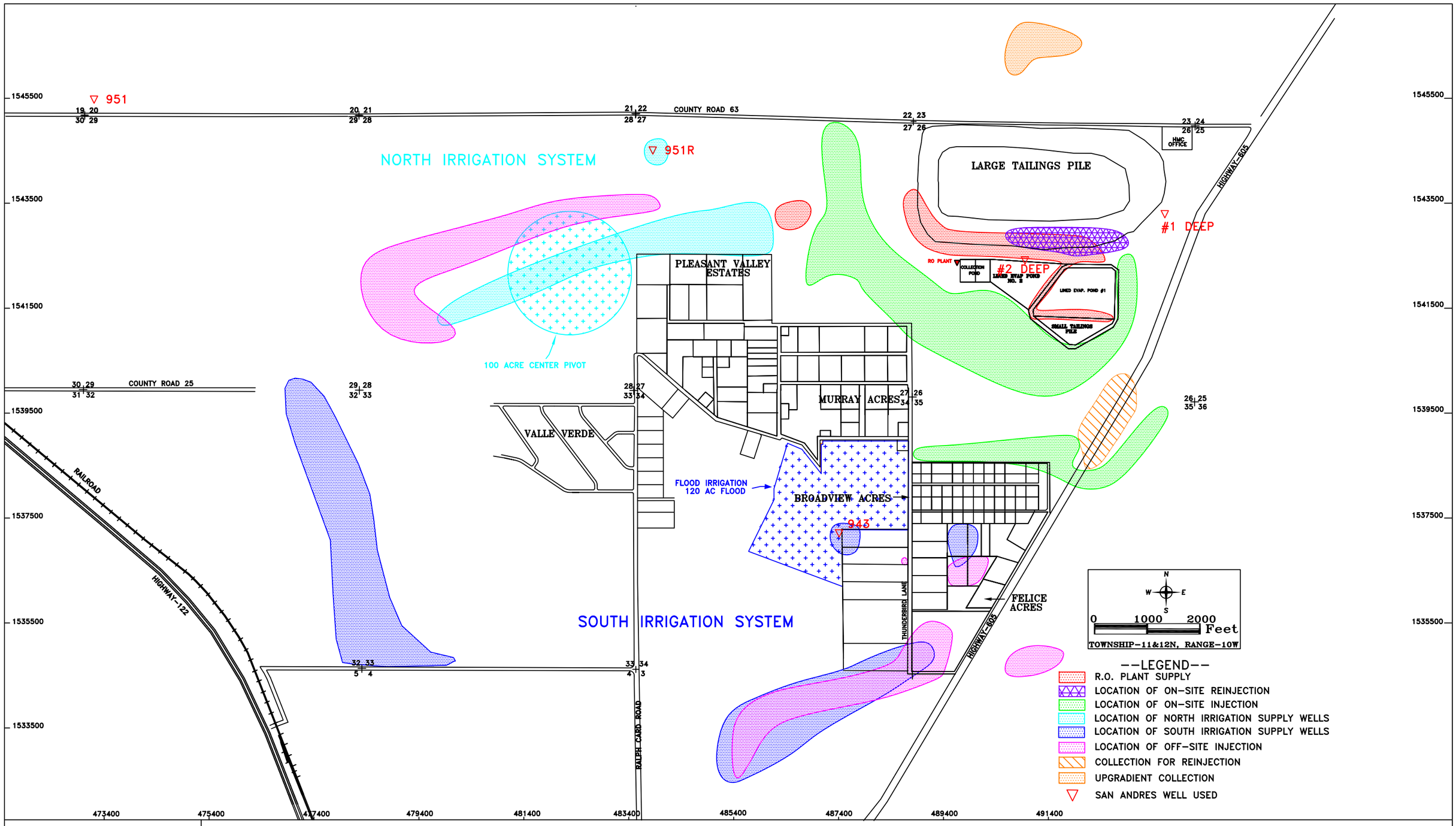

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FIGURE 6-7
ALLUVIAL OPERATION LOCATIONS,
2010-2012

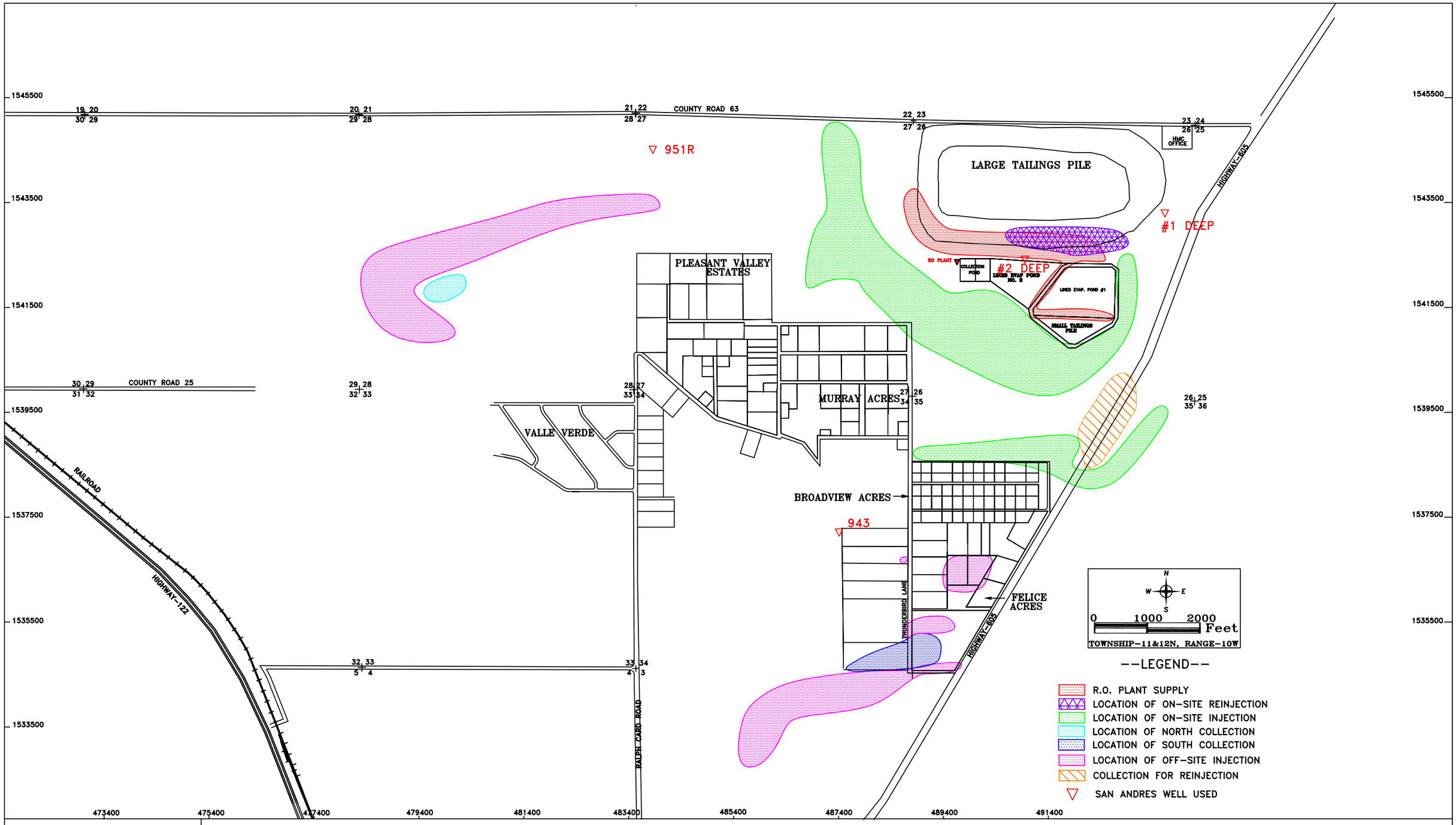

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FIGURE 6-8
ALLUVIAL OPERATION LOCATIONS,
2013-2015

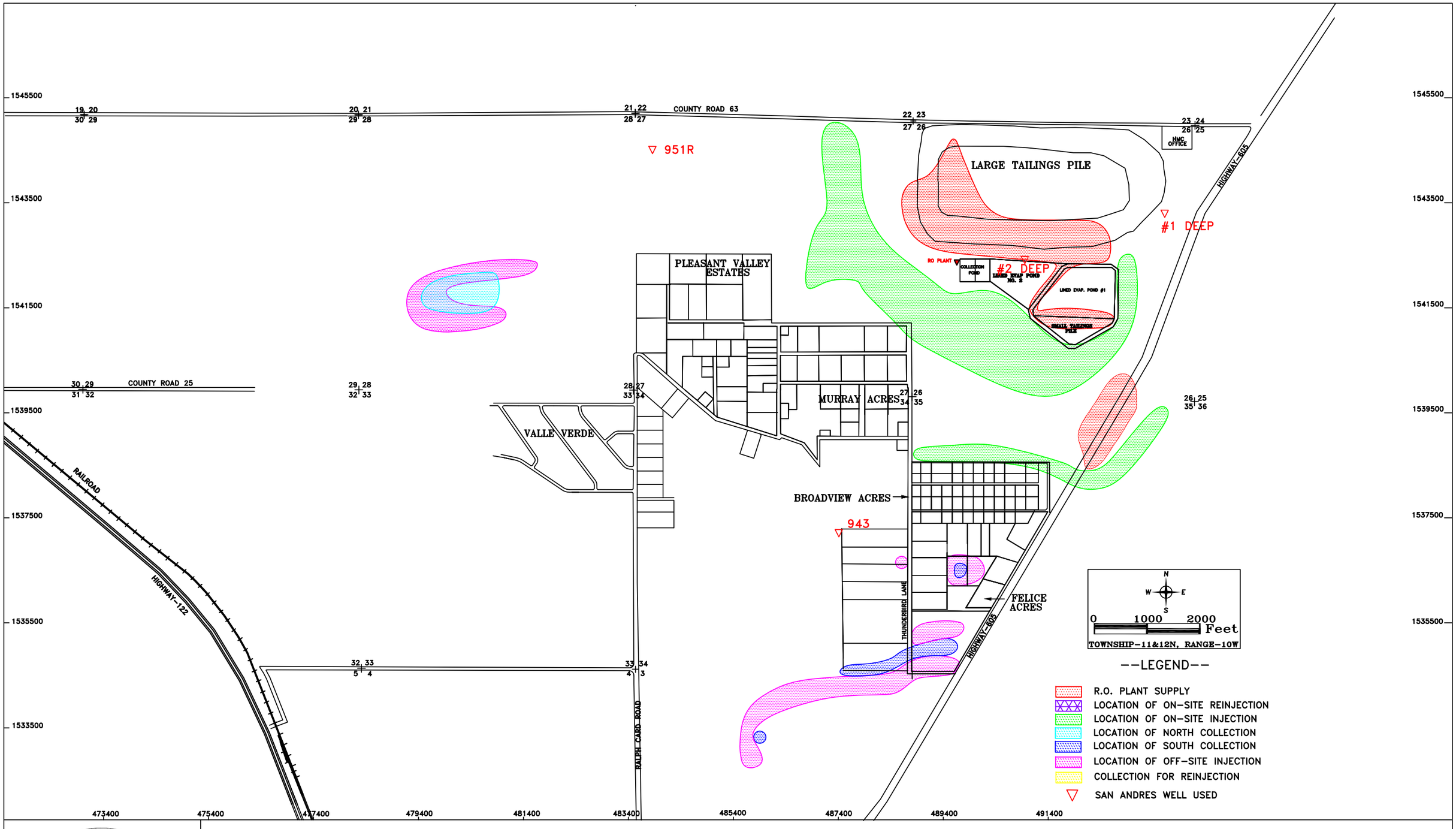

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FIGURE 6-9
ALLUVIAL OPERATION LOCATIONS,
2016-2018

