North Valleys Flood Control
Hydrologic Analysis and Mitigation Options
City of Reno and Washoe County, Nevada

Volumes I and II

Prepared For:

Washoe County Regional Water Planning Commission and City of Reno

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- 1-Foot Contour Topographic Data from US Geomatics and N.A.M.

North Valleys Flood Control Study
Volume 1: Hydrologic Analysis

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EXECUTIVE SUMMARY

Detailed hydrologic analysis of 100-year water surface elevations in the North Valleys, for Silver Lake and Swan (Lemmon) Lake playas, was completed for existing and buildout development conditions. The 100-year (one percent chance) water surface elevations calculated for existing development conditions in Silver and Swan Lake playas are 4,971.8' and 4,922.9' (NAVD 1988) respectively. The 100-year water surface elevations calculated for buildout development conditions in Silver and Swan Lake playas are 4,974.4' and 4,924.4' (NAVD 1988) respectively.

A basin-wide, lumped parameter, HEC-1 hydrologic model was utilized to calculate 100-year water surface elevations for Silver Lake and Swan Lake. Subconsultant U.S. Geomatics, Reno, Nevada, and their sub consultant North American Mapping, Sparks, Nevada, generated new one-foot contour topographic data of the Silver and Swan Lake playa areas. The new topographic data was used to calibrate constant loss rates in the Silver and Swan Lake watersheds to the 1986, 9-day storm event. New precipitation data from the National Weather Service, NOAA Atlas 14 dataset was used in the 100-year hydrologic model. Current land use data from the Washoe County Assessors Office, as of November 2005, and land use projections at buildout conditions prepared by the Truckee Meadows Regional Planning Agency were included in the model.

A curve number method, HEC-1 hydrologic model for a 25-year, 24-hour storm was utilized to calculate an initial storage condition for the playa lakes. The 2000 Stantec HEC-1 model was used for this analysis and modified with the addition of NOAA Atlas 14 precipitation data, new curve numbers calculated in this study, percent impervious data calculated from updated land use data, and the new one-foot topographic data generated for this study. Curve numbers were recalculated based on a study of Hydrologic Condition Rating in the North Valleys by Walker & Associates, subcontracted for this study.

New 100-year water surface elevation for Silver Lake playa for existing development conditions identifies an excess volume of stormwater above the current FEMA regulatory

Base Flood Elevation (4968.74' NAVD 1988) of 3,249 acre-feet. The calculated water surface elevations for buildout development conditions identified a volume in excess of the Base Flood Elevation in Silver Lake playa of 6,893 acre-feet, and a volume in excess of the Base Flood Elevation in Swan Lake playa of 1,102 acre-feet. Ten different mitigation options were evaluated to mitigate the excess volumes in Silver Lake and Swan Lake to the existing conditions Base Flood Elevations. Cost comparisons of multiple combinations of mitigation options were evaluated; mitigating Silver Lake playa to the current FEMA Base Flood Elevation appears cost prohibitive. Quad Knopf recommends to apply for a LOMR with FEMA to reset the Base Flood Elevation in Silver Lake to 4971.8' (NAVD 1988).

To mitigate future development in Silver Lake watershed, Quad Knopf recommends and Infiltration Facility on Airport Authority property, adequate capacity in the Effluent Reservoir proposed by ECO:LOGIC to include 718 acre-feet of stormwater volume, and excavation of select areas in and around the playa, yet to be specified. To mitigate future development in Swan Lake watershed, Quad Knopf recommends retention ponds and/or excavation of select areas in and around the playa, yet to be specified.

1.0 – PURPOSE AND SCOPE

This report has been prepared to document a hydrologic study performed by Quad Knopf in late 2005 and early 2006 to evaluate the impacts of current and future development on potential flooding in the Silver Lake and Swan (Lemmon) Lake Basins (Figure 1). The study was authorized and funded by the Washoe County Regional Water Planning Commission and the contract for the study was administered by the City of Reno under an inter-local agreement. In addition to hydrologic analyses, the study also explored options for the mitigation of impacts that are anticipated from the increased volume of stormwater runoff due to new growth, which will result in higher lake levels if not properly addressed. The Silver Lake and Swan Lake watersheds (basins) are closed basins collectively referred to as the North Valleys and exist north and west of the downtown Reno area. A portion of the North Valleys lie within the limits of the City of Reno and the remainder is within the jurisdiction of Washoe County.

Growth planned in the North Valleys basins has been limited in the past by the availability of water. Current water supplies will soon be augmented by importation of water from outside the basin. The increased water supply from this importation project will impact both wastewater and stormwater volumes. This study, which addresses the mitigation of stormwater runoff, has been conducted in parallel with a study being done by ECO:LOGIC which addresses the wastewater disposal options.

The interim water policies developed by the Regional Water Planning Commission, as mandated by the Truckee Meadows Regional Planning Settlement Agreement, included provisions to protect the existing flood storage volumes available within closed basins. Projects which propose to either:

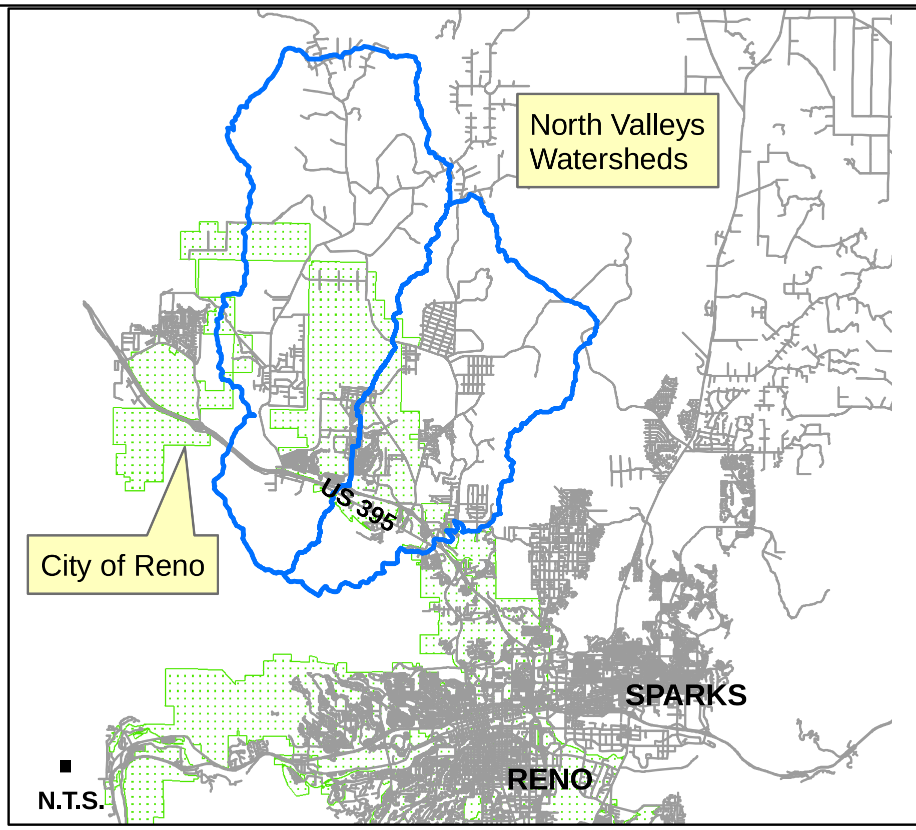
a) develop within these basins and displace volumes of storage within the floodplain of the various playas, or
b) develop outside of the floodplain boundary but ultimately deliver a greater volume of water to the floodplain site,

must provide mitigation for the potential loss in storage to the satisfaction of the agencies having jurisdiction over the floodplain in those basins. In order to provide a regional approach to this problem, area wide flood storage mitigation options were explored with this study.

The scope of services for this project are divided into the tasks completed for Volume I of this report, and those completed and discussed in Volume II of this report.

Volume I: Hydrologic Analysis

- Obtain 1-foot contour topographic mapping of the Silver and Swan Lake playa areas in order to refine the stage-storage relationship,
- Evaluation of existing (through November 2005) and buildout (per Truckee Meadows Regional Planning Agency, Regional Land Use Model, January 2006) land use conditions to be employed in hydrologic models,



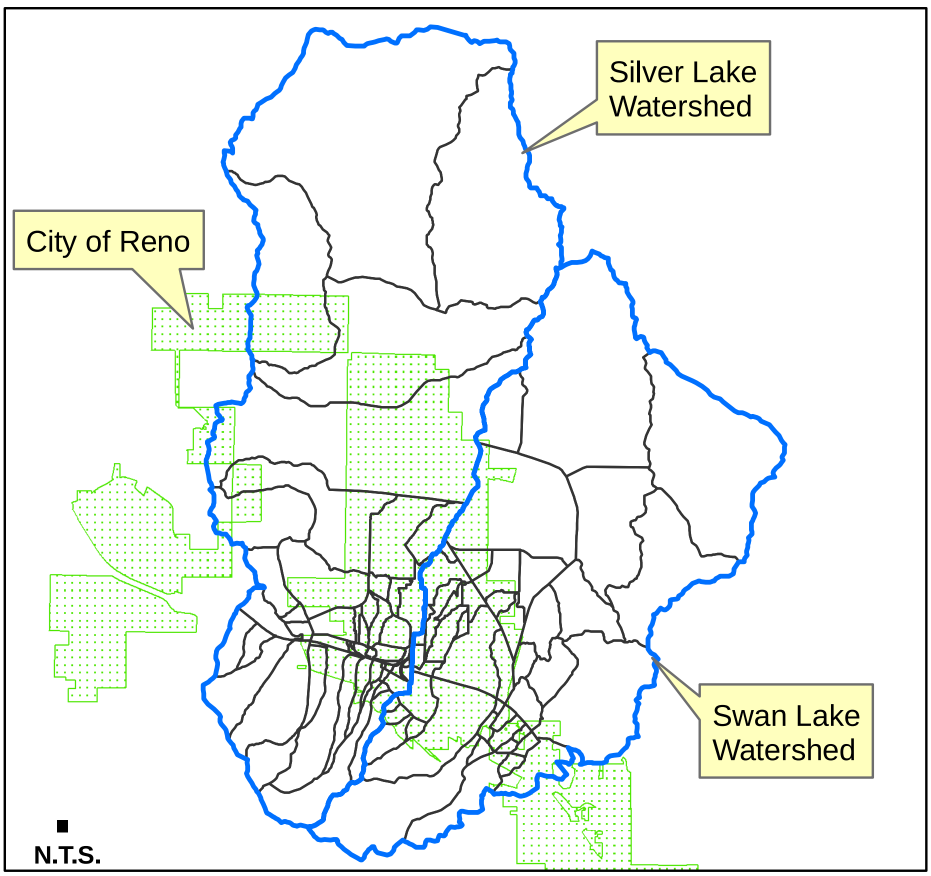


FIGURE 1

Vicinity Map

North Valleys Flood Control Project

City of Reno & Washoe County RWPC

Quad Knopf

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- Determine appropriate carry-over storage volume from a 5-year or 25-year, 24-hour storm
- Update FEMA models as appropriate
- Perform Detailed Watershed Analysis Update
    - Calibrate new land use and new stage-storage relationship to 1986 storm data to determine new loss rates for use in the design storm model
    - Apply new NOAA-14 rainfall data in new design storm models
    - Apply new land use data in new design storm models
    - Determine new 100-year lake levels for existing and buildout conditions

Volume II: Mitigation Options and Alternatives

- Develop Alternatives for Mitigation/Disposal including but not limited to;
    - removal of material from playa lake bottoms,
    - construction of levees,
    - using Low Impact Development practices as a short or long term solution,
    - injection of stormwater into the Vadose Zone,
    - removal of material from floodplain fringes to develop more storage capacity,
    - infiltration,
    - draining stormwater from Silver to Swan Lake for consolidated pump site and exportation out of the basins,
- Research legal impediments of proposed solutions.
- Estimate capital costs of proposed solutions.
- Apply new model to determine effectiveness of alternatives.
- Present findings in Final Report.

The hydrologic evaluation portion of this study was based upon an earlier study performed by Nimbus Engineers under contract to the Federal Emergency Management Agency in 1987 for a detailed flood insurance re-study of the area (Ref. 31). Information from a Flood Control Master Plan for the Stead Area, prepared by Stantec Consulting for the City of Reno in 2000, was also incorporated into the study (Ref. 32). These studies were conducted for entirely different purposes and used different methodologies. The Nimbus Study purpose was to determine the lake levels resulting from a storm event or two consecutive events having a one percent chance of occurring any year. The Stantec analysis developed peak flows for shorter duration, but more intense storm events. The purpose of the Stantec analysis was to determine discharges which could be used to size infrastructure.

In 1987, the Nimbus Engineers study was prepared in conjunction with a Federal Emergency Management Agency (FEMA) flood insurance re-study for the Reno/Sparks area. The re-study included a hydrologic and hydraulic analysis for the Silver Lake and Swan Lake watersheds in order to determine 100-year water surface elevations for the major playas within these areas. The previous flood insurance study had mapped these playas using approximate methods. Due to the increase in development immediately adjacent to these playa lakes in the years prior to 1986, Washoe County and the City of Reno requested that FEMA determine regulatory flood elevations for the lake areas.

During February 1986, a significant precipitation event occurred which allowed collection of valuable data for evaluating the hydrologic characteristics of these watersheds. The results of Nimbus Engineers calibration of the HEC-1 hydrologic models, using the available data from the February 1986 event, were presented in the 1987 re-study report. The calibration was used to determine reasonable initial and constant loss rates to be used in the hydrologic models that determined the runoff volumes from a 100-year, 10-day event.

In 2006, using more accurate topographic mapping, updated land use data and more than twenty years of additional precipitation records, Quad Knopf has updated the calibration model and the runoff volumes which can be anticipated from a 100-year, 10-day storm event.

Both the Silver Lake and Swan Lake playas are terminal lakes within closed basins. Closed basin lakes present a unique and difficult regulatory problem for floodplain management. The outflow from most of these lakes is limited to evaporation and infiltration, as is the case with the playas evaluated in this study. When flooding occurs from lake level fluctuations, the period of inundation can be weeks or months. This results in substantially higher damages to structures and roadways than shorter duration riverine flooding. Considerable care must be taken in determining an accurate lake level for the desired recurrence interval to be used for management purposes.

Due to insufficient historical lake level data for the playas evaluated in this and the earlier Nimbus study, the lake level for a 100-year recurrence interval storm was established with a hydrologic model and tested with a variety of potential types and patterns of storms. The method used to calibrate the hydrologic model, and the rainfall patterns and distributions to determine the potential lake level were presented in the Nimbus Report and are detailed and updated in this report.

2.0 – PHYSICAL DESCRIPTION OF STUDY AREA

The Silver and Swan Lake watersheds evaluated in this report are shown on the Vicinity Map (Figure 1). These basins are located in southern Washoe County, just north of the Reno area. Most of the area is within unincorporated Washoe County, Nevada with some portions incorporated into the City of Reno. Elevations within the watersheds range from a maximum of 8,266 feet to a minimum of 4,906 feet. Vegetation types in the watersheds vary from sparse Pinon pine in the upper elevations to sage/grass in the majority of the watersheds. Large portions of these watersheds consist of gently sloping alluvial material with a poorly defined drainage pattern. Most of the runoff within the watershed occurs as shallow sheet flow and braided flow. The primary drainages are poorly defined and many of the major drainages are not readily discernable from the ground. Aerial photos provide a good reference for identification of drainage patterns. Both watersheds in the study area are closed basins draining to playas. The only losses from these playas are evaporation and infiltration (Ref. 31).