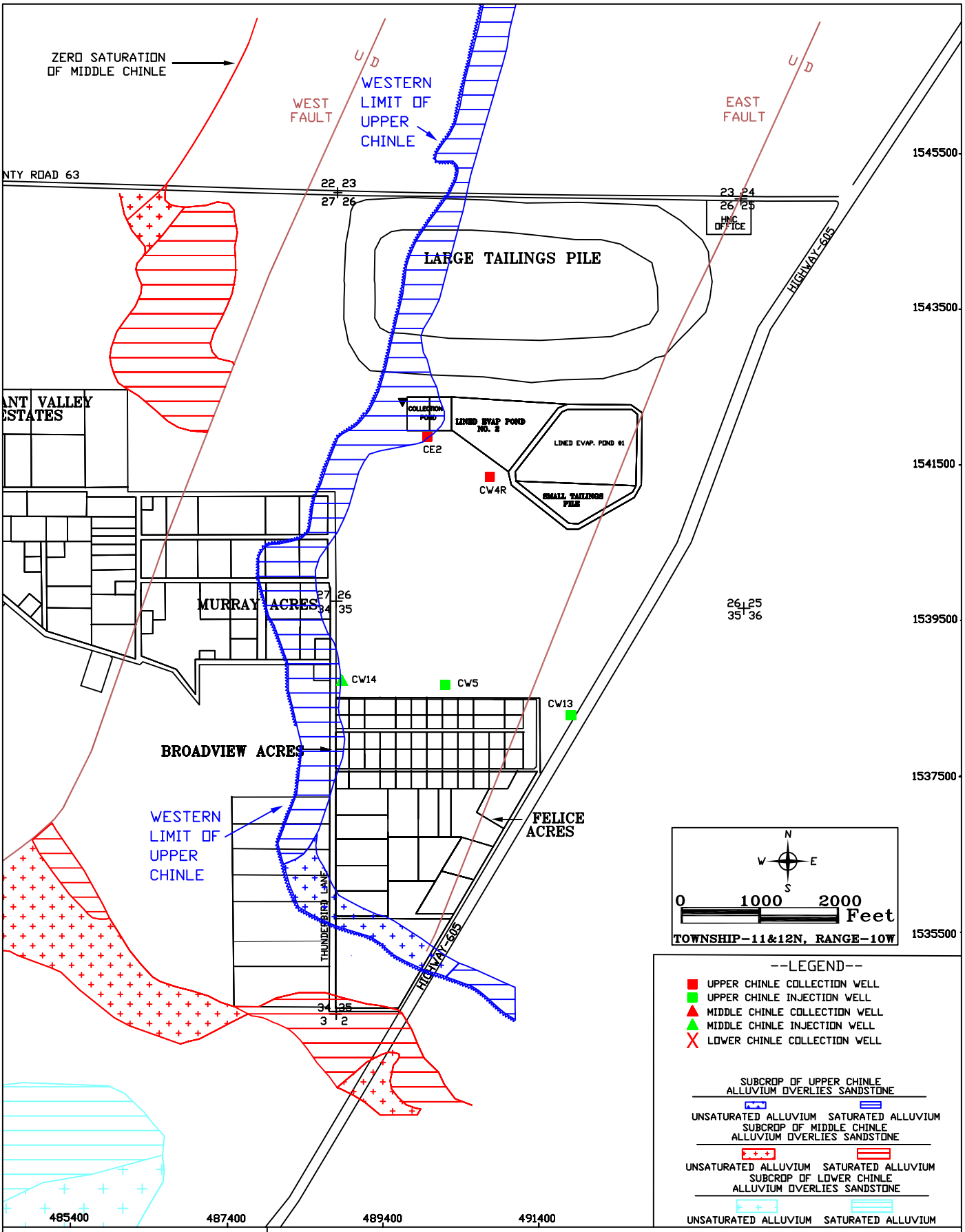

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FIGURE 6-10
CHINLE OPERATION LOCATIONS,
1984-1999

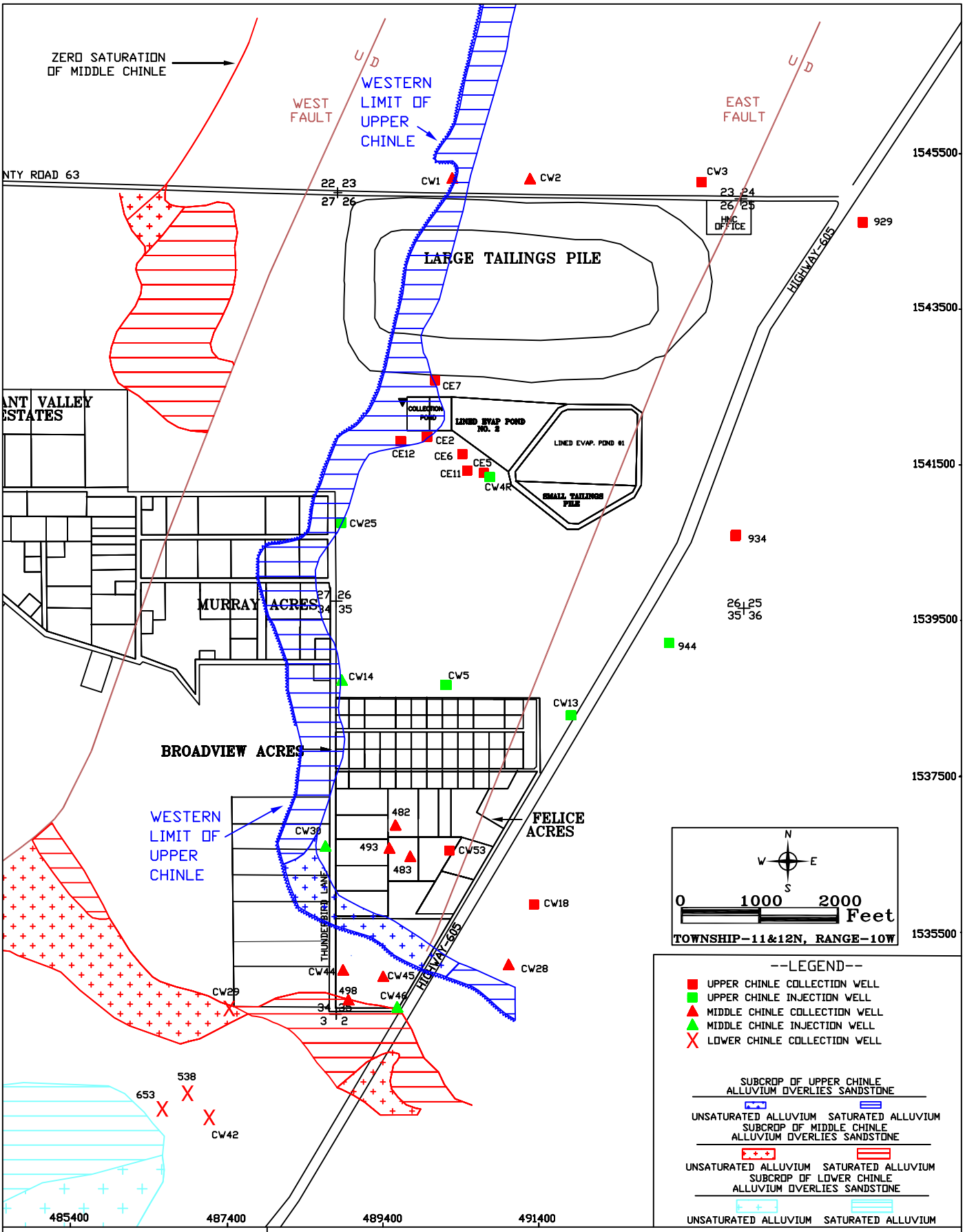

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FIGURE 6-11
CHINLE OPERATION LOCATIONS, 2000-2012

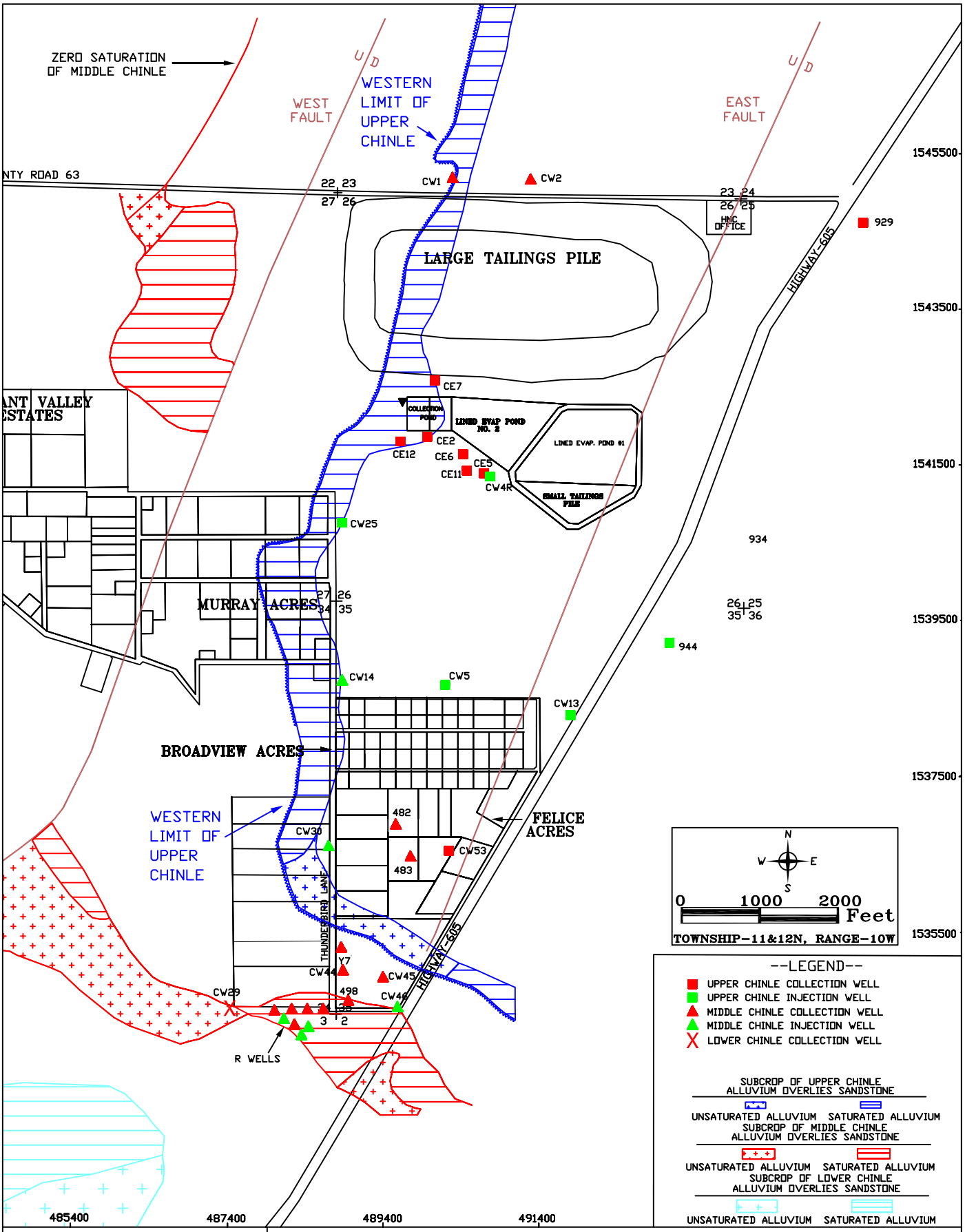

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FIGURE 6-12
CHINLE OPERATION LOCATIONS,
2013-2015

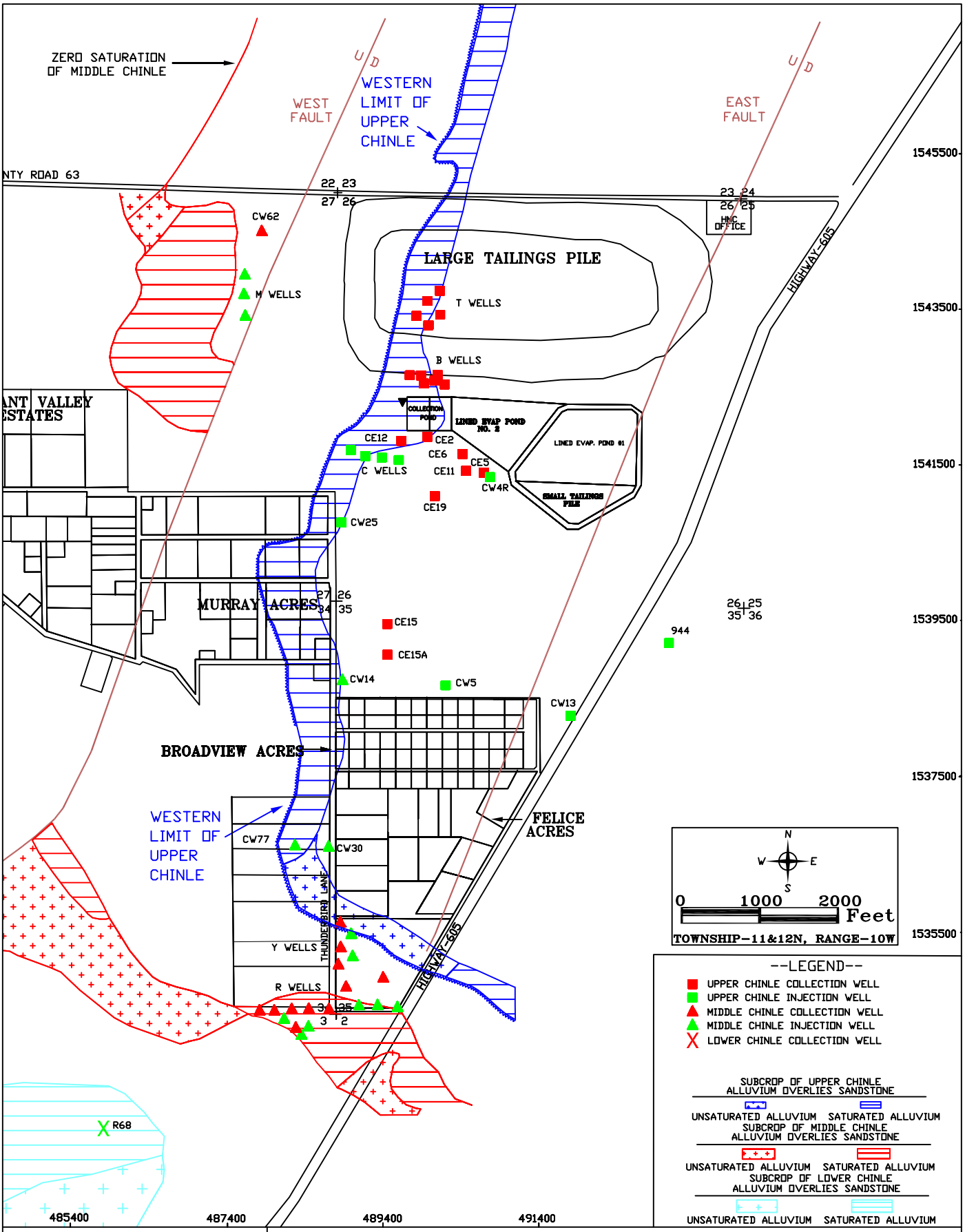

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FIGURE 6-13
CHINLE OPERATION LOCATIONS,
2016-2018

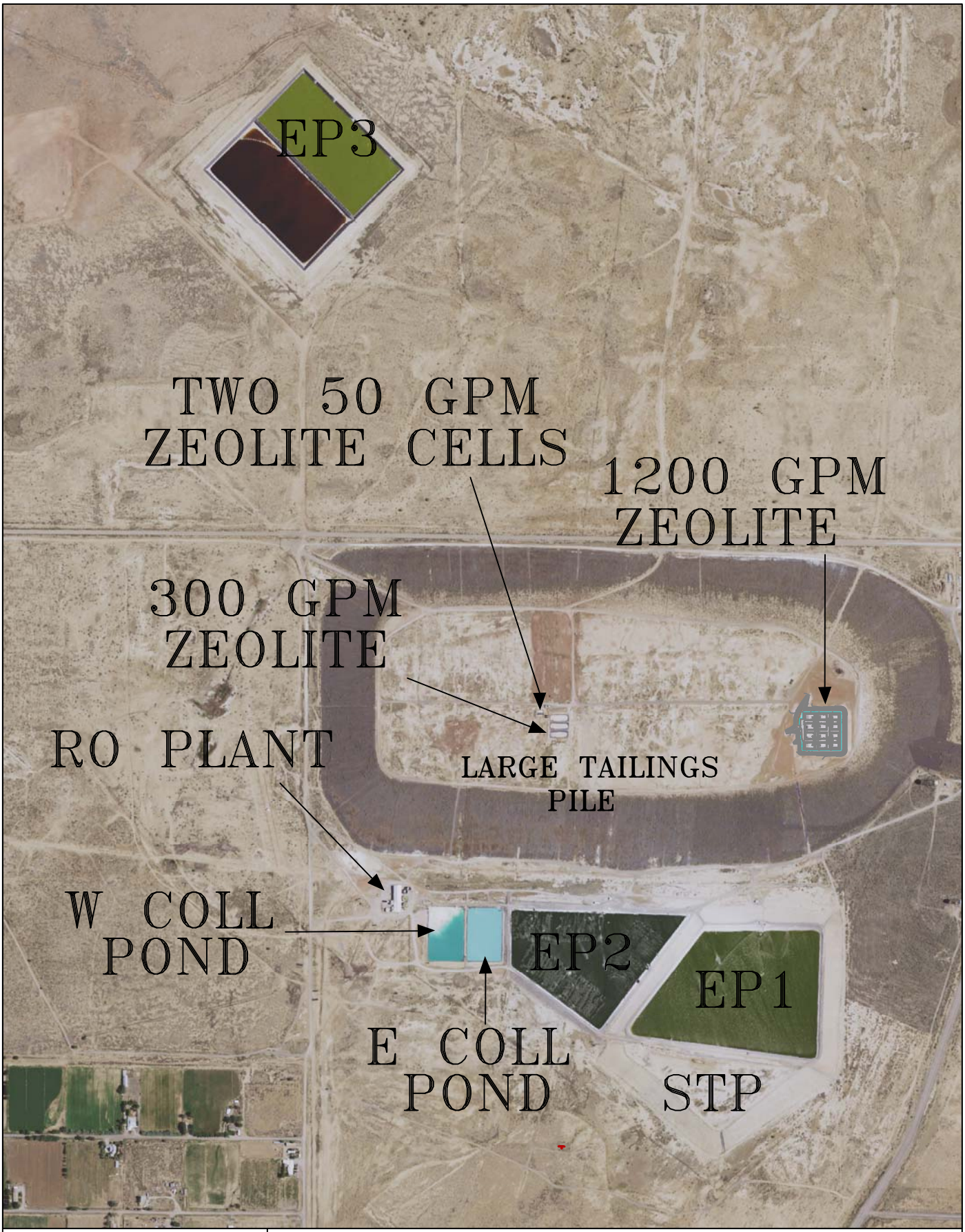

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FIGURE 6-14
LOCATIONS OF THE GRP EVAPORATION PONDS, RO PLANT AND ZEOLITE CELLS