The Silver Lake watershed is 56.52 square miles in size. The watershed is long and narrow with the playa located in the southern portion of the watershed. The Swan Lake watershed is 39.99 square miles in size with the playa being centrally located within the basin. Further discussion of watershed boundaries is included in Section 6.2.1.

The geology of the North Valleys is characterized by Quaternary age alluvial basin fill deposits which overly Tertiary volcanic rocks, Tertiary sediments, Cretaceous intrusive rocks and Mesozoic metamorphic rocks. In the northern portion of both basins, Cretaceous granitic rocks provide the primary parent material for the fluvial deposits that provide permeable sequences for surface water infiltration. In the southern portion of both basins, metamorphic rocks of the Peavine Sequence have contributed to less permeable alluvial sequences resulting in perched aquifers in the vicinity of Silver Lake.

Flooding of the playa lakes has historically occurred in response to low probability storm events that have affected the study area. Section 3 discusses the major storm events that produced high stage elevations at the playa lakes.

3.0 – HISTORICAL DATA

Peak water levels in the playa lakes have not been consistently recorded in the past since the lakes did not historically threaten any structures. Only recent encroachments have resulted in damage to structures. The only information on lake levels prior to 1983 are a few photos with uncertain dates and indistinguishable shorelines.

In 1982 the Desert Research Institute (DRI) installed a staff gauge in Silver Lake to monitor lake level fluctuations. The purpose of their study was to determine the surface and groundwater contributions to the lake throughout the year for water supply studies. The staff gauge was destroyed by vandals soon after it was installed and has been re-established periodically but has not remained in place for measurable periods of time.

Beginning in 1985, Pyramid Engineers and Land Surveyors began monitoring the water levels of Silver Lake and the two adjacent playas to the northeast with periodic surveys of the water surface elevations.

During the flooding of February 1986, the Washoe County Utility Department began monitoring the water surface elevations of Swan Lake playa. The lake had risen to the point that it was inundating the sewage treatment plant at the southeast corner of the playa. The flooding of the playa resulted in closure of the plant and temporary discharge of raw sewage into the playa lake.

3.1 – 4 Day Storm of December 1955

The 1955 storm was used by the U.S. Army Corps of Engineers in their analysis of the Truckee River Basin (Ref 25). The Corps developed an isohyetal map of the December 21-25, 1955 event for the Truckee River Basin. This map suggests that the precipitation totals within the study area were 1.2 to 1.4 times greater than the totals at Reno-Tahoe International Airport. This event consisted of a 4-5 day rainfall on an existing snow pack that caused significant runoff to many of the major watercourses, such as the Truckee River.

3.2 – 3 Day Storm of February 1963

The Corps of Engineers also prepared an isohyetal map of the January 30 to February 1, 1963 event, for their use in the Truckee River analysis (Ref 25). This event produced one of the highest recorded discharges on the Truckee River. The storm was a 3 day rainfall event. The Corps considered the snow pack to be light enough to be insignificant to the peak runoff response in the Truckee River.

Precipitation totals in the study area during the 1963 event appear to have been 1.6 to 2.3 times greater than the totals at the Reno airport gauge.

3.3 – Winter of 1982 to 1983

Unusually wet conditions existed before and during the winter of 1982-83. Many of the terminal lakes and sinks in Nevada experienced higher than average runoff volumes and lake levels. The peak elevation of Silver Lake during 1983 was estimated by the Desert Research Institute as 4962.5 (NGVD 1929).

3.4 – 9 Day Storm of February 1986

A significant amount of flooding occurred in the Reno/Sparks area during February 1986. The flooding was caused by a large, warm Pacific storm that began February 12th and extended through February 20th. Daily precipitation totals for the storm were collected at 14 sites in and around the Reno area. Three of these gauges are located within the study area; two in the southern portion of the Silver Lake watershed and one in the northern portion of the Swan Lake watershed. The only continuously recording rain gauge in the area was the National Weather Service gauge at the Reno-Tahoe International Airport. Hourly totals of the rainfall which occurred at the Reno-Tahoe Airport are graphed and shown in Figure 2.

Analysis of the rainfall data collected during that event was done by Washoe County Department of Comprehensive Planning (Ref. 4). Their analysis indicates that the rainfall totals vary consistently with elevation. This would suggest that the storm was large enough to have a relatively consistent spatial and temporal distribution over the area of interest. Rainfall totals at specific sites appeared to be dependant upon orographic effects. The National Weather Service (NWS) Forecast Office at Reno prepared a report on the February 1986 event, which included a map of the 1-day precipitation totals for the Truckee River Basin (Ref. 28). Using the rainfall information from the 15 rain gauges, the NWS report, and the analysis by Washoe County, a reasonable Isohyetal Map was constructed for Reno and North Valleys area for the 1986 event. This map is included as Figure 3, as revised by NWS staff.

Figure 4 is a rainfall mass curve from the event using the hourly totals from the NWS gauge at the Reno-Tahoe airport. This mass curve indicates that the highest intensity rainfall occurred between 2300 hours on February 18th and 0400 hours on February 19th. Figure 5 shows the short duration precipitation that indicates intensities during the storm were low. The storm was a long duration, low intensity event that only produced high peak flows in the larger watercourses. Since the most significant portion of the total rainfall occurred at the end of the nine day period, the soils within the watershed were saturated during the latter part of the storm.

Nimbus Engineers performed field inspections of the study area before, during, and after the February event. The Washoe County Utility Department took frequent water level measurements of the Swan (Lemmon) Lake, playa which recorded the lake's response to the runoff from the watershed. The graph prepared by Washoe County is included as Figure 6. Frequent lake level measurements that recorded Silver Lake's response to the event were also recorded by Pyramid Engineers. Their data has been plotted in the same format as the Swan (Lemmon) Lake playa and is included as Figure 7. Both playas had minimal or no initial volume at the beginning of the event.

The precipitation data and lake levels are the only hard data collected. Watercourses were also inspected by Nimbus staff during and after the event to determine which areas of the watersheds contributed significantly to the watershed discharges.

3.5 New Year's Day Storm of 1997

A more recent low probability event occurred from December 31st, 1996 through January 3rd, 1997. This event produced one of the higher recorded discharges on the Truckee River. An extensive snow pack accumulated during the last two weeks of December 1996. Warm rains began on December 30th, 1996 and continued until January 3rd, 1997. The warmth of the rains melted most of the accumulated snow pack below 7000 feet. Damages from this storm included flooding throughout the Truckee River basin and severe flooding of downtown Reno, the East Sparks Industrial Area, the eastern Truckee Meadows and the Reno-Tahoe Airport which was closed for 36 hours. The local tributaries to the Truckee River and the North Valley playas were not subjected to the severe flooding which occurred on the main stem of the Truckee from upstream snow melt.

3.6 New Year's Eve Storm of December 2005

From approximately 3:00 pm on December 30th, 2005 to approximately 3:00 pm on December 31st, 2005, a short but intense storm produced levels on the Truckee River well above flood stage and caused some flooding on the Truckee River and significant flooding of smaller tributaries and local drainageways.

The lake levels in the study area rose rapidly as swollen tributaries flooded local streets and caused local mudslides. The high water levels of Silver and Swan lakes were measured by US Geomatics, Inc. shortly following the storm.

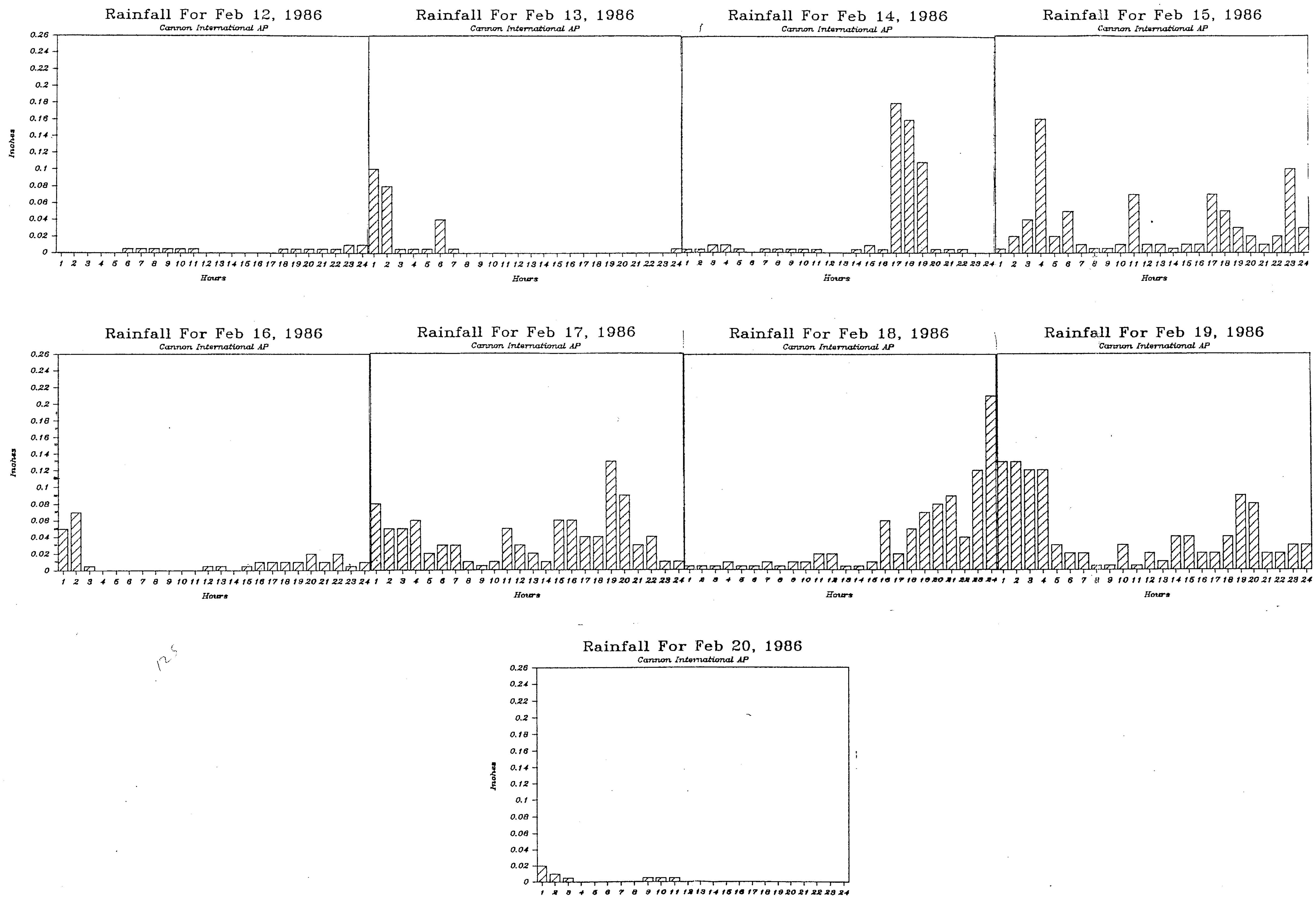

FIGURE 2

Nimbus Engineers
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Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630