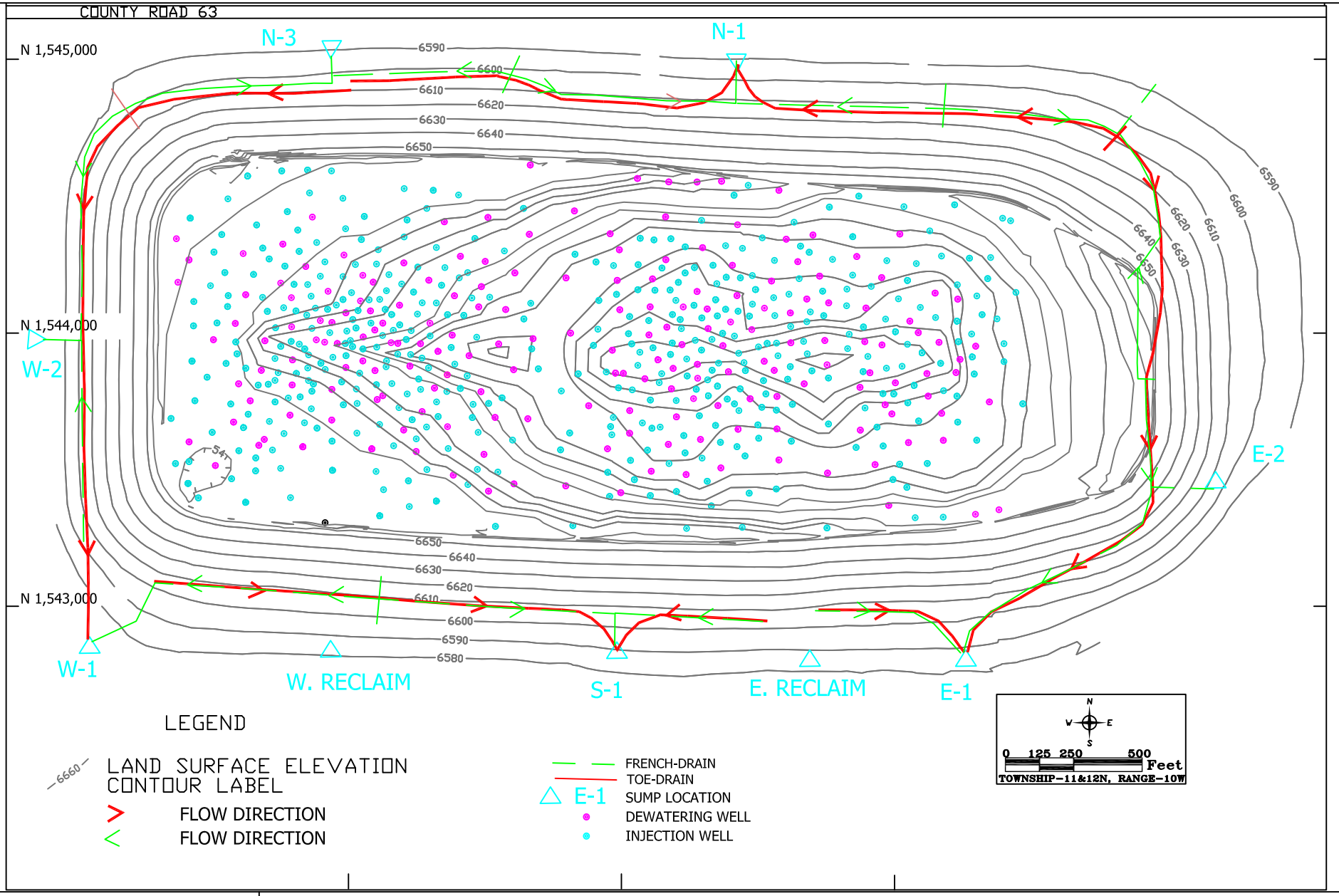

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FIGURE 6-15
LOCATIONS OF THE LTP TOE DRAINS,
DEWATERING WELLS AND INJECTION WELLS

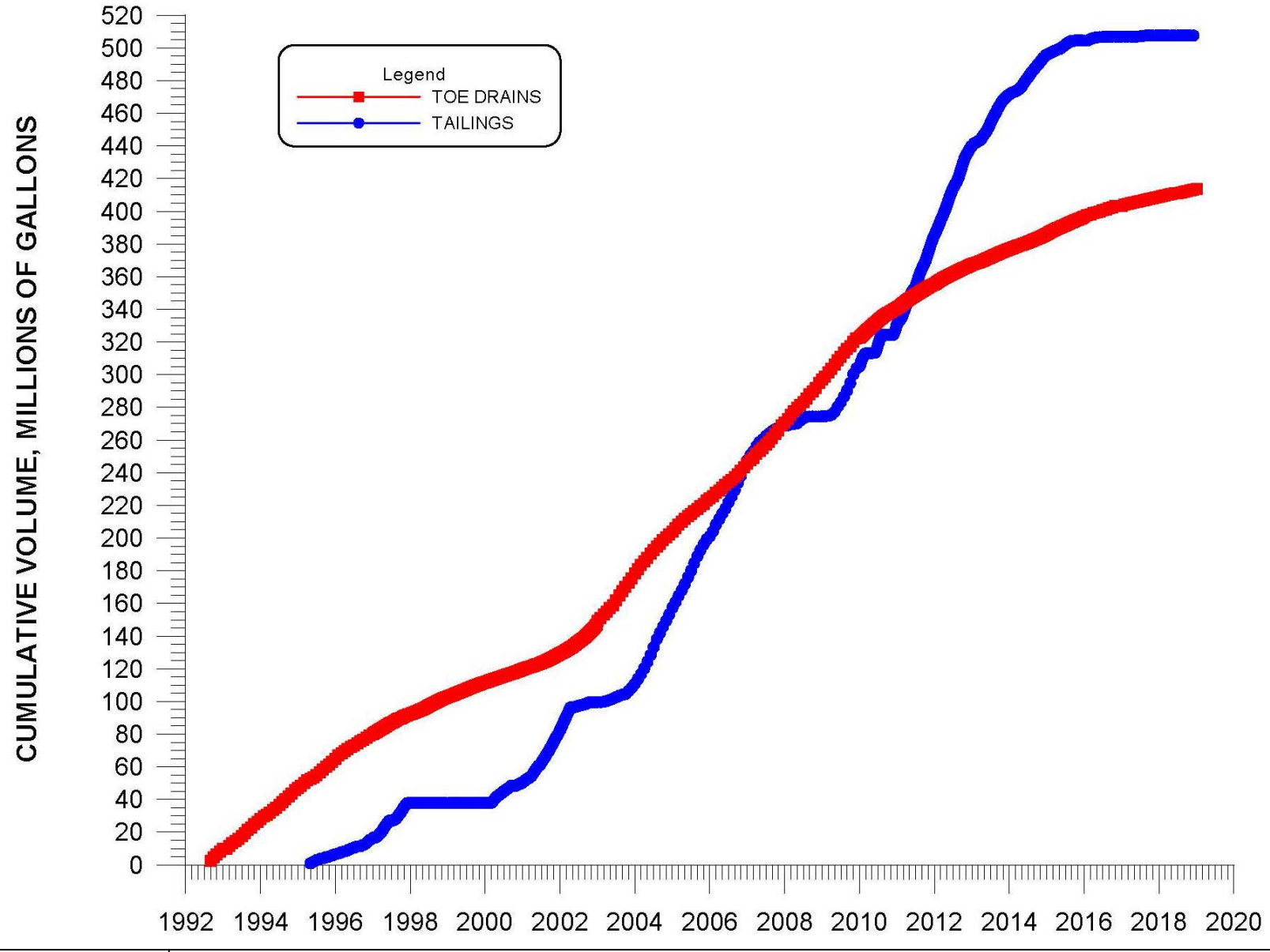

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FIGURE 6-16
CUMULATIVE VOLUME OF COLLECTION
WATER FROM TAILINGS DEWATERING WELLS
AND TOE DRAINS

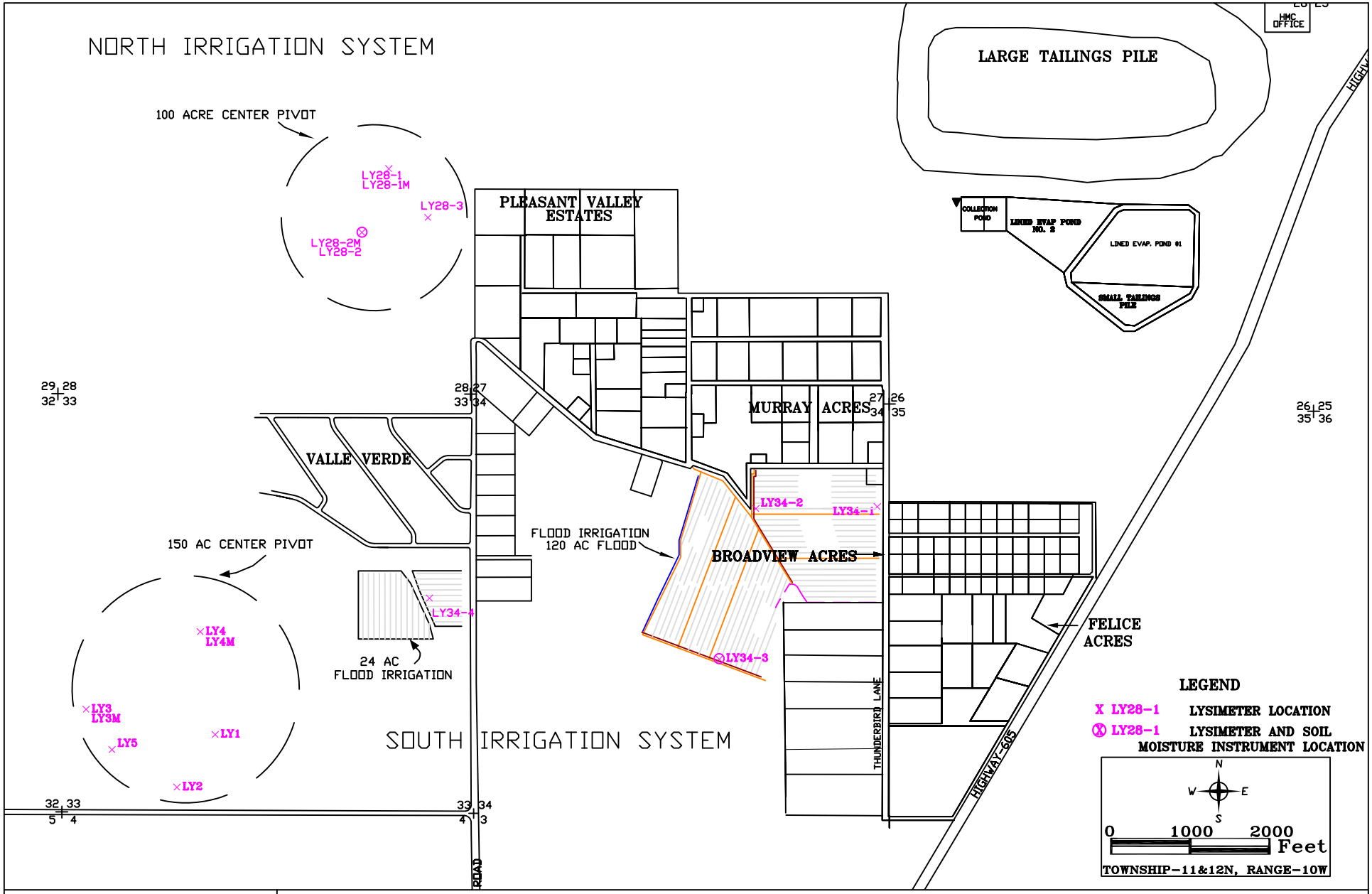

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FIGURE 6-17
LOCATIONS OF THE IRRIGATED AREAS, SOIL MOISTURE LYSIMETERS AND SOIL MOISTURE INSTRUMENTS