PLF 1830

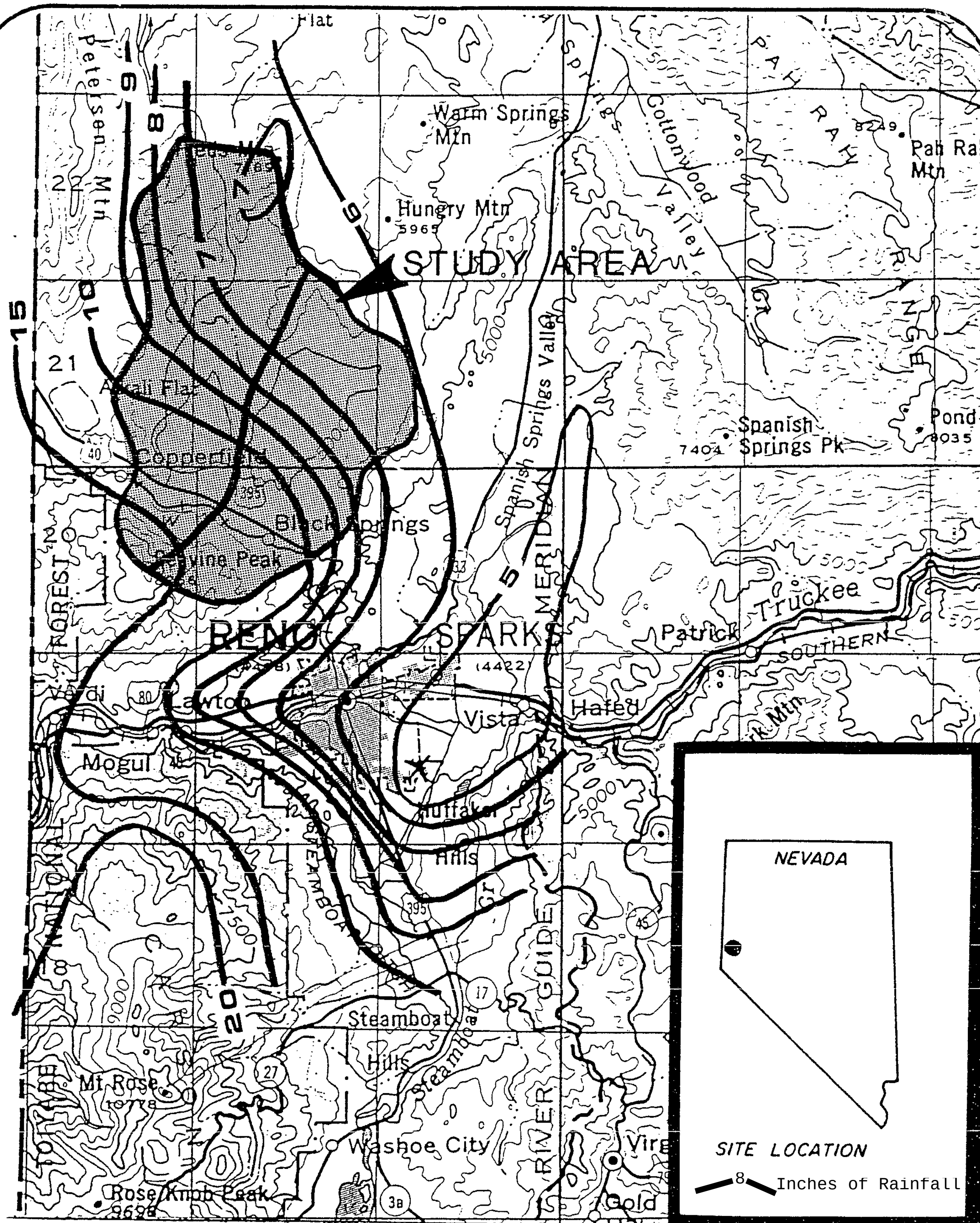

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FIGURE 3

ISOHYETAL MAP

FEBRUARY 12-20, 1986

PLF 1831

RAINFALL MASS CURVE FOR FEB 13–19, 1986

CANNON INTERNATIONAL AIRPORT GAUGE

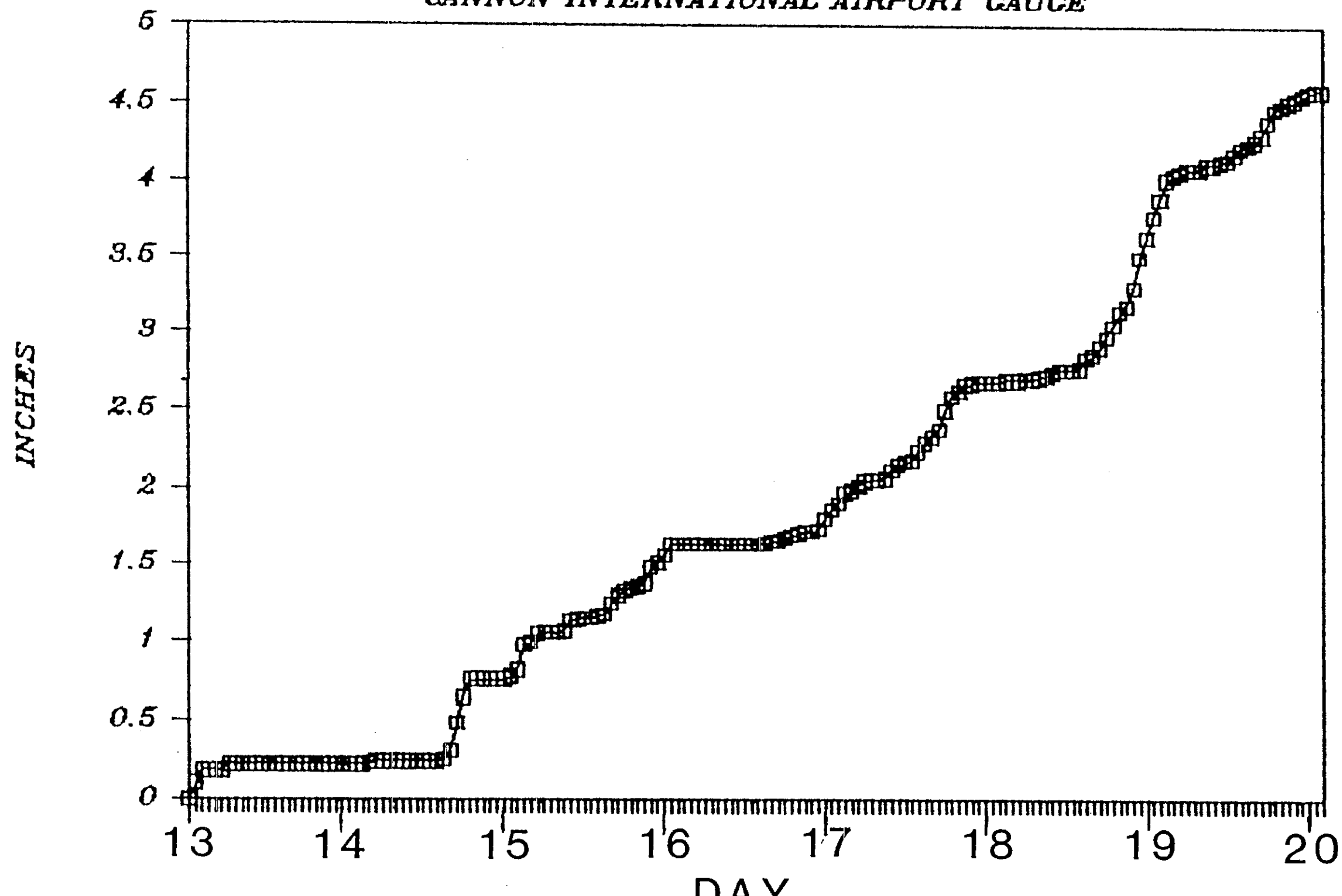

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FIGURE 4

Maximum Short Duration Precipitation

Cannon International AP

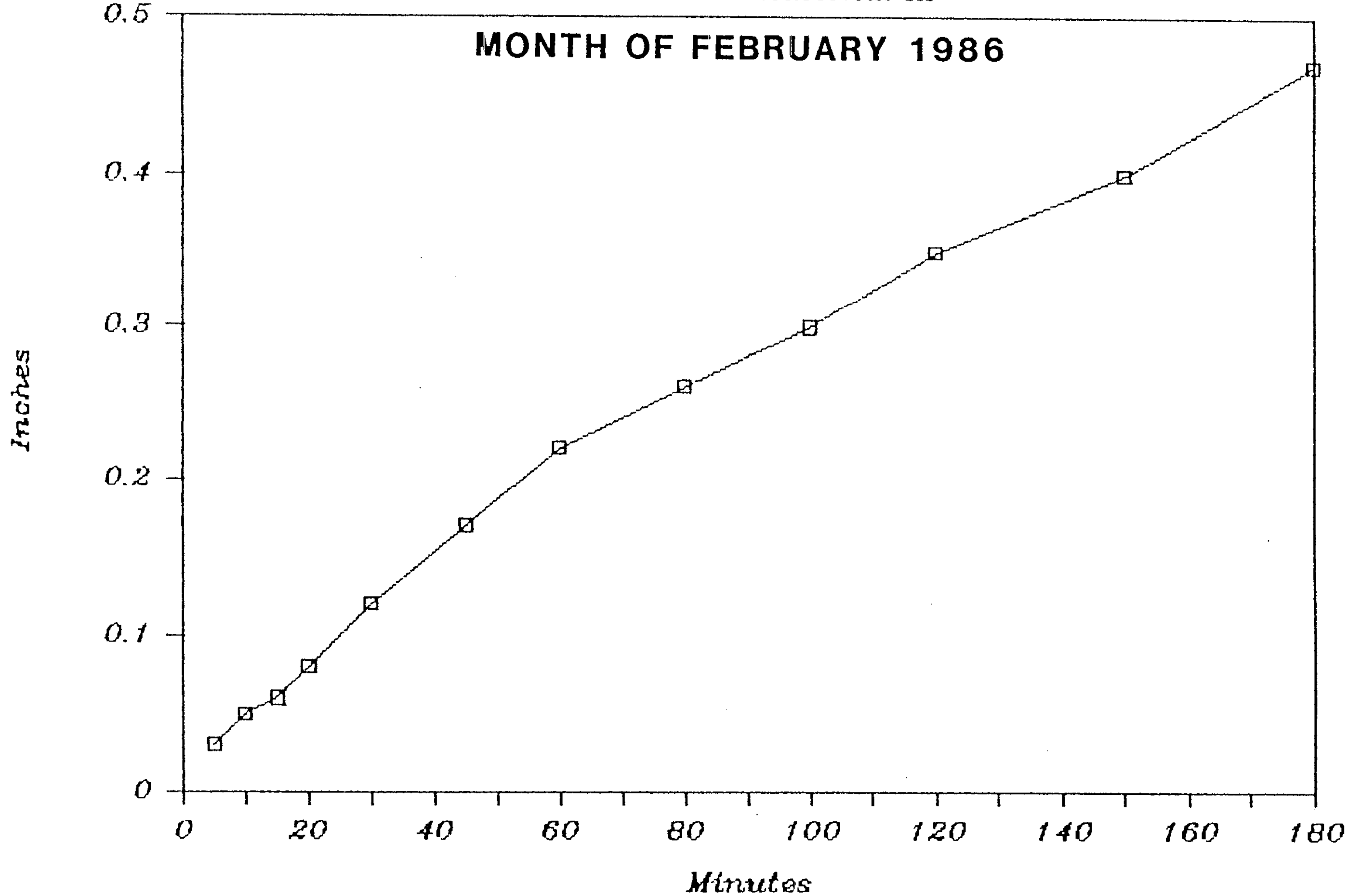

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FIGURE 5

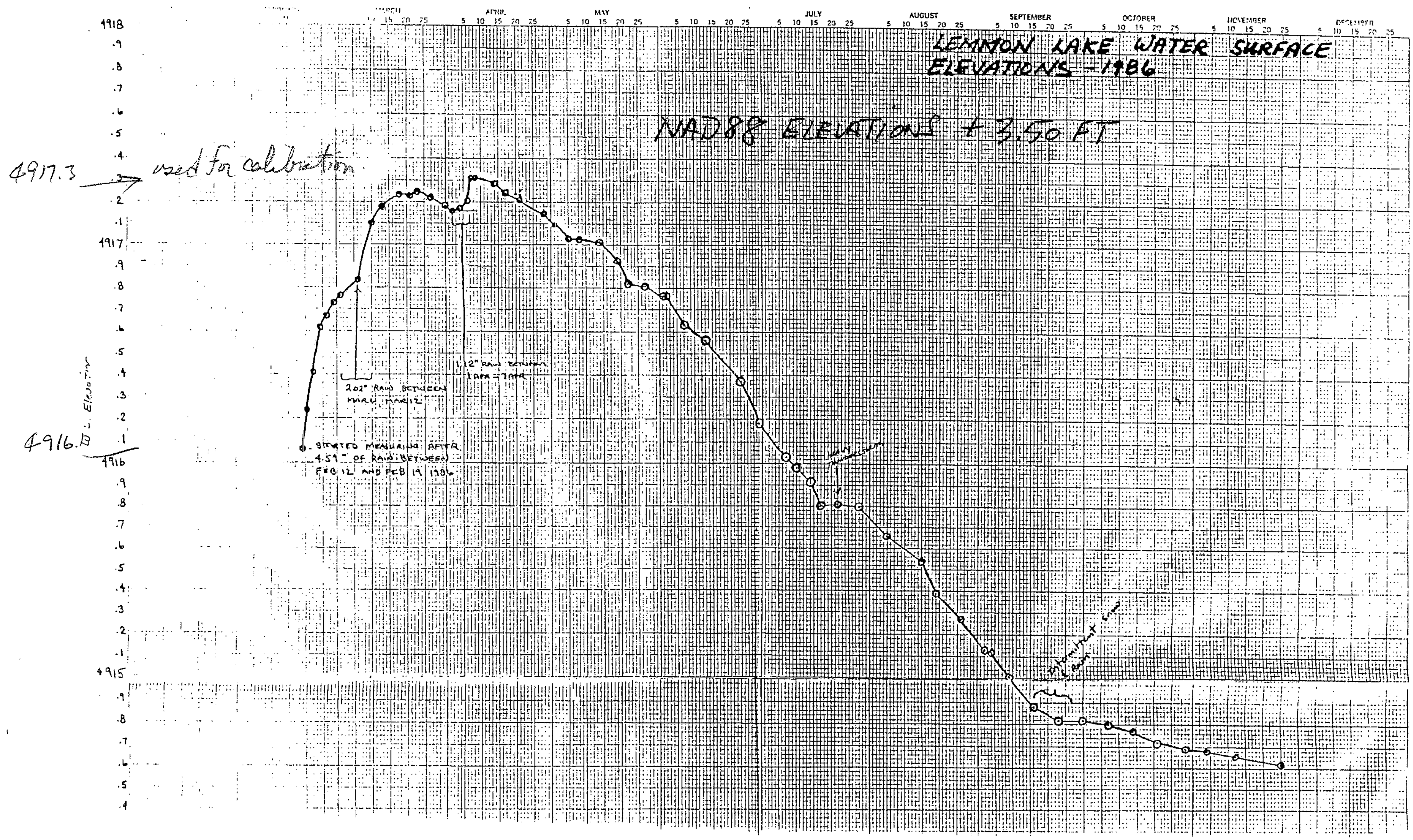

LEMMON LAKE WATER SURFACE
ELEVATIONS - 1986
NAD88 ELEVATIONS + 3.50 FT
4917.3
used for calibration
4916.13
MARCH
APRIL
MAY
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
4918
4917
4916
4915
STARTED MEASURING AFTER 4.51" OF RAIN BETWEEN FEB 12 AND FEB 19 1986
2.02" RAIN BETWEEN MAR 1 - MAR 12
1.12" RAIN BETWEEN 1 APR - 7 APR

FIGURE 6

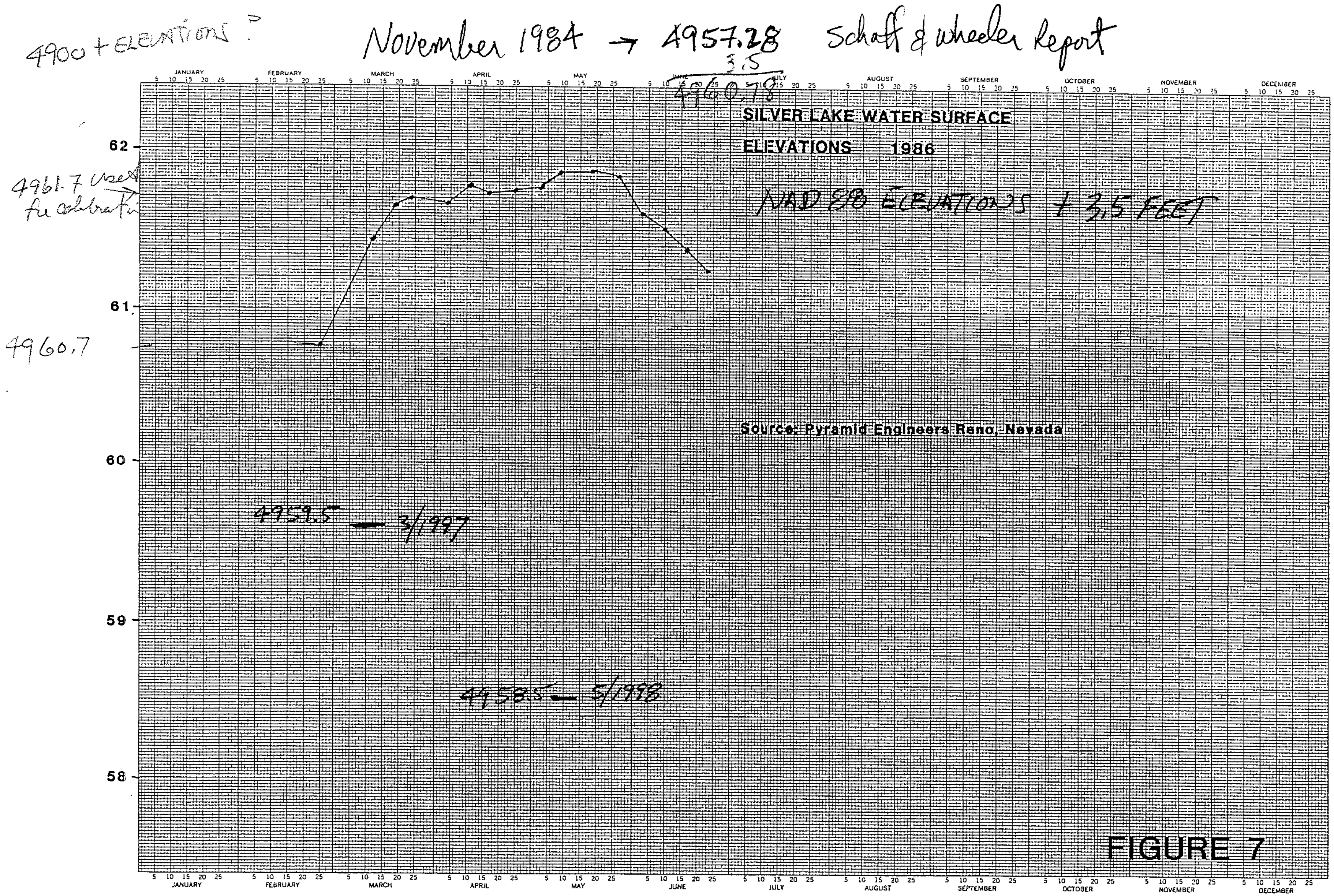


FIGURE 7

PLF 1835

4.0 – PREVIOUS STUDIES

The original flood insurance study for Washoe County developed flood limits for these playas using approximate methods. Therefore, the study did not provide useful information for any of the subsequent studies.

Reimer and Associates of Burlingame, California and Schaff & Wheeler Consulting Civil Engineers of San Jose, California submitted a request for Letter of Map Revision (LOMR) to the FEMA (Refs. 12 & 14) in 1985. This LOMR request included a hydrologic analysis of Silver Lake for the purpose of establishing a 100-year lake level. This level was needed for the design of a project that was proposed for a site at the northeast side of Silver Lake. The study used the curve number method of computing runoff volumes from the watershed. The rainfall used in the computations was derived from NOAA Atlas 2 (Ref. 26) with a rainfall pattern distributed according to the pattern observed during the December 1955 to January 1956 event. The resulting water surface elevation from this analysis of Silver Lake was 4,965 (NGVD 1929).

The Desert Research Institute (DRI) has performed studies of the Silver Lake Watershed for water harvesting purposes. These studies were performed to develop information on recharge and yield from smaller events, and to determine information for average annual conditions. The studies were also isolated to small watersheds on Peavine Mountain. The information developed by DRI does not address extreme events.

The Nimbus Engineers Flood Insurance re-study (Ref. 31), as introduced in Section1.0, included detailed documentation of the February 1986 event and is used as the basis for this 2006 investigation. The Nimbus re-study used data collected during and following the February 1986, 9-day storm to calibrate the modeling efforts presented. This study arrived at water surface elevations of 4,966.5' (NGVD 1929) for Silver Lake and 4,920.3' (NGVD 1929) for Swan Lake. Information from the Nimbus Engineers report is presented throughout this study.

In 1994, an application for Letter of Map Revision for the Silver Lake water surface elevation was prepared by Schaff & Wheeler and forwarded to FEMA by the City of Reno and Washoe County. Essentially, the Schaff & Wheeler (1994) report concluded the methods and findings in the 1987 Nimbus Engineers' study were acceptable, but they preferred a different approach to determine the carry-over storage volume than the one used in the Nimbus re-study. Schaff & Wheeler (1994) asked FEMA for the carry-over storage volume to be reduced from a 25-year storm volume to a 5-year storm volume. The study was accepted by FEMA and the regulatory lake level elevation was reduced from 4,966.5 to 4,965 feet (NGVD 1929). Quad Knopf believes the approach by Schaff & Wheeler, to use the 5-year storm volume for carry-over storage, should not have been used to reset the BFE in Silver Lake.

Stantec Consulting prepared a Drainage Master Plan for Stead, NV for the City of Reno in August 2000 (Ref. 32). This study was prepared using more detailed topography than the other studies to date. The purpose of this study was to develop peak flows for individual subbasins so that planned infrastructure could be properly sized. Some of the information in the Stantec study was used to evaluate a series of storms for possible carry-over storage values for this 2006 analysis.

Other studies have been prepared for portions of each subbasin in order to meet the requirements of the Community Development regulations; however, those studies have not developed new information.

5.0 – ALTERNATIVES FOR HYDROLOGIC ANALYSIS

Insufficient historical lake level data are available to perform statistical analysis of lake level recurrence intervals, therefore these levels must be estimated with hydrologic analysis. This study does not include calculation of water surface profiles; therefore, peak discharge is not important to the study. Runoff volumes from the watershed for a given storm pattern or series of storm patterns is the desired result. The total runoff volume for the storm(s) deemed to be a reasonable estimate of a 100-year condition would then be translated into a lake level based on the calculated stage – discharge relationship for the lake of concern.

5.1 – Single Event Models

5.1.1 – Curve Number Procedure

The most common method of calculating runoff volumes from a watershed is the SCS curve number method. This can be done using 24-hour daily rainfall information with 24-hour curve numbers and then summing the volumes for each day of the storm of interest. The curve number method can also be applied to a 10-day storm by reducing the 24-hour curve number to a 10-day curve number using the procedure described in the SCS Technical Release No. 60 (TR-60), (Ref. 19).

5.1.2 – SCS Computer Program TR-20

The SCS computer program, TR-20, develops a hydrograph for a watershed using the equations developed for the curve number procedure. The results using TR-20 should be very similar to the hand calculation method of the curve number procedure, in terms of runoff volume.

5.1.3 – Corps of Engineers Computer Program HEC-1

The Corps of Engineers Hydrologic Engineering Center developed a single event flood hydrograph package called HEC-1 (Ref. 22). HEC-1 is commonly used by engineers for developing hydrographs to be used in flood studies. HEC-1 allows the use of many methods of computing rainfall distributions, infiltration losses, impervious coverage's, routing methods, and hydrograph generation. One of the options includes the curve number method that is very similar to TR-20.

5.2 – Continuous Event Models

There are several continuous event models that will model long term runoff and soil moisture accounting for a watershed. One example of this type of model is the Stanford Watershed Model. A continuous event model would likely produce the most accurate information for use in this type of study, but the data required to perform a continuous event simulation is extensive and is not available for the study area.

6.0 – MODEL CALIBRATION

The February 1986 event was very significant because it produced severe flooding in many parts of California and Nevada. As discussed in section 3.4, rainfall and lake level data were collected during and after this event. There is sufficient information from this event to reasonably model the runoff response from the watershed as a single event simulation. Using this information, the HEC-1 program was used to test the curve number method versus a method utilizing infiltration losses and impervious coverage, for their ability to reproduce the results that were observed from the 1986 storm event.

6.1 – SCS Curve Number Method

The curve number hydrologic method is very sensitive to the curve numbers used in the model. In the 1985 study by Schaff & Wheeler (Ref. 14), they estimated the 24-hour curve numbers to be 82 and 86 (for AMC II) for Silver and Swan Lake watersheds respectively. In the 2000 Stantec study (Ref. 32), the average 24-hour curve numbers were 76 for both the Silver and Swan Lake watersheds. In USDA publication TR-60 (Ref. 19), a table is provided to adjust a 24-hour curve number to a 10-day curve number for areas with 100-year, 10-day point rainfall greater than 6 inches. The 10-day curve numbers were determined using this table and were input into a curve number model of each watershed to compare computed volumes versus observed volumes for the 1986 storm event. The table below summarizes the above 10-day curve numbers, the observed versus computed volumes, and lake level elevations.

Table 1. Comparison of Observed versus Modeled Volumes and Lake Levels, 1986 Storm.

SILVER LAKE	24-hr curve number	10-day curve number	Volume (ac-ft)	Water Surface Elev. (NAVD 1988 feet)[1]	Measured Water Surface Elev. (NGVD 1929 feet)[2]
1986 Observed Data	-	-	3,988	4,965.4	4,961.7
1985 Schaff & Wheeler Study	82	68	9,300	4,971.2	-
2000 Stantec Study	76	60	7,836	4,969.9	-
SWAN LAKE	24-hr curve number	10-day curve number	Volume (ac-ft)	Water Surface Elev. (NAVD 1988 feet)[1]	Measured Water Surface Elev. (NGVD 1929 feet)[2]
1986 Observed Data	-	-	6,206	4,921.0	4,917.3
1985 Schaff & Wheeler Study	86	74	10,200	4,923.6	-
2000 Stantec Study	76	60	6,435	4,921.2	-

1 Elevation determined from new stage-storage curve from 1-foot contour topographic data, US Geomatics and N.A.M.(2006).
2 Elevation measured in NGVD
1929.

For Silver Lake watershed, both the Schaff & Wheeler and Stantec curve numbers predict approximately double the volume than was observed in the 1986 event.

For Swan Lake watershed, the Schaff & Wheeler curve number predicted 1.64 times the volume observed in the 1986 event and the Stantec curve number predicted 1.04 times the volume observed in the 1986 event.

This comparison demonstrates how the curve number method is very sensitive to the curve numbers used and how it has a tendency to over-predict volumes for a 100-year, 10-day storm event. Thus, the curve number method is determined not the best method to calibrate to the 1986 storm event. The alternative method, utilizing infiltration losses and impervious coverage, as chosen in the 1986 study, is the preferred method to calibrate to the 1986 storm event in this study and is discussed in detail below.

6.2 – Infiltration Losses and Impervious Coverage Method

A lumped parameter model was created and the following parameters were entered into the model: 1) basin area, 2) precipitation data, 3) lag time, 4) stage-storage relationship for the playa lakes, and 5) initial and constant loss rates. The following section describes how these parameters were determined for the calibration model for each watershed. The precipitation and lag time parameters were the same as those used in the 1987 Nimbus re-study (Ref. 31). New values for basin area and stage-storage relationships were used in the calibration-run for this study. In general, basin-wide average values for each parameter were entered into the models and the constant loss rate was varied to reproduce the lake levels observed from the 1986 event. The constant loss rate parameter determined from the model calibration will be used in the design storm HEC-1 model, with current (2005) and projected land use data, to determine the new 100-year lake levels in this study.

6.2.1 – Watershed Boundaries

The watershed boundaries from the 1987 Nimbus Engineers report (Ref. 31) for Silver and Swan Lake watersheds were compared with those prepared by Stantec in 2000 (Ref. 32) and were found to differ. Stantec placed all properties west of Stead Boulevard in the Silver Lake watershed. Nimbus, based upon USGS quad maps, placed a portion of these properties (east half of Stead golf course) in the Swan Lake watershed (Plate 1). The analysis by Stantec used 2-foot topographic data supplied by Washoe County in addition to "subdivision site plans, NDOT highway plans, major roadway profiles, and field investigations supplemented by spot surveys" (Ref. 32). Quad Knopf reviewed 2002 2-foot contours supplied by Washoe County and confirmed the Stantec determination is more accurate. Review of a 1984 aerial photograph of the Silver Lake/Reno-Stead area shows that the railroad spur that heads north from the main Western Pacific tracks into the Reno-Stead industrial park existed in 1987 and should have been accounted for in the Nimbus report.

Moving these drainage areas from Swan Lake watershed to Silver Lake watershed reconfigures the watershed areas from 53.8 to 56.52 square miles in Silver Lake, and from 43.02 to 39.99 square miles in Swan Lake.

6.2.2 – Adjustment of Effective Watershed Areas to Snow Level
Observations made during and after the 1986 storm indicated that the upper elevations within the watersheds received a considerable amount of their precipitation as snowfall. Since snowfall would not contribute to the initial runoff response from the watershed, a portion of the watershed was excluded from the model. Based on the information presented in the NWS report and observations made in the field, the area above 5,600 feet was selected as the area that received the bulk of the precipitation as snowfall. This interpretation was embedded in the 1987 Nimbus report (Ref. 31).

The reduction in area contributing to the runoff response of the watersheds results in a reduction of runoff volume to the playa lakes. Since the water levels at the playa lakes were measured following the storm, the reduction in runoff volume needs to be offset by a reduction in the constant loss rate parameter to obtain the measured water surface elevations. When the lower constant loss rates are then applied in the design storm HEC-1 model, more runoff will be predicted at the playa lakes than if higher constant loss rates were used. Thus, selecting the 5,600-foot snow level will give conservatively higher volumes at the playa lakes.

This modification decreased the effective watershed area for Silver Lake from 56.52 to 39.57 square miles, and for the Swan Lake playa from 39.99 to 34.36 square miles.

The 5,600-foot snow level will only be used in the calibration model since it is based on empirical data from the NWS and from field observations from the 1986 storm. The entire watershed area will be used in the design storm HEC-1 model as the possibility exists for a cold storm to be followed by a warm storm that could melt a temporary snowpack and deliver the runoff potential of the entire watersheds to the playa lakes.

6.2.3 – Precipitation Data and Modeling Period
A discussed in Section 3.4, an isohyetal map was constructed for the North Valleys area for the 1986 storm event and is presented in Figure 3. Precipitation data for the 1986 storm event was extracted from the isohyetal map and used for the precipitation parameters in the calibration model, as was done by Nimbus in the 1987 re-study.

The period of rainfall modeled was from 1100 hours on February 14th, 1986 to the end of the storm. The modeling period does not include the first portion of the storm in order to concentrate the computational period to the end of the storm. This assumes that the rainfall that occurred prior to the 1100 hours on the 14th was lost as initial abstraction. The precipitation that occurred prior to this period was minimal and occurred primarily as snow, thus this assumption is not considered to be significant. Including this rainfall into the model would increase the runoff volume predicted and thus cause the predicted losses to be higher.

6.2.4 – Lag Time Parameter

The lag time (T-Lag) values estimated in the 1987 Nimbus re-study, determined by the average of both the curve number and Upland methods, were used in the calibration model for this study. Since the lake levels are not very sensitive to the timing of the peak flows, it was determined unnecessary to re-calculate the T-Lag parameters for this study.

6.2.5– New Stage-Storage Relationship

A 1-foot contour topographic survey of the Silver Lake and Swan Lake playa areas was sub-contracted by Quad Knopf to US Geomatics (USG), Reno, NV. USG established ground control in order to meet National Map Accuracy Standards for 1-foot contours at a scale of one inch equals 40 feet. USG sub-contracted the Aerial Photogrammetry survey to North American Mapping (NAM), Sparks, NV. USG conducted quality control of the contour data which included ground surveying of 10% of the data points produced by NAM and determined no measurable differences. USG also calculated areas per 1-foot of elevation for each watershed with ArcGIS software. This data was input into HEC-1 and the new stage-storage relationships were calculated using the conic method. Figures 8 and 9 show the new stage-storage relationship for each playa lake, and the stage-storage relationships from the 1987 Nimbus study (adjusted to NAVD 1988) for comparison.

The differences in the stage-storage curves compared the 1987 study can be attributed the greater accuracy of the new one foot topographic data. The Nimbus study used 5-foot contour data, with frequent spot elevations, and estimated 1-foot contours which were compared to the bathometric survey map in Reference 2. The areas under each contour were measured and compared to the information on the 7.5 min USGS quad.

In Silver Lake playa, the new data illustrates an increase in playa area relative to the Nimbus data, primarily at lower elevations. Figure 8 shows the 2006 stage-storage curve has shifted to the left relative to the 1987 Nimbus data, indicating an increase in volume starting at the 4,958' elevation. In Swan Lake playa, the new data illustrates a decrease in playa area relative to the Nimbus data at lower elevation and an increase in playa area at higher elevation. This is seen on the stage-storage curve in Figure 9, where the 2006 data curve shifts to the right starting at elevation 4,913' and returns back to almost the same value at elevation 4,924'.

6.2.6– Adjustment of 1986 Storm Lake Levels from NGVD 1929 to NAVD 1988

Lake level elevations following the 1986 storm event were measured in the NGVD 1929 vertical datum. The new one foot topographic data and stage storage curves were measured by USG/NAM in the NAVD 1988 vertical datum. To compare the results of the calibration model to the lake levels from the 1986 storm event, the measured elevations were adjusted to the NAVD 1988 datum.

The National Geodetic Survey's interactive website (Ref. 34) was used to determine the vertical datum shift for each playa. To convert from NGVD 1929 to NAVD 1988, an elevation adjustment of +3.74 feet was determined for Silver Lake, and an adjustment of

+3.71 feet was determined for Swan Lake. Table 2 below summarizes the NAVD 1988 elevation after applying the above datum adjustment.