SEE FIGURE 6-21
FOR RESTORATION
WELLS IN THIS AREA

SEE FIGURE 6-19
FOR RESTORATION
WELLS IN THIS
AREA

SEE FIGURE 6-22
FOR RESTORATION
WELLS IN THIS
AREA

SEE FIGURE 6-20
FOR RESTORATION
WELLS IN THIS
AREA

COUNTY ROAD 63
COUNTY ROAD 25
RAILROAD
HIGHWAY-122
HIGHWAY-285
THUNDERBIRD LANE
RALPH CARD ROAD
ALLUVIAL AQUIFER LIMIT
PLEASANT VALLEY ESTATES
MURRAY ACRES
VALLE VERDE
BROADVIEW ACRES
FELICE ACRES
LARGE TAILINGS PILE
SMALL TAILINGS PILE
COLLECTION POND
LINED EVAP. POND #1
LINED EVAP. POND #2
HMC OFFICE
ETA1
ETA2
NPV1
NPV2
NPV3
NPV4
NPV5
NPV6
NPV7
NPV8
NPV9
NPV10
NPV11
EBA1
EBA2
EBA3
EBA4
EBA5

1545500
1543500
1541500
1539500
1537500
1535500
1533500

473400
475400
477400
479400
481400
483400
485400
487400
489400
491400

0 1000 2000 Feet
TOWNSHIP-11&12N, RANGE-10W

LEGEND
- ALLUVIAL COLLECTION WELL
- ALLUVIAL INJECTION WELL
- WELLS IN RESTORED AREA (POTENTIAL MONITORING WELL)
- OTHER ALLUVIAL WELL
- INFILTRATION LINE
- UNUSED INFILTRATION LINE
- FUTURE OPERATIONS
- EXISTING OPERATIONS
- 0.1 URANIUM CONCENTRATION (mg/L) CONTOUR AND LABEL
- ALLUVIAL AQUIFER

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FIGURE 6-18
EXISTING ALLUVIAL COLLECTION/INJECTION WELL LOCATIONS

22 23
27 26
23 24
26 25
T
ETA3
ETA1
ETA2
HMC OFFICE
LARGE TAILINGS PILE
10
10
5
1.0
0.5
1.0
0.5
1.0
0.5
0.1
0.05
1.0
5
S. INFILTRATION LINE
EMA1
EMA2
EMA3
EMA4
EMA5
COLLECTION POND
LINED EVAP POND NO. 2
LINED EVAP. POND #1
SMALL TAILINGS PILE
HIGHWAY
- LEGEND -
ON-SITE COLLECTION WELL
TREATED AND/OR FRESH WATER INJECTION WELL
OTHER ALLUVIAL WELL
INFILTRATION LINE
UNUSED INFILTRATION LINE
0.1 URANIUM CONCENTRATION (mg/L) CONTOUR AND LABEL
FUTURE ON-SITE OPERATIONS
EXISTING ON-SITE OPERATIONS
ALLUVIAL AQUIFER
N
W
E
S
0 250 500 1000 Feet
TOWNSHIP-11&12N, RANGE-10W

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FIGURE 6-19
EXISTING ALLUVIAL COLLECTION/INJECTION WELL LOCATIONS, OS

FELICE ACRES

THUNDERBIRD LANE

HIGHWAY-605

RALPH CARD ROAD

ALLUVIAL AQUIFER LIMIT

WFA1

FA1

FA2

FA3

FA4

SFA1

SFA2

RCR1

RCR2

RCR3

RCR4

RCR5

RCR6

RCR7

RCR8

0.1

0.3

0.05

N

W E

S

0 250 500 1000 Feet

TOWNSHIP-11&12N, RANGE-10W

LEGEND

- OFF-SITE COLLECTION WELL
- TREATED AND/OR FRESH WATER INJECTION WELL
- WELLS IN RESTORED AREA (POTENTIAL MONITORING WELLS)
- OTHER ALLUVIAL WELL
- INFILTRATION LINE
- UNUSED INFILTRATION LINE
- 0.1 URANIUM CONCENTRATION (mg/L) CONTOUR AND LABEL
- FUTURE SOUTH OPERATIONS
- EXISTING SOUTH OPERATIONS
- ALLUVIAL AQUIFER

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FIGURE 6-20
EXISTING ALLUVIAL COLLECTION/INJECTION WELL LOCATIONS, SOS

ALLUVIAL AQUIFER LIMIT

NPV1 NPV2 NPV3 NPV4 NPV5 NPV6 NPV7 NPV8 NPV9 NPV10 NPV11

0.1 0.5 1.0 0.05

PLEASANT VALLEY ESTATES

28 27

N W E S

0 250 500 1000 Feet

TOWNSHIP-11&12N, RANGE-10W

LEGEND

- OFF-SITE COLLECTION WELL
- TREATED AND/OR FRESH WATER INJECTION WELL
- WELLS IN RESTORED AREA (POTENTIAL MONITORING WELLS)
- OTHER ALLUVIAL WELL
- INFILTRATION LINE
- UNUSED INFILTRATION LINE
- 0.1 URANIUM CONCENTRATION (mg/L) CONTOUR AND LABEL
- FUTURE SOUTH OPERATIONS
- EXISTING SOUTH OPERATIONS
- ALLUVIAL AQUIFER

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FIGURE 6-21
EXISTING ALLUVIAL COLLECTION/INJECTION WELL LOCATIONS, NOS

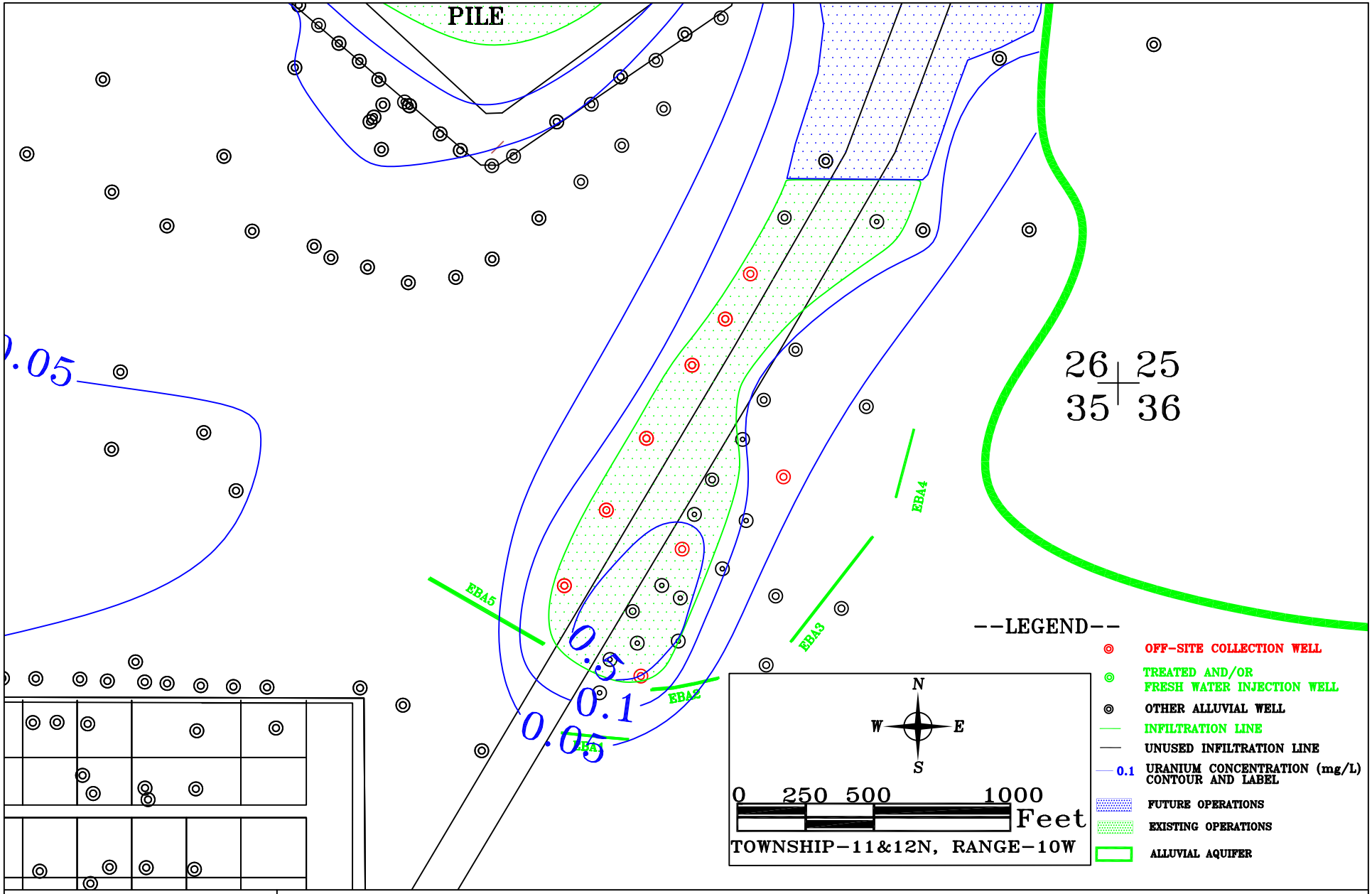

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FIGURE 6-22
EXISTING ALLUVIAL COLLECTION/INJECTION WELL LOCATIONS, L AREA