Table 2. Measured Lake Levels after 1986 Storm Adjusted from NGVD 1929 Vertical Datum to NAVD 1988 Vertical Datum

WATERSHED	MEASURED ELEVATION NGVD 1929 (feet)	ELEVATION ADJUSTED TO NAVD 1988 (feet)
Silver Lake	4961.7'	4965.44'
Swan Lake	4917.3'	4921.01'

6.2.7 – Initial and Constant Loss Rates

The Sacramento District of the U.S. Army Corps of Engineers prepared a hydrology report for the Truckee River basin in 1980 (Ref. 25). This report presents the results of their calibration of the initial and constant loss rates within that watershed during the 1955 and 1963 events. The results of their analysis indicated that an initial loss rate of 0.30 and constant loss rates between 0.05 and 0.23 resulted in reasonable duplications of observed hydrographs for those events. They adopted a constant loss rate of 0.10 for general rain, probable maximum and standard projected events.

Since the calibration model for the 8-day, 1986 event was not very sensitive to the initial loss rate, the value of 0.30 was chosen as a reasonable value. To determine the constant loss rate, the stage-storage relationship generated from the new 1-foot topographic data was entered in the HEC-1 calibration models. The calibration model for each watershed was then tested using varying constant loss rates to determine which rate would produce the observed stage-elevation measured following the 1986 storm. The results of this analysis are presented in graphical form in Figures 10 and 11.

SILVER LAKE PLAYA

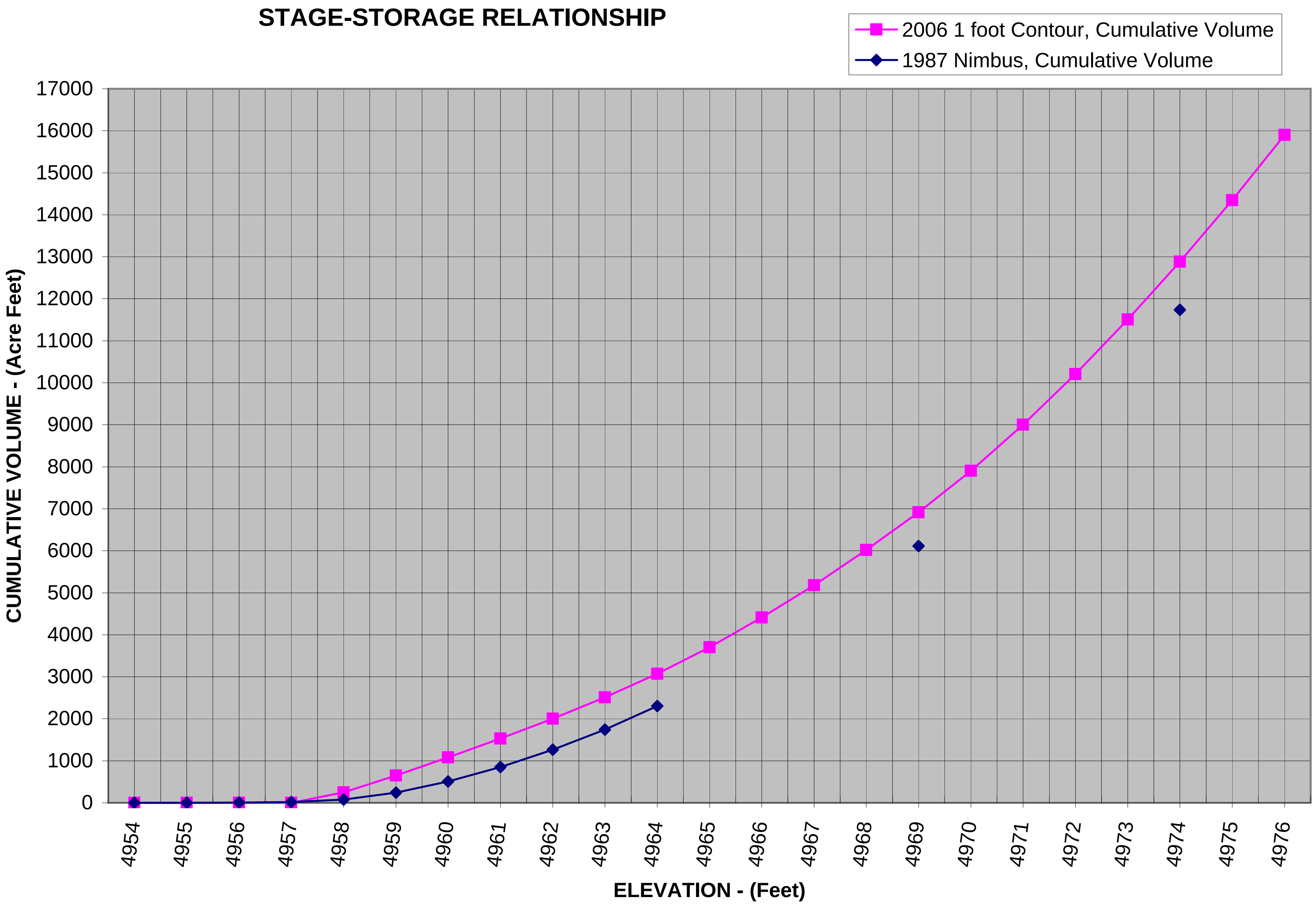


Figure 8

SWAN LAKE PLAYA

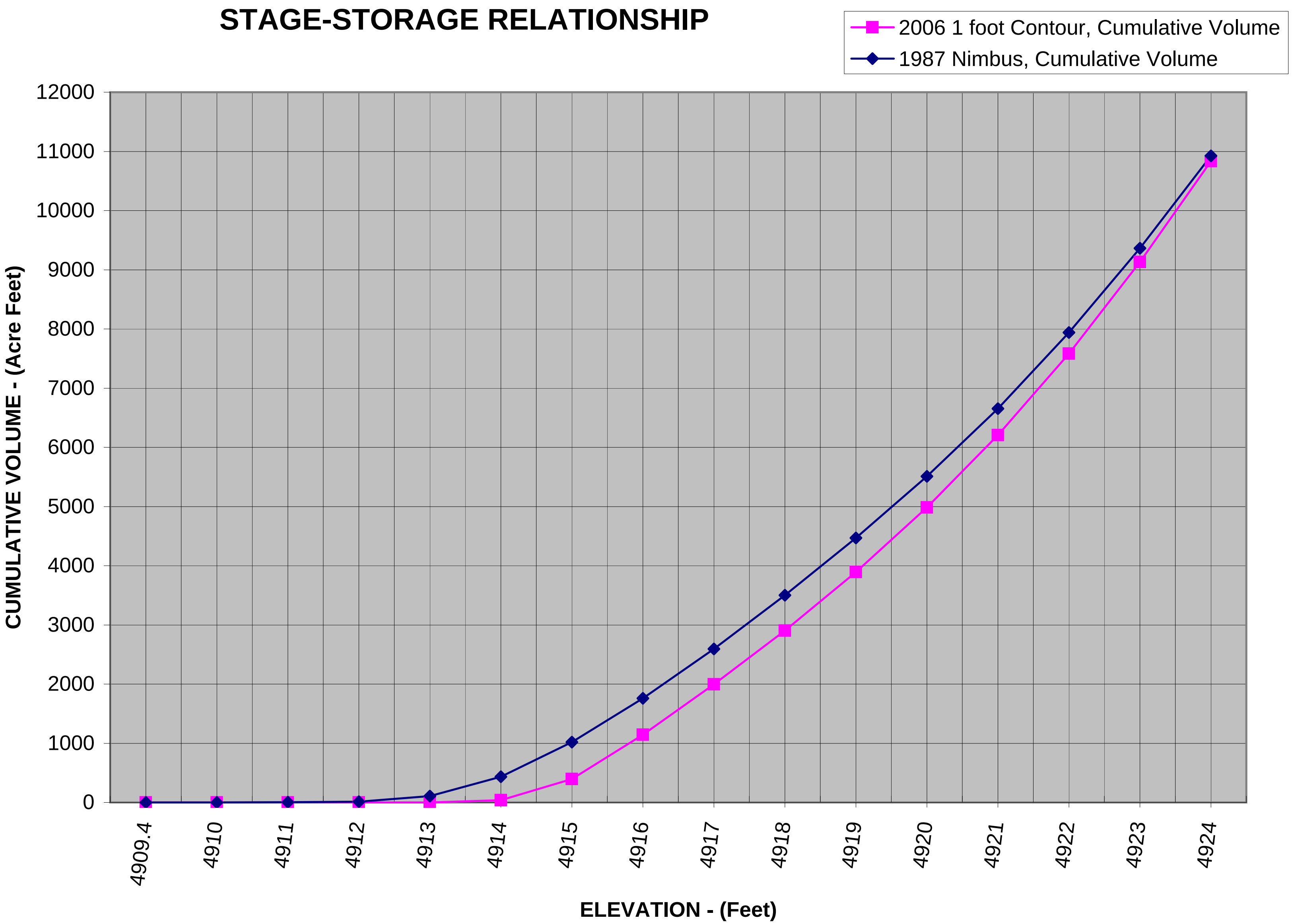


Figure 9

SILVER LAKE PLAYA

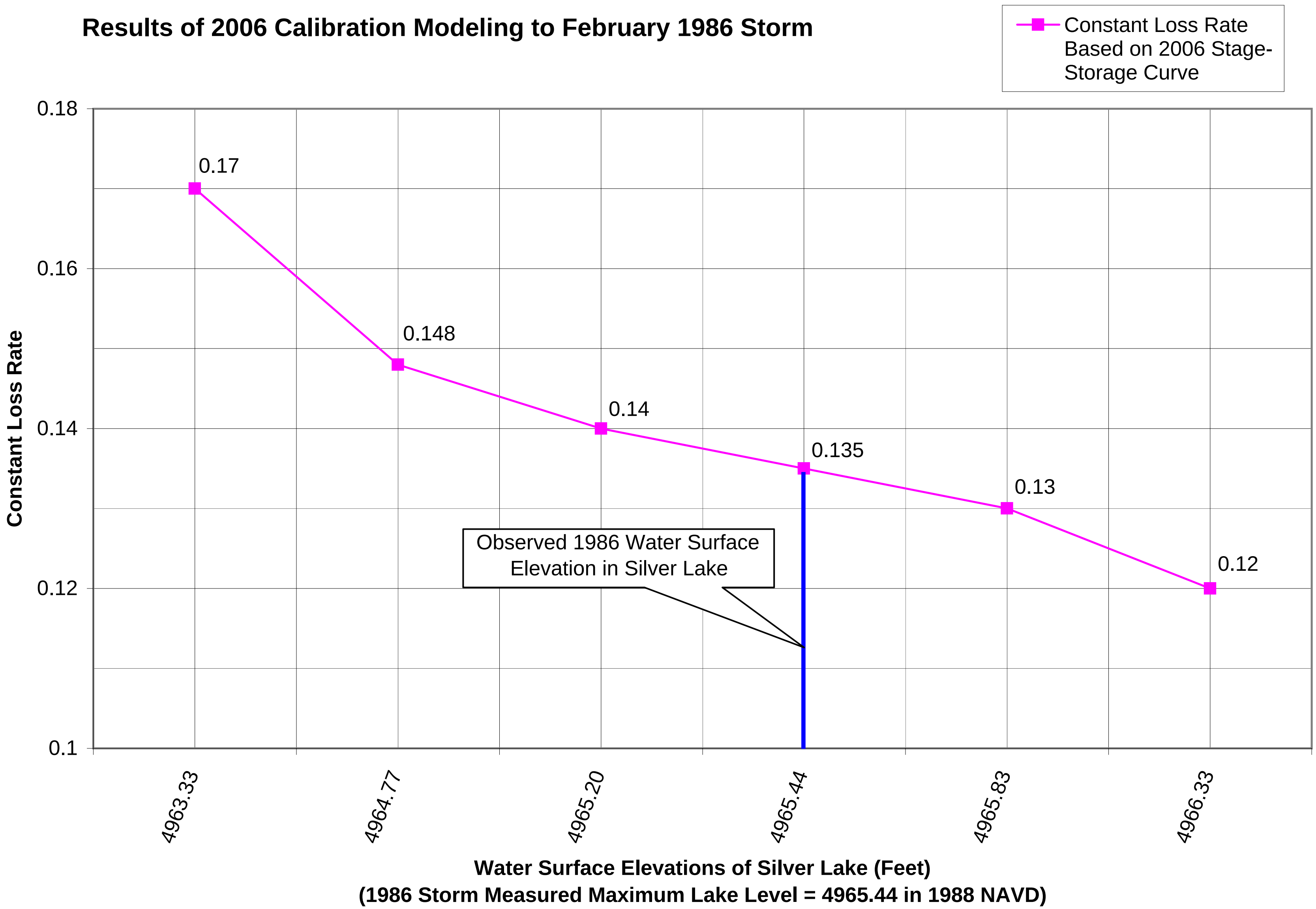


Figure 10

SWAN LAKE PLAYA

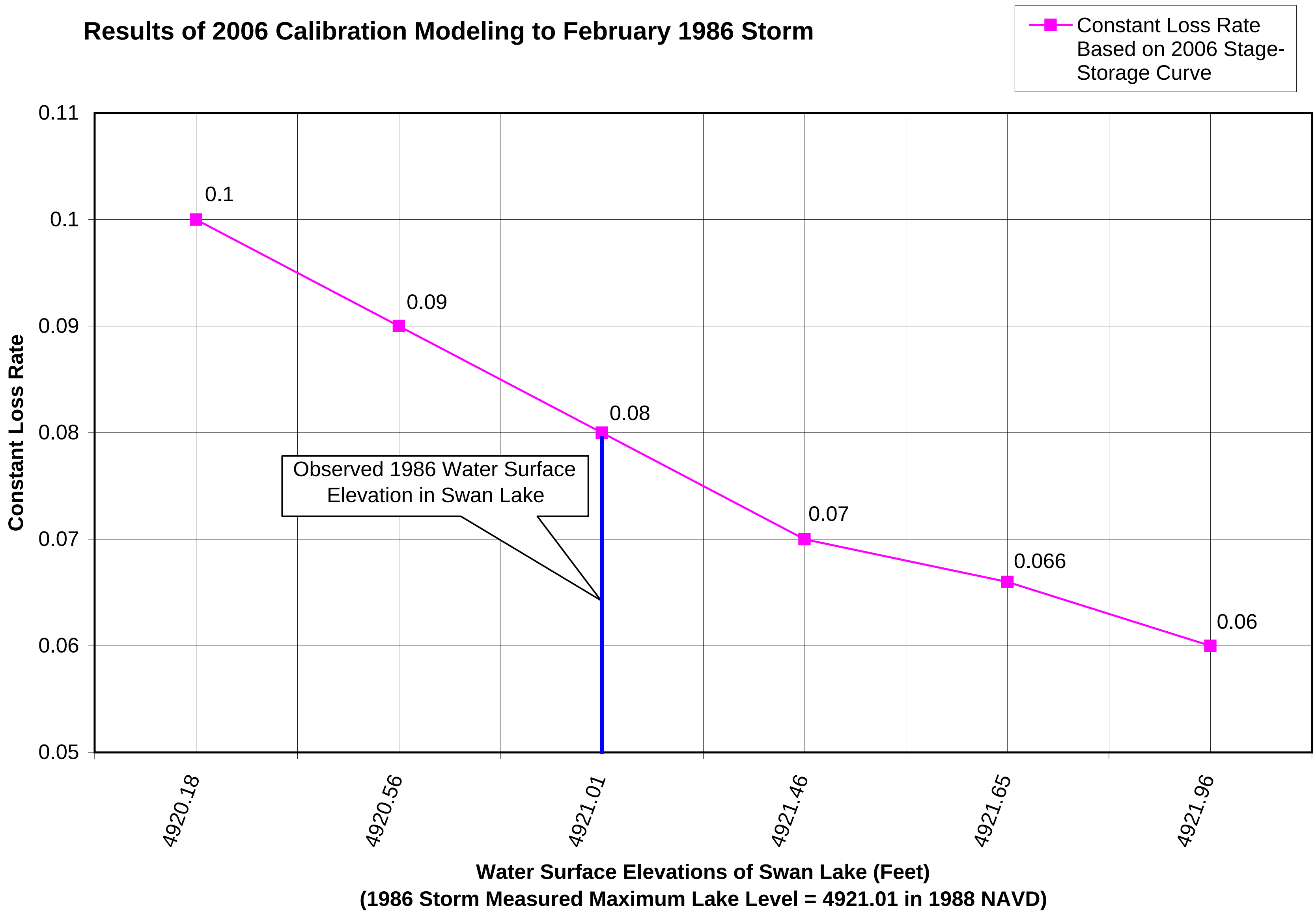


Figure 11

PLF 1847

6.3 – Results of Calibration Modeling

The new 1-foot topographic data presents an increase in capacity (volume) for Silver Lake and a decrease in capacity (volume) for Swan Lake relative to the 1987 Nimbus stage-storage curve. To account for the increase in volume in Silver Lake, a reduction in the constant loss rate from the 1987 Nimbus value of 0.148 to 0.135 was determined in this calibration model. To account for the decrease in volume in Swan Lake, an increase in the constant loss rate from the 1987 Nimbus value of 0.072 to 0.080 was determined in this calibration model. The results indicate that the appropriate constant loss rates, with the adjusted basin area and new stage-storage relationship, for the Silver Lake and Swan Lake watersheds are 0.135 and 0.080 respectively.

These values are within the range of values observed by the Corps of Engineers for the adjacent watershed areas. These values are also very similar to the infiltration rates reported for the soils in the watersheds (Ref. 21).

Runoff volumes for Swan Lake playa are higher per unit area (of the watershed) than for Silver Lake. The higher observed volume per area that reaches the playa lake is reflected in the lower calibrated loss rate for Swan Lake playa than Silver Lake. An additional factor that influences the runoff volume is channel infiltration losses. The Silver Lake watershed has longer channel reaches than Swan Lake due to the differences in watershed shape and location of the playa within the watershed. This higher potential for channel infiltration losses in the Silver Lake watershed results in higher constant loss rates than Swan Lake. These two factors provide a reasonable explanation for the differences noted between the constant loss rates obtained in the calibration analysis.

The use of initial and constant loss rates was determined to be the most accurate means of duplicating the watershed characteristics observed during the February 1986 event, with the limited data available. The constant loss rate values determined by this analysis are the result of a one-event calibration attempt with limited data. Since the purpose of the calibration is to determine the loss rates to use in a 100-year, 10-day event, which is similar to the type of event experienced, the results are considered to be appropriate for use in the final analysis.

In order to get a final 100-year lake level for each of the playa areas, the model should incorporate an estimate of initial storage and possibly a smaller event that precedes (or follows) the 100-year event within the same year. This scenario will be discussed in Section 8.0.

7.0 – STATISTICAL RAINFALL INFORMATION

In 2003, the National Weather Service (NWS) replaced the NOAA Atlas 2 precipitation data with the NOAA Atlas 14 precipitation dataset. The NWS also created an interactive website (Ref. 33) to obtain precipitation data by latitude and longitude for storm durations from five minutes to sixty days. In addition, the data is also available for download as a GIS grid file that can be used to calculate average precipitation over large areas.

For this study, the GIS grid data was used to determine the basin-wide average precipitation values for the Silver Lake and Swan Lake watersheds. The interactive website was used to obtain precipitation data for each subbasin in each watershed. The centroid of each subbasin was calculated in AutoCAD. The coordinates of each centroid from the AutoCAD drawing were converted from Nevada State Plane, West to latitude and longitude using the Corpscon 6.0 software, by the US Army Corps of Engineers, for entry into the NOAA 14 website. Precipitation data from the NOAA-14 website for each subbasin in each watershed are attached in Appendix A.

For the 1987 Nimbus re-study of 100-year lake levels in the North Valleys, Nimbus conducted a thorough evaluation of which precipitation dataset was most accurate for the North Valleys area. The detailed discussion from the 1987 Nimbus report is included as Appendix B. The following paragraphs are a summary of this analysis.

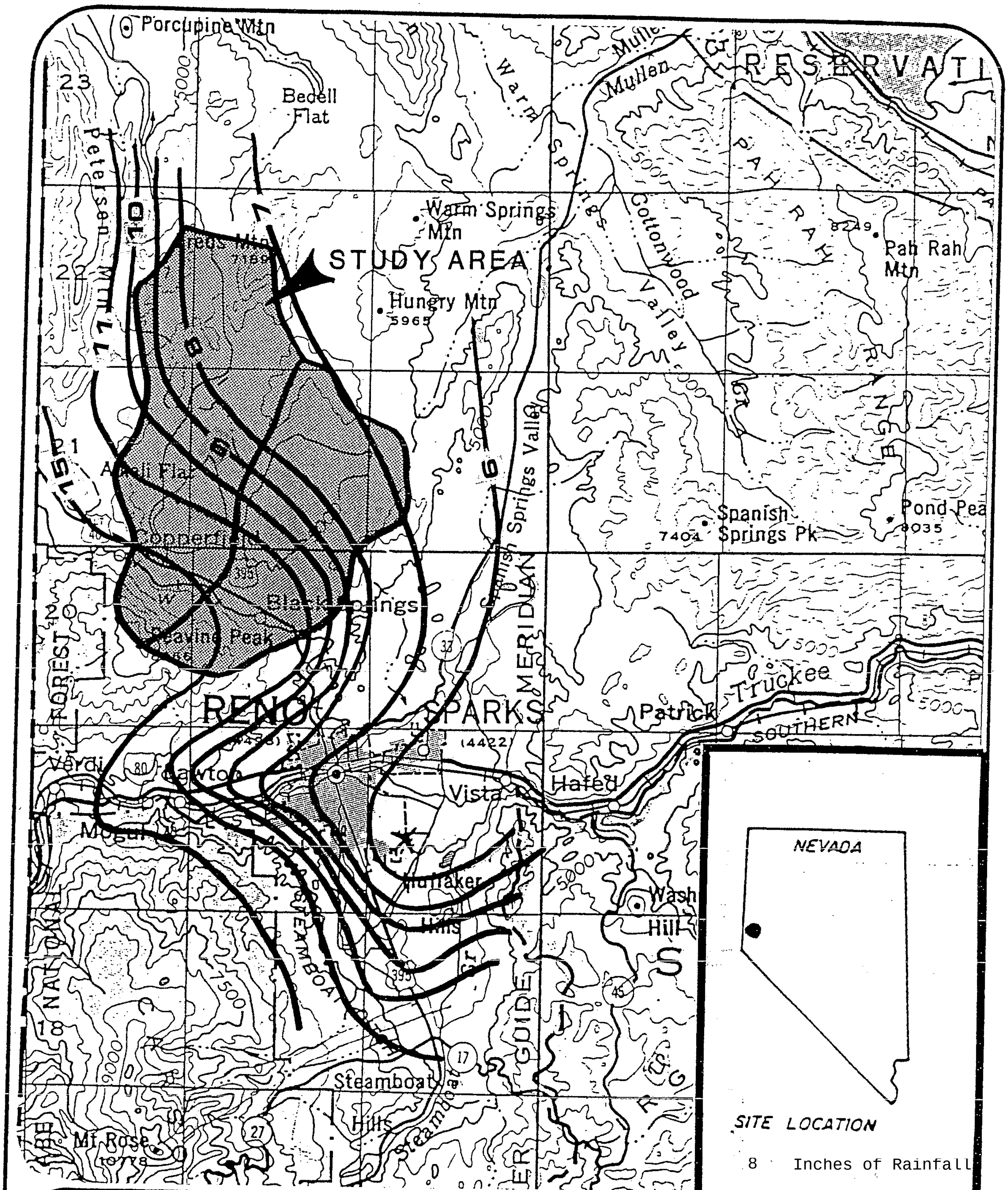
A number of references, including NWS Technical Papers No. 40 and No. 49, NOAA Atlas 2, and SCS Technical Note PO-6 were reviewed for project specific relevance. The NOAA Atlas 2 data replaced NWS Technical Paper No. 40 in the late 1970's and SCS Technical Note PO-6 was based on the NOAA Atlas 2 data. Nimbus consulted with the Washoe County Department of Comprehensive Planning (WCDCP) and the NWS office in Reno, Nevada for their input on obtaining accurate precipitation data for the North Valleys area.

Both the WCDCP and the NWS believed the NOAA Atlas 2 data under predicted rainfall amounts near the eastern slopes of the Sierras.

The California Department of Water Resources published a report that contained a Log Pearson Type III analysis of each gauge in California and extreme western Nevada (Ref. 1). Four sites were selected from this study and compared to measured precipitation data from the February 1986 storm event. The Reno gauge was determined to have the best correlation with the measured data in the North Valleys area. Leonard Crowe of the WCDCP suggested that a ratio of the February 1986 event totals be applied to the 10-day value for the Reno gauge to obtain a value for the study area. This approach was also discussed with Ron Olson at the NWS who agreed, that in absence of more definitive data, this approach would provide a more reasonable estimate than the other available sources.

Figure 12 is the 100-year, 10-day Isopleth map adopted by Nimbus Engineers in 1987. In the Nimbus model, the 100-year, 10-day precipitation value for the combined Silver and Swan Lake watersheds was 10.1 inches. Figure 13 is an Isohyetal (Isopleth) map of the

NOAA Atlas 14 data for the 100-year, 10-day storm. Basin-wide precipitation values for the Silver lake and Swan Lake watersheds generated by the NOAA Atlas 14 data are 12.6 and 10.6 inches respectively. Thus, NOAA Atlas 14 dataset predicts approximately 15% more rainfall than that predicted by the isohyetal map adopted by Nimbus in 1987.



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(702) 689-8630

FIGURE 12

100 YEAR, 10 DAY ISOPLETH MAP

BASED UPON FEBRUARY 1986 STORM PATTERN

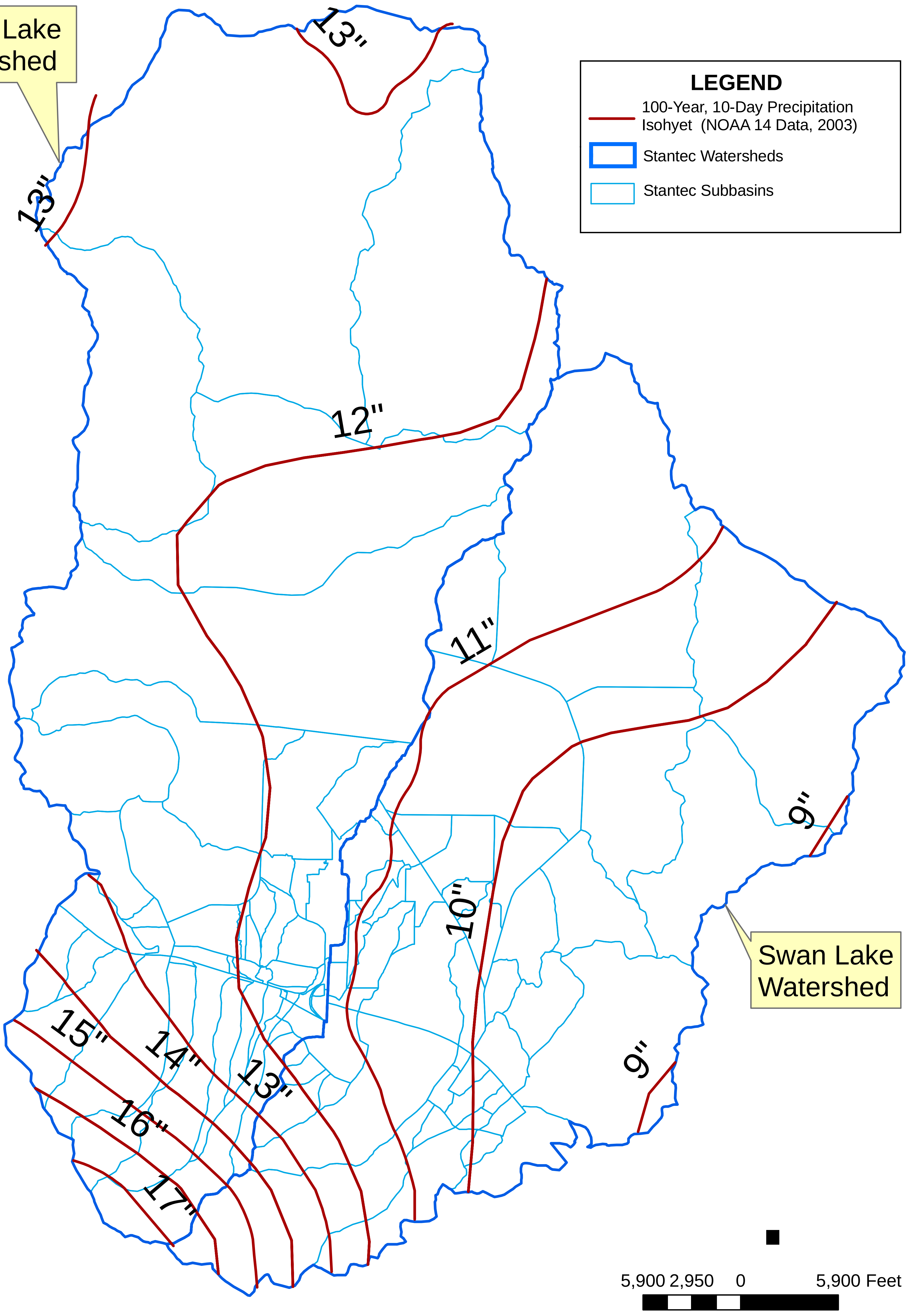

FIGURE 13
NOAA ATLAS 14, 100 Year, 10 Day Isohyetal Map
Silver Lake and Swan Lake Watersheds

Quad Knopf Job: 050665

February 2007

Quad Knopf

PLF 1852

8.0 – 100-YEAR LAKE LEVEL ANALYSIS

8.1 - Introduction

The lumped parameter (basin-wide) HEC-1 model was chosen as the best method to calibrate loss rates to the 1986 storm event as discussed in Section 6.1. Similarly, the lumped parameter (basin-wide) HEC-1 model was chosen to model 100-year lake levels in Silver and Swan Lakes. The following parameters were entered into this model: 1) basin area, 2) precipitation data, 3) lag time, 4) stage-storage relationship for the playa lakes, 5) initial and constant loss rates, 6) land use percent impervious data for existing and buildout development conditions. In addition to these parameters, a volume to represent an initial storage condition was also included in the model. From the model, lake levels for a 100-year, 10-day storm for the Silver Lake and Swan Lake playas were determined for existing and buildout development conditions.