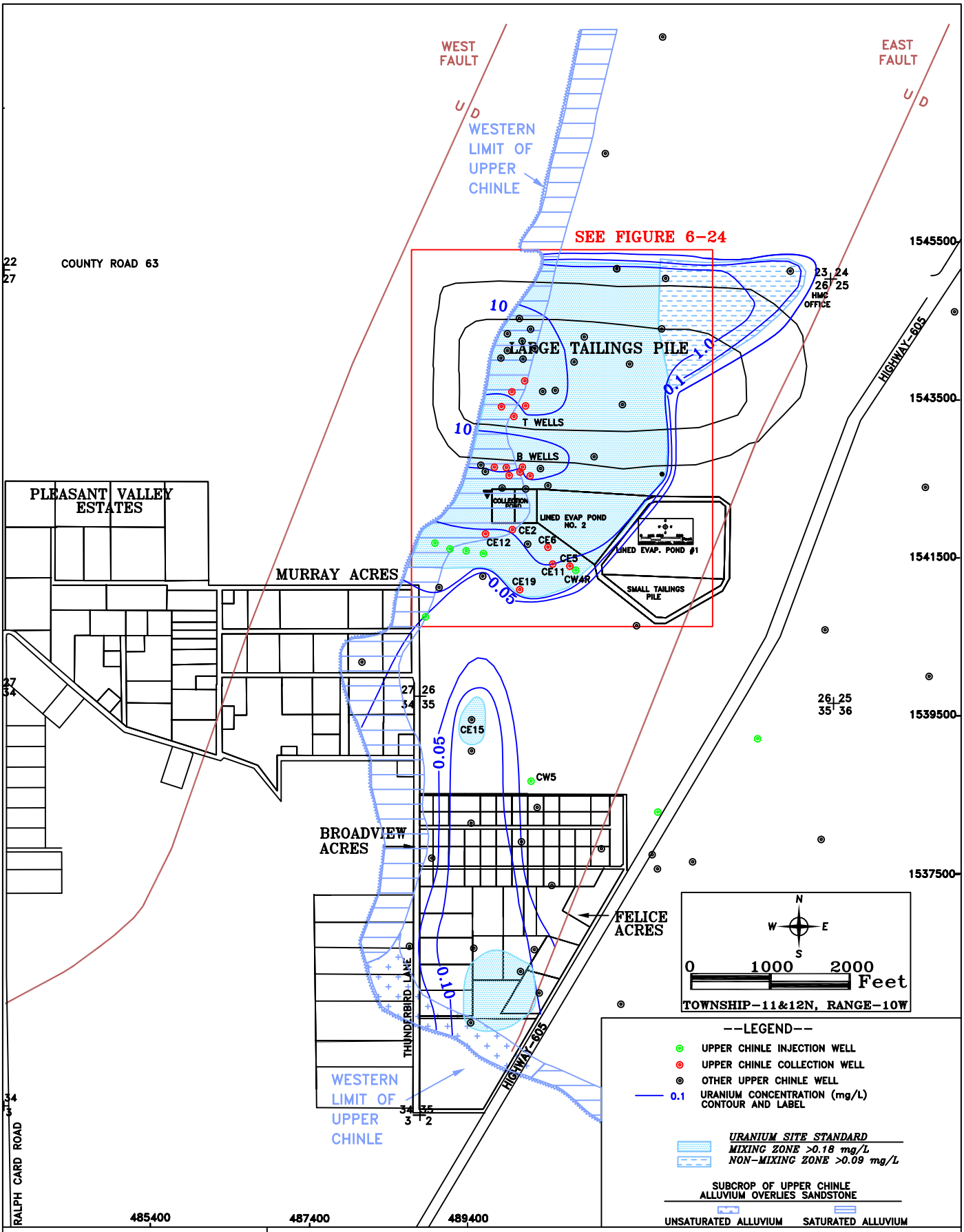

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FIGURE 6-23
EXISTING UPPER CHINLE
COLLECTION/INJECTION WELL LOCATIONS

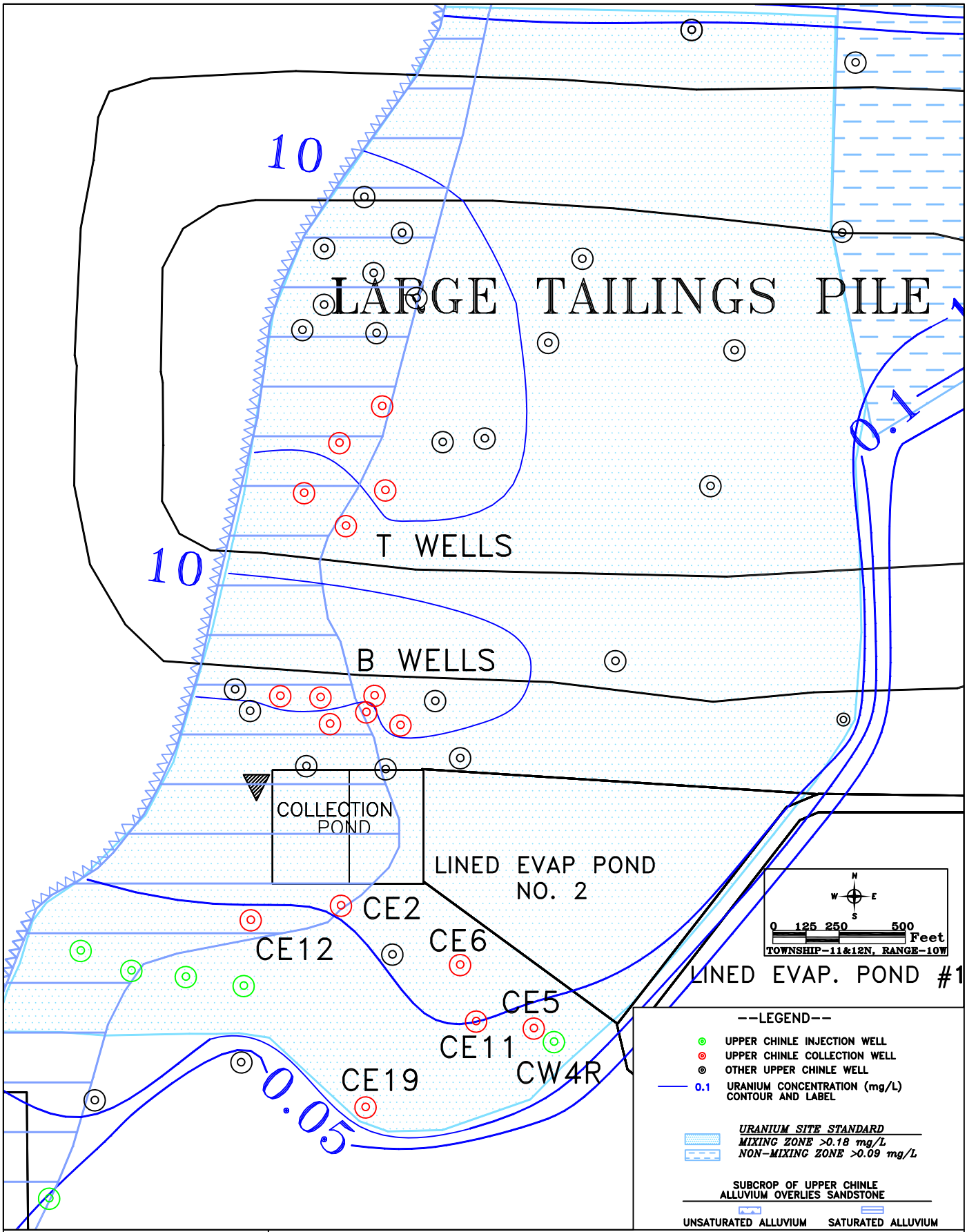

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FIGURE 6-24
EXISTING UPPER CHINLE
COLLECTION/INJECTION WELL LOCATIONS, OS

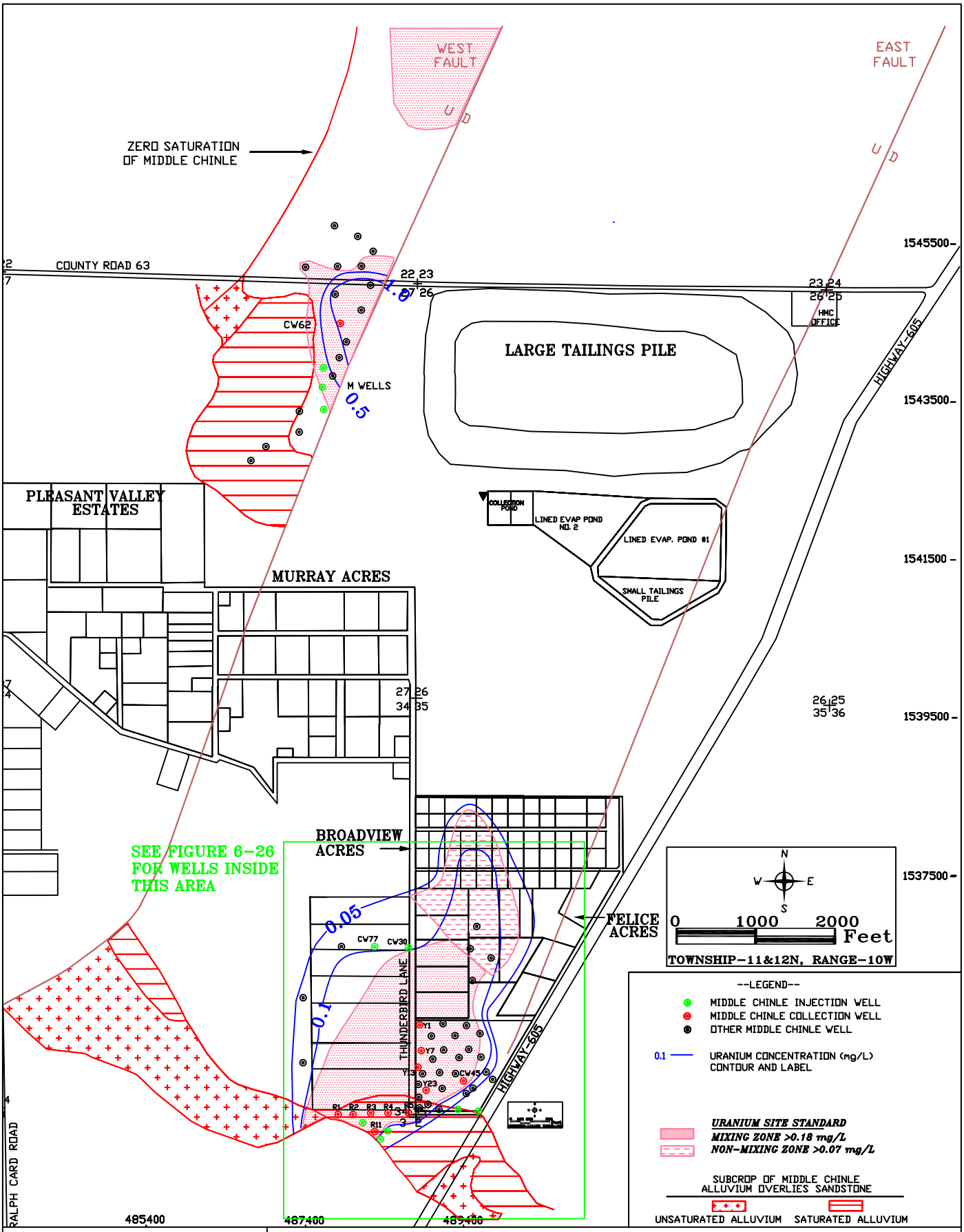

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FIGURE 6-25
EXISTING MIDDLE CHINLE
COLLECTION/INJECTION WELL LOCATIONS