8.2 - Initial Storage Condition (Carry-Over Storage)

The Quad Knopf model of 100-year lake levels includes an estimate of an initial storage condition, also referred to in this report as carry-over storage volume, which represents volume contributions to the playa in addition to runoff volumes from the 100-year, 10-day storm event. In the 1987 Nimbus Flood Insurance Study, the volume from a 25-year, 24-hour storm was used to represent water residing in the playas from a previous year and an additional storm event occurring in the same water year as a 100-year event. In 1994, Schaff & Wheeler conducted a study of the 100-year lake level of Silver Lake (Ref. 38) using a 5-year, 24-hour storm volume at the playa for an initial storage condition.

8.2.1 Selection of 25-Year, 24-Hour Storm

A peer review of a draft version of Volume I of this report (Hydrologic Analysis) was undertaken and included peer hydrologic consultants, and City of Reno and Washoe County personnel. A list of comments from peer review attendees was compiled by the City and is attached with Quad Knopf's responses in Appendix C. During the peer review, the decision to use a 5-year or a 25-year, 24-hour storm for a carry-over storage volume was discussed. The general consensus was to use the 25-year, 24-hour storm to be conservative, considering the significant impacts of flooding in closed basins.

It was also recommended to review historical climatic records to investigate if a 25-year storm or a 5-year storm has a higher likelihood of occurring in the same water year as a 100-year storm. Ron Olson, a retired climatologist from the National Weather Service in Reno, NV, was sub-contracted by Quad Knopf to carry out this review. His summary report titled *Probability of Multiple Excessive Rainfall/Runoff Events in the Same Water Year in Reno, Nevada North Valleys Historical Analysis*, is attached as Appendix D. The report states that historical precipitation data in the North Valleys is too limited to show a conclusive relationship of a 100-year storm with a 25-year or a 5-year storm. However, investigation of return rates of flood events on the Truckee River indicate that of the nine flood events with return rates greater than fifty years, in the 100-year period from 1907 to

2006, two of them were followed by a second flood event in the same water year with a return rate of ten years or greater. The report concludes that using a 25-year event makes sense, considering the limited amount of data available (Ref. 40). Thus, based on consensus in the peer review and the report by Ron Olson, Quad Knopf will use the 25-year, 24-hour storm for the purposes of calculating a carry-over storage volume.

8.2.2 Selection of Curve Number Method for Model of 25-Year Storm

The 1987 Nimbus study used a lumped parameter model to calculate a carry-over storage volume. As discussed in section 6.1, the curve number method has a tendency to over-predict runoff volumes for a 10-day storm event and the lumped parameter model was chosen as the best method to calibrated to the 1986 storm event and to calculate the volumes for the 100-year, 10-day design storm. However, we evaluated the lumped parameter method versus the curve number method for a 24-hour storm and determined the lumped parameter method over-predicts the volume relative to the curve number method. This is a result of using the constant loss rates calibrated to the 10-day storm, since we have no means to calibrate loss rates to a 24-hour storm. Thus, the curve number method was chosen as the best method to model the carry-over storage volume for the 25-year, 24-hour storm.

The 2000 Stantec Drainage Master Plan study (Ref. 32) used a curve number method, HEC-1 model to calculate peak flows for proper sizing of storm drainage infrastructure. The model divided the Silver and Swan lake watersheds into a total of 101 subbasins and contained unique parameters including curve numbers for each subbasin. This model was used as the framework to determine the carry-over storage volumes for the 25-year, 24-hour storm. A discussion of how the curve number was determined will follow in Section 8.8.

8.3 - Watershed and Subbasin Boundaries

As discussed in section 6.2.1, the watershed boundaries from the 1987 Nimbus Engineers report for Silver and Swan Lake watersheds were compared with those prepared by Stantec in 2000 and were found to differ. It was determined that the Stantec watershed boundary determination was more accurate.

Reconfiguring the watersheds as described in section 6.2.1, the watershed areas change from 53.8 to 56.52 square miles in Silver Lake, and from 43.02 to 39.99 square miles in Swan Lake.

The subbasin boundaries from the 2000 Stantec model (Ref. 32) were used for this study unmodified and are shown in Plate 1.

8.4 - Precipitation Data

As described in section 7.0, the new NOAA Atlas 14 (2003) precipitation data from the National Weather Service website was utilized.

For the lumped parameter model, the average basin-wide precipitation was calculated from the NOAA Atlas 14 grid data in GIS. For the 24-hour curve number models used to calculate carry-over storage volumes, the precipitation data was downloaded from the website by the centroid coordinates for each subbasin and are attached in Appendix A. Figure 14 is an Isohyetal map of both watersheds for the 25-year, 24-hour storm.

8.5 - Time Lag Parameter

As described in section 6.2.4, it was determined unnecessary to re-calculate the T-Lag parameters since the lake levels are not very sensitive to peak flows. The lag time parameters used in the calibration model from the 1987 Nimbus study were used in the calibration model for this study and were also used in the lumped parameter basin-wide models for calculation of 100-year lake levels for this study.

Similarly, the lag time (T-Lag) values used in the 2000 Stantec study were adopted and unchanged for use in our 25-year, 24-hour curve number models to calculate initial storage volumes for both playa lakes.

8.6 - Stage – Storage Relationship

As described in section 6.2.5, a new stage-storage relationship was developed from new one-foot contour topographic data delivered by USG and NAM for this study. The same stage-storage relationship used in the calibration model was also used in both the lumped parameter and curve number HEC-1 models.

8.7 – Initial and Constant Loss Rates

The results from the calibration modeling in Section 6.3, which were adjusted for corrections in basin areas and the new stage-storage relationship, were calibrated to the 1986 storm event and indicate the appropriate constant loss rates for Silver Lake and Swan Lake watersheds are 0.135 and 0.080 respectively. These values were entered into the lumped parameter, design storm, HEC-1 model.

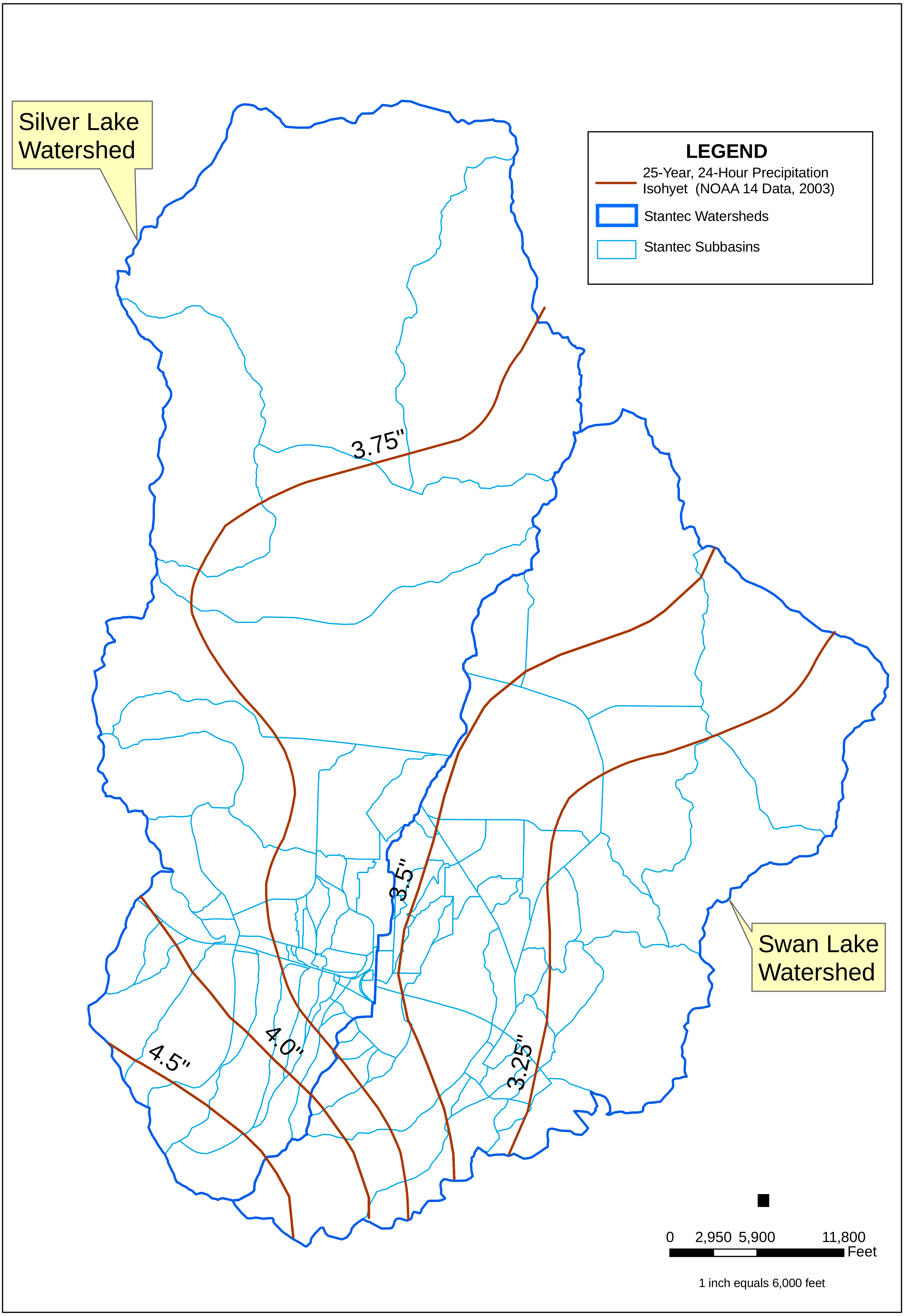

FIGURE 14
NOAA ATLAS 14, 25 Year, 24 Hour Isohyetal Map
Silver Lake and Swan Lake Watersheds

Quad Knopf Job: 050665

February 2007

Quad Knopf

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8.8 - Land Use and Impervious Coverage

To update the percent impervious parameter for current and future land use development conditions, a GIS based Regional Land Use Model was obtained from Randy Baxley at the Truckee Meadows Regional Planning Agency (TMRPA). This model contained Washoe County Assessor's Land Use for 2005 and buildout land use data projected by TMRPA, consistent with the Regional Plan in the North Valleys. The Washoe County Assessor's Land Use was current through November, 2005. The buildout land use projections were updated in January 2006.

The Land Use Model was parcel-based and allowed calculation of percent impervious coverage by subbasin and by watershed. Appendix E contains a detailed discussion of how the TMRPA Land Use Model was used to calculate percent impervious coverage. The following is a summary of this analysis.

To determine impervious coverage for existing (2005) development conditions, the Washoe County Assessors office parcel data for 2005, which is included in the Regional Land Use Model, was utilized. A map of existing Washoe County Assessors Land Use Codes is presented in Plate 2. To assign percent impervious values to the Washoe County Land Use Codes, each code was classified into one of the nineteen "Land Use or Surface Characteristic" classes in table 702 (Table E1, Appendix E) of the Washoe County Hydrologic Criteria and Drainage Design Manual (Ref. 35) and assigned the associated percent impervious value. A shapefile containing this data was generated and a map of the assigned "Land Use or Surface Characteristic" per parcel for existing development is presented in Plate 3. Digital shapefile data is attached in Appendix M. From the shapefile, summaries of acres per "Land Use or Surface Characteristic", per subbasin were exported from ArcGIS. The percent impervious values from Table 702 (Table E1, Appendix E) were applied to the acres per "Land Use or Surface Characteristic" in an Excel spreadsheet and a weighted percent impervious value per subbasin was determined. From the subbasin impervious coverage, a basin-wide weighted average was calculated.

For buildout development conditions, the TMRPA Regional Land Use Model includes realistic buildout projections of residential and non-residential development (Ref. 36). The TMRPA land use projections are based upon the following: 1) the current Washoe County Master Plan, 2) zoning designations from Reno, Sparks and Washoe County regional plan policies, 3) recent development trends from the past decade relating to density and intensity of development, and 4) land uses specific to each master plan/zoning classification (Ref. 36). The buildout land use of each parcel, if any exists, is identified by a series of development potential fields in the GIS model. This potential was classified into one of the nineteen "Land Use or Surface Characteristics" classes to assign a percent impervious value per parcel. The same shapefile generated for existing conditions land use data also contained buildout land use data. A map of the assigned "Land Use or Surface Characteristic" per parcel, for buildout conditions is presented in Plate 4. As performed for existing conditions, summaries of acres per "Land Use or Surface Characteristic", per subbasin were exported from ArcGIS. The percent impervious values from Table 702

(Table E1, Appendix E) were applied to the acres per "Land Use or Surface Characteristic" in an Excel spreadsheet and a weighted percent impervious value per subbasin was determined for buildout conditions. From the subbasin impervious coverage's, a basin-wide weighted average was calculated. Percent impervious data per subbasin and per watershed are attached in Appendix F.

8.9 Curve Number Determination for Carry-Over Storage Condition Models

As introduced in section 8.2.2, the 2000 Stantec HEC-1 model was used as the framework for the 25-year, 24-hour carry-over storage condition curve number models. All parameters in this model have been addressed above in preceding sections, except determination of the curve number. To determine representative volumes of water at the playa lakes for carry-over storage, a review of the curve numbers used in the Stantec report was carried out.

8.9.1 Basis for Revision of Curve Numbers

The Stantec curve number model was modified with 10-day curve numbers using Table 2-3b in SCS TR-60 (Ref. 19). For the 100-year, 10-day storm, this model produces volumes of approximately 20,200 and 10,400 ac-ft at Silver and Swan lake playas respectively. In comparison, the lumped parameter model for the 100-year, 10-day storm, with loss rates calibrated to the 1986 storm, produces 7,210 and 6,956 ac-ft at Silver and Swan lake playas respectively. Thus, there is a large discrepancy between the volumes predicted using the Stantec curve numbers, adjusted to 10-day values, versus the lumped parameter model with loss rates calibrated to the 1986 storm.

The volume determined from the curve number model is very sensitive to the curve numbers applied and the curve number is partially dependent on the 'Hydrologic Condition Rating', also referred to as 'vegetative cover density', assigned for a given subbasin or watershed. A possible explanation for the discrepancy in volume generated by the Stantec model with 10-day curve numbers versus the lumped parameter model is that the 'Hydrologic Condition Rating' values in the Stantec model were underestimated.

8.9.2 Revision of 'Hydrologic Condition Rating' for 'Sagebrush w/Grass' Vegetation Type

In SCS publication TR-55, graph NEH-4 (Ref. 20) plots a relationship between 'vegetative cover density' (Hydrologic Condition Rating) versus curve number, per soil group for vegetation type 'Sagebrush w/grass'. In the 2000 Stantec report (Ref. 32), this relationship was used to calculate a curve number for this vegetation type in each subbasin.

Quad Knopf retained Walker & Associates, Minden, Nevada, to independently evaluate the 'Hydrological Condition Rating' in the study area. An initial study was carried out where the transect method was used to measure 'vegetative cover density' with one cover transect on each of 11 sites. The City of Reno hired Walker & Associates to carry out a follow-up study to refine the 'Hydrologic Condition Rating', incorporating an additional five transects per site and an additional six sites. Both studies are documented in the report *North Valleys' Hydrological Condition Rating Report,* attached as Appendix G. Table 1 in the Walker & Associates report lists the average 'Cover %' of all transects per site. The follow-up study also delineated fifteen 'Vegetation Cover Zones', which correspond to the average of all 'vegetative cover density' transect values within each of the fifteen zones and are shown in Figure 15. For vegetation type 'Sagebrush w/grass', graph NEH-4 in SCS TR-55 (Ref. 20), was used to determine curve numbers for soil groups B, C, and D for each of the fifteen 'Vegetation Cover Zones'. The percent cover for each zone and curve numbers determined from graph NEH-4 are listed on the sheets in Appendix F.