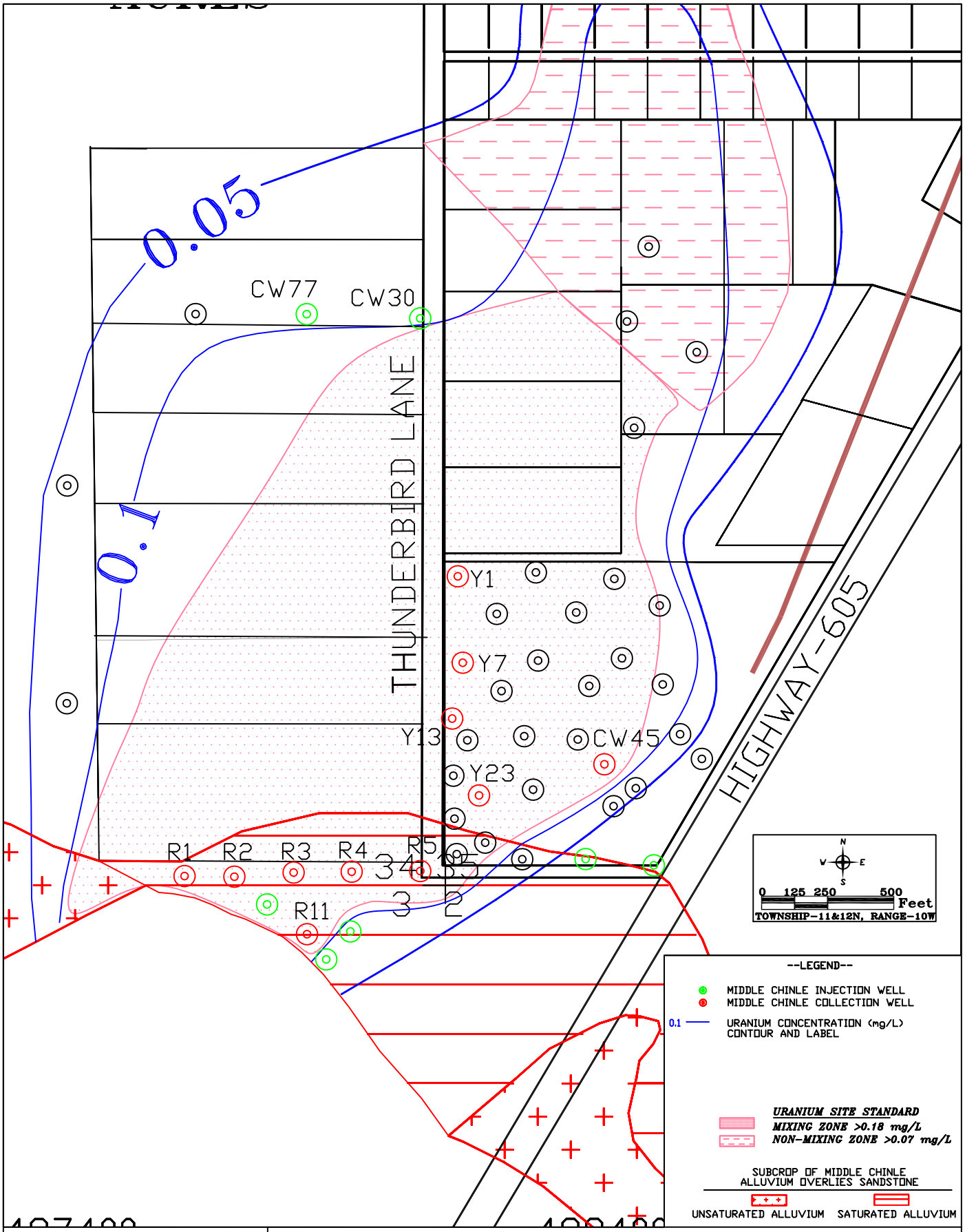

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FIGURE 6-26
EXISTING MIDDLE CHINLE COLLECTION/INJECTION WELL LOCATIONS, SOS

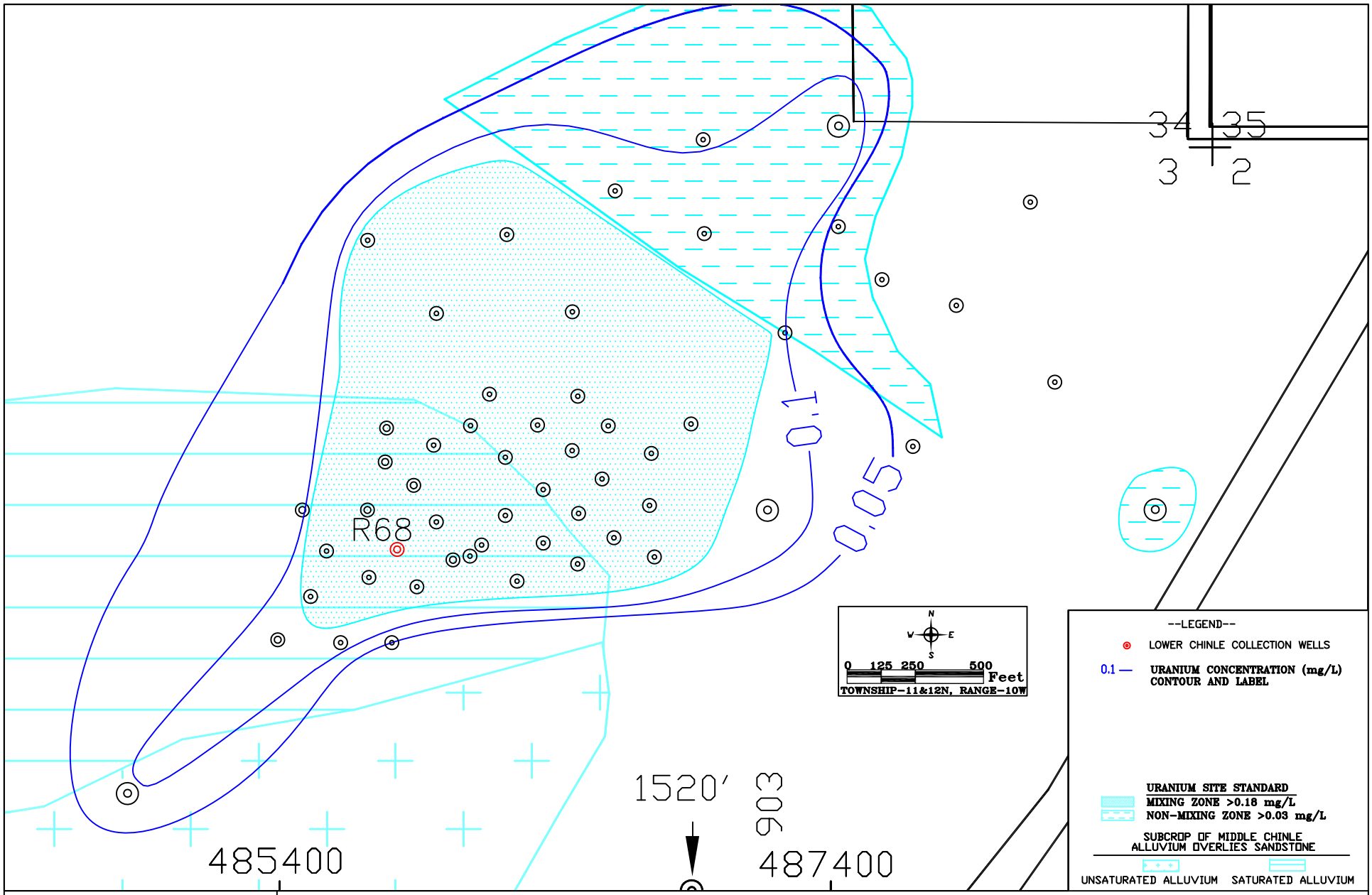

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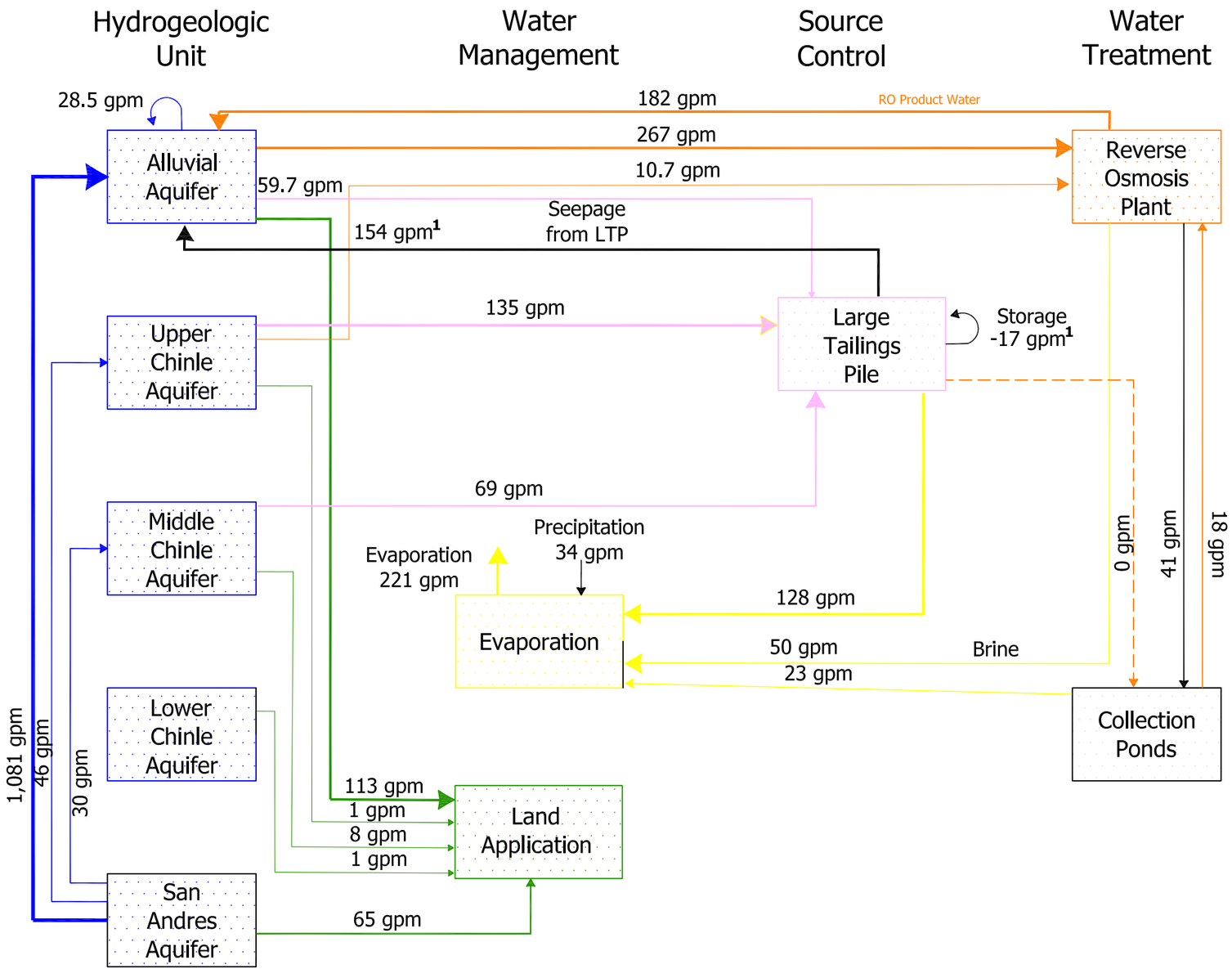
FIGURE 6-27
EXISITING LOWER CHINLE
COLLECTION/INJECTION WELL LOCATIONS



LEGEND:

Flow Range (gpm= gallons per minute)

- 0-10 gpm
- 11-50 gpm
- 51-100 gpm
- 101-500 gpm
- >500 gpm

Restoration Strategy

- Land Treatment
- Source Control
- Evaporation
- Reverse Osmosis Treatment
- Plume Control

Note[1] : LTP seepage and storage were based on the mixing model.

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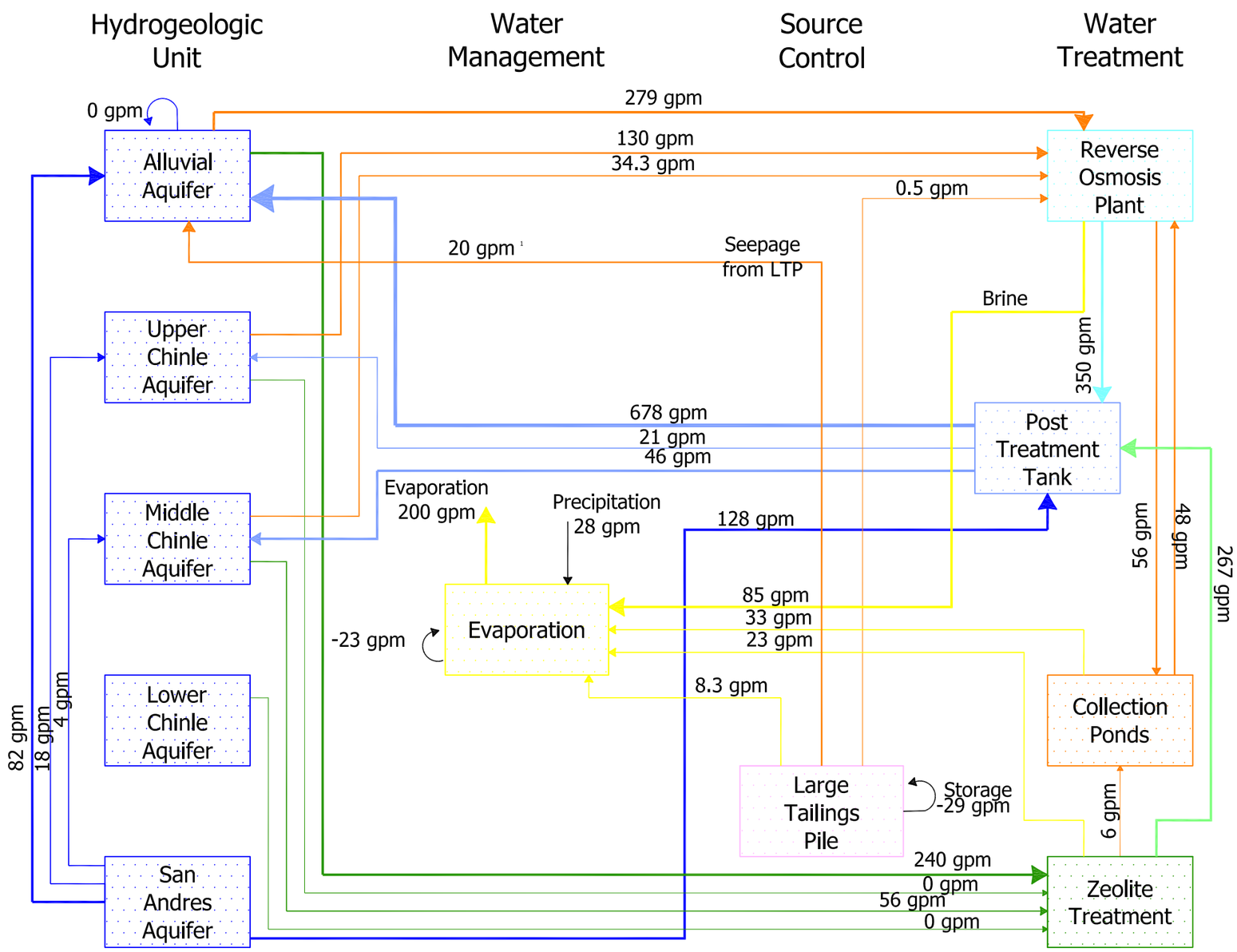
FIGURE 6-28
2012 MAJOR OPERATIONAL AVERAGE FLOWS



LEGEND:

Flow Range (gpm= gallons per minute)

- 0-10 gpm
- 11-50 gpm
- 51-100 gpm
- 101-500 gpm
- >500 gpm

Restoration Strategy

- Zeolite Feed
- Zeolite Treated Water
- Evaporation
- Reverse Osmosis Treatment
- Fresh Water
- Post Treatment Tank

Note [1]: LTP seepage based on the water balance.

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FIGURE 6-29
2018 MAJOR OPERATIONAL AVERAGE FLOWS

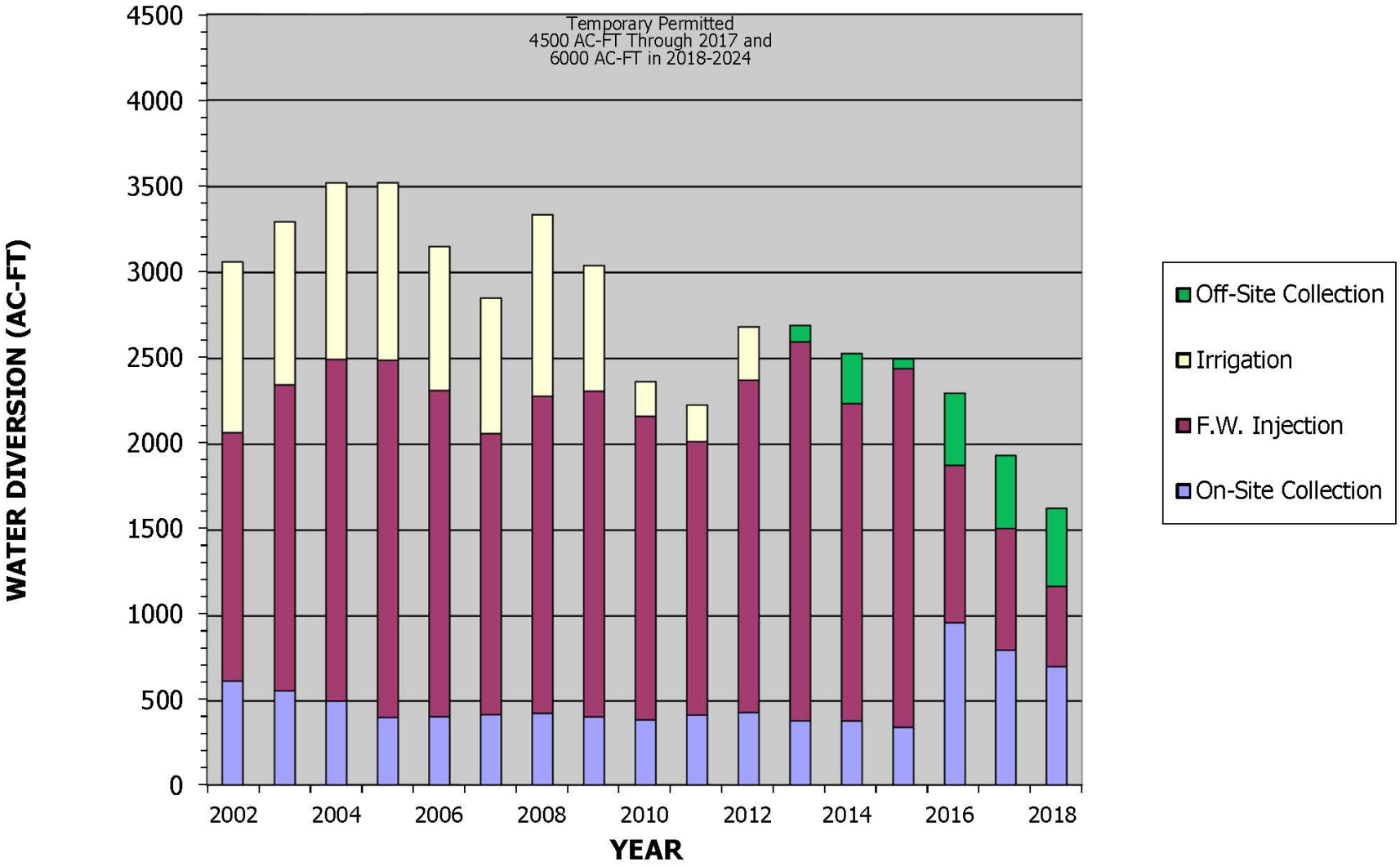

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FIGURE 6-30

HISTORICAL GROUNDWATER DIVERSION AT
THE GRANTS SITE