<u>8.9.3 Delineation of Vegetation Types</u>

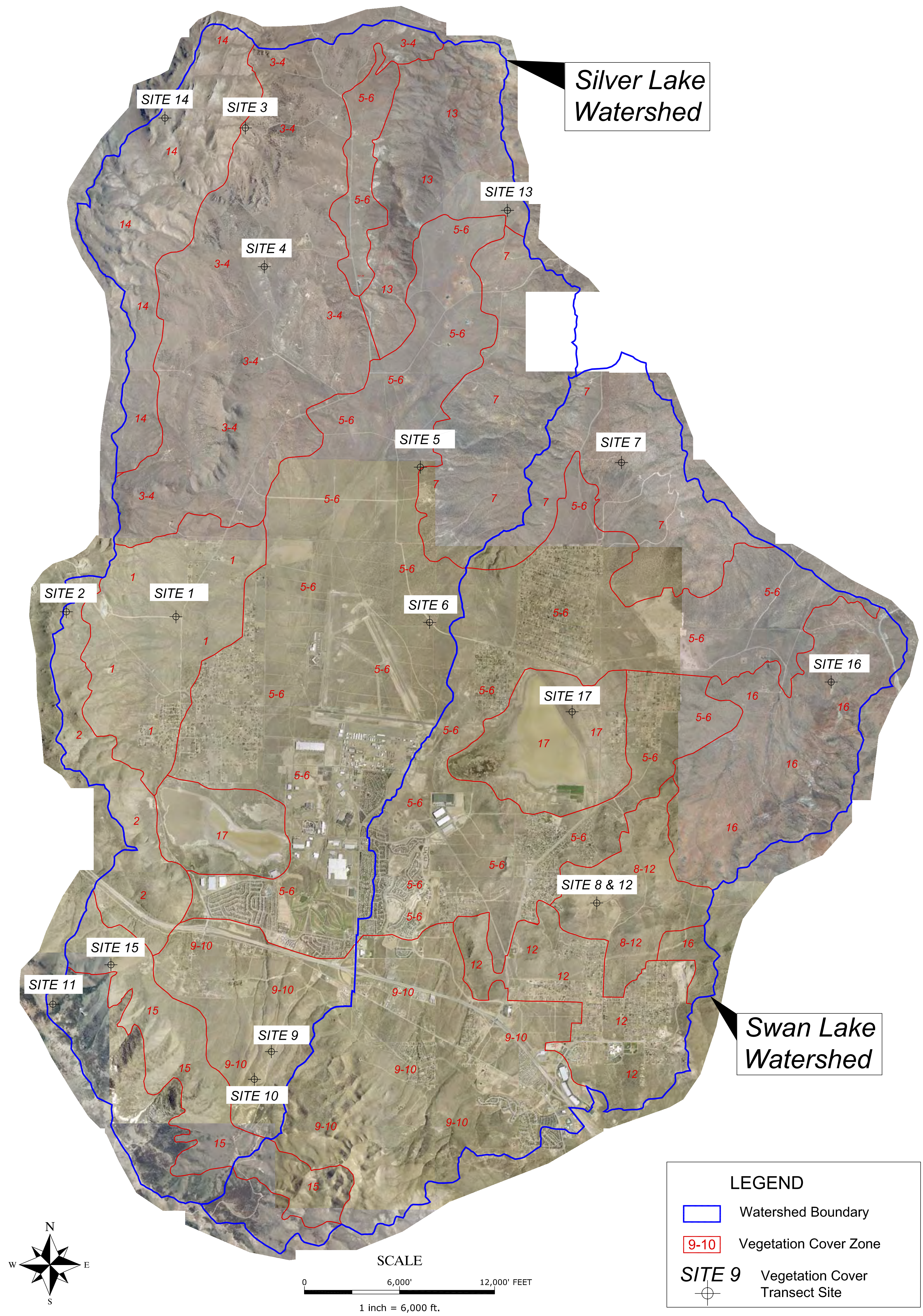
Two other vegetation types occur in the North Valleys, 'Herbaceous (grasses)' and 'Mixed Grass and Shrub'. For these vegetation types, the relationship between curve number and vegetation type and soil group listed in Table 702 of the WCHCDDM (Ref. 35) (Table E1, Appendix E) can be used to assign curve numbers per subbasin. Data on vegetation type distribution in the North Valleys was supplied by Washoe County Department of Water Resources. A report by Justin Huntington, conducted under supervision by Randy Vanhooser, titled *Water Resource Investigation of Lemmon Valley, Washoe County, Nevada* (Ref. 39), delineated areas that could be classified as 'Herbaceous (grasses)' and 'Mixed Grass and Shrub'. The remainder of the area in the Silver and Swan Lake watersheds were classified as 'Sagebrush w/Grass' vegetation type.

<u>8.9.4 Calculation of Curve Number</u>

ArcGIS was used to overlay the areas (polygons) representing the 'Vegetation Cover Zones', vegetation types, soil groups and subbasins in each watershed. The data was selected by subbasin and areas of unique soil group, vegetation type and Vegetation Cover Zone were exported to Excel spreadsheets, which were used to calculate a curve number for each subbasin. For vegetation types 'Herbaceous (grasses)' and 'Mixed Grass and Shrub', the curve numbers per soil group in Table 702 of the WCHCDDM (Ref. 35) (Table E1, Appendix E) were applied to the area of each soil group per subbasin to determine partial curve numbers for these vegetation types. For vegetation type 'Sagebrush w/grass', the curve numbers determined per 'Vegetation Cover Zone' (listed on the sheets in Appendix F) were applied to the area of each soil group per subbasin to determine partial curve numbers for vegetation type 'Sagebrush w/grass'. The partial curve numbers were summed to determine a total weighted curve number per subbasin. Appendix F contains the curve numbers calculated for each subbasin and subsequently used in the 24-hour carry-over storage HEC-1 models. Appendix M contains all the Excel spreadsheets on compact disc.

<u>8.9.5 - Comparison of Lumped Parameter to Curve Number Models for 24-hour Storm</u>

To evaluate the impact on the computed volumes of using the curve number model versus the lumped parameter model to estimate the additional volume in the playas, a 25-year lumped parameter model was created with NOAA 14 rainfall data, the new constant loss rates calculated in section 6.2.7, and updated percent impervious figures for existing development conditions. Table 4 below summarizes the changes in volumes per watershed for the lumped parameter and curve number methods.



Sheet 1 of 1	FIGURE 15 Map of Vegetation Cover Zones & Transect Site Locations North Valleys Flood Control Project	Scale: 1" = 6,000'	Revisions:	Quad Knopf
Quad Knopf Job: 050665		CI: 1 foot		9600 Prototype Ct. Reno, Nevada 89521 TEL: (775) 324-1212 FAX: (775) 324-2311 WEB: www.quadknopf.com
		File Name: centroids-of-subs.dwg		
		Drawn By: GH		
Date: Dec. 2006	Reno City of Reno, NV Nevada	Designed By: GH/PB		050665

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Table 3. Volume Differences of 25-year, 24-hour Lumped Parameter versus Curve Number Models for Existing Conditions.

Watershed	Lumped Parameter Volume	Curve Number Volume	Difference
Silver Lake	3,579	2,724	(855)
Swan Lake	3,507	2,083	(1,424)

The curve number model predicts lesser volumes for both playa lakes than the lumped parameter model. This is interpreted as a result of using constant loss rates in the lumped parameter model calibrated to the 10-day storm. If loss rates could be calibrated to a 24-hour storm, the lumped parameter model would likely yield volumes closer to those generated by the curve number model. The larger difference in volume in Swan Lake can likely be explained by the difference in constant loss rates. As described in section 6.2.7, the loss rate for Swan Lake was calibrated to 0.080 and the loss rate for Silver Lake was calibrated to 0.135.

Since the curve number method is a commonly used approach to account for losses in a 24-hour storm, and without means to calibrate reasonable loss rates in the North Valleys area to a 24-hour storm, the curve number model was determined to be the best method to calculate initial storage volume (carry-over storage) at the playa lakes.

8.10 - HEC-1 Modeling and 100-year Lake Level Results

For the lumped parameter model, the initial loss rate remained at 0.30 as determined in the 1987 Nimbus re-study. The constant loss rate was modified to reflect the new stage-storage relationship determined in this study. The new constant loss rate for Silver Lake was 0.135 and the new constant loss rate for Swan Lake was 0.080. The impervious coverage's were calculated for each watershed for existing and buildout conditions and entered in the HEC-1 models for the 100-year, 10-day storm for Silver Lake and Swan Lake.

For the 24-hour storm carry-over storage volume models, a curve number model with updated curve numbers, the new stage-storage relationship developed in this study, and impervious coverage's calculated for each subbasin for existing and buildout conditions, were entered into HEC-1 models for Silver Lake and Swan Lake.

The 100-year lake levels are summarized in Table 4 with the current, FEMA 100-year regulatory Base Flood Elevations for comparison. Plates 5 and 6 show the approximate location of each of the elevations for Silver Lake and Swan Lake respectively. The new existing conditions lake levels, using a 25-year, 24-hour storm for carry-over storage, are 4971.8' and 4922.9' (NAVD 1988) for Silver Lake and Swan Lake respectively.

The lumped parameter HEC-1 models are attached as hard copies in Appendix H and digitally on compact disc in Appendix M. Due to the extensive size of the curve number models they were only included digitally on compact disc in Appendix M.

The results of the calibrated lumped parameter model present a reasonable estimate of runoff volumes that would result from a 100-year, 10-day storm.

Table 4. 100-year Lake Levels for Existing and Buildout Conditions, Compared to Current FEMA Base Flood Elevations.
(25 year, 24 hour storm for initial storage condition)

WATERSHED	Current FEMA Regulatory BFE	Existing Conditions	Buildout Conditions
	Water Surface Elev. (ft)	Water Surface Elev. (ft)	Water Surface Elev. (ft)
SILVER LAKE	4,968.74 [1,3]	4,971.8 [2]	4,974.4 [2]
SWAN LAKE	4923.71 [1]	4,922.9 [2]	4,924.0 [2]

1 Adjusted from NGVD 1929 vertical datum to NAVD 1988 vertical datum

2 Calculated using 2006, 1-foot contour (NAVD 88) stage-storage curve, Quad Knopf.

3 Uses 5 year storm for initial storage condition, Schaff & Wheeler, 1994.

North Valleys Flood Control Study
Volume II: Mitigation Options

9.0 INTRODUCTION

Volume I of this report documented the hydrologic analysis used to determine new 100-year lake levels for Silver and Swan Lake playas for both existing (2005) and buildout development conditions. In Silver Lake, both existing and buildout conditions water surface elevations are above the existing FEMA, 100-year regulatory Base Flood Elevation (BFE). In Swan Lake, only the buildout conditions water surface elevation is above the existing FEMA, 100-year regulatory BFE (Table 5).

Volume II of this report discusses mitigation options to address the increase in water surface elevations at the playa lakes. A thorough analysis of mitigation alternatives, including calculation of preliminary costs, was carried out to determine the feasibility of mitigating the increase in water surface elevations to the existing FEMA, 100-year regulatory BFE. The report first discusses the volumes and costs of flood control facility alternatives to mitigate to the existing BFE for both playa lakes. The report discusses the preferred mitigation options which include applying for a LOMR to change the current FEMA BFE for Silver Lake and mitigating only for additional stormwater runoff generated through buildout development conditions.

10.0 MITIGATING TO CURRENT BASE FLOOD ELEVATION

Before discussing the mitigation options evaluated in this study, the volumes used as bases for the mitigation options analysis will be reviewed. A summary of the volumes used and the assumptions made to calculate those volumes are described below.

10.1 Volume to Mitigate to Current Base Flood Elevation

The volume to mitigate in order to maintain the existing BFE is the difference between the volume of the new, 100-year stormwater volume at the playa lakes and the stormwater volume of the existing BFE. Table 5 compares the current BFE's and stormwater volumes with those calculated for existing and buildout conditions for Silver and Swan Lakes. The values were calculated using the 25-year, 24-hour storm event for a carry-over storage condition. Table 6 tabulates the difference in volumes between the BFE and the new, 100-year stormwater volumes for existing and buildout development conditions.

Table 5. 100-year Lake Levels and Volumes for Existing and Buildout Conditions, Compared to Current FEMA Base Flood Elevations and Volumes.
(25 year, 24 hour storm for initial storage condition)

WATERSHED	Current FEMA Regulatory BFE		Existing Conditions (this study)		Buildout Conditions (this study)	
	Water Surface Elev. (ft)	Volume (ac-ft)	Water Surface Elev. (ft)	Volume (ac-ft)	Water Surface Elev. (ft)	Volume (ac-ft)
SILVER LAKE	4,968.74 [1,3]	6,682 [2]	4,971.8 [2]	9,931	4,974.4 [2]	13,575
SWAN LAKE	4923.71 [1]	10,341 [2]	4,922.9 [2]	9,045	4,924.0 [2]	10,837
SWAN LAKE *	4923.71 [1]	10,341 [2]	4,923.3 [2]	9,653 [4]	4,924.4 [2]	11,439 [4]

1 Adjusted from NGVD 1929 vertical datum to NAVD 1988 vertical datum

2 Calculated using 2006, 1-foot contour (NAVD 88) stage-storage curve, Quad Knopf.

3 Uses 5 year storm for initial storage condition, Schaff & Wheeler, 1994.

*, 4 Adds volume from a net flow 1.85 MGD, and an additional 0.65MGD in march, of Effluent to playa as additional storage

Table 6. Volumes to Mitigate for Existing and Buildout Conditions Relative to Current Base Flood Elevations. Effluent Volume included in Swan Lake.

WATERSHED	BFE vs. Existing Conditions Volume (ac-ft)	BFE vs. Buildout Conditions Volume (ac-ft)
SILVER LAKE	3,249	6,893
SWAN LAKE	(690) [1]	1,102 [1]

1 Volume of treated effluent generated from Max permitted flow of 2.35MGD from RSWRF less 0.5MGD to irrigation (Net 1.85 MGD); See Appendix I for a summary of the Effluent Inflow Analysis.

10.1.1 Silver Lake

The volume to mitigate Silver Lake to the current BFE is 3,249 ac-ft for existing development conditions and 6,893 ac-ft for buildout development conditions.

As noted in section 4.0 of Volume I, the current BFE for Silver Lake was lowered from 4,967' (NGVD 1929), as determined by Nimbus Engineers in 1987, to 4965.0 (NGVD 1929) in a 1994 study by Schaff & Wheeler. The Schaff & Wheeler study used a 5-year, 24-hour storm for carry-over storage as opposed to the 25-year, 24-hour storm which was used by Nimbus. This is one of the reasons the excess volumes to mitigate in Silver Lake are larger than those in Swan Lake. Further discussion of the differences in volumes between Silver Lake and Swan Lake are discussed in Section 10.1.3.

10.1.2 Swan Lake

For Swan Lake playa, in addition to the volume from the 25-year, 24-hour storm, a volume of treated effluent from Reno-Stead Wastewater Reclamation Facility (RSWRF) and from Lemmon Valley Water Reclamation Facility (LVWRF) was added to 100-year storm volume to determine the 100-year lake level. A volume of 606 ac-ft of treated effluent was determined to reside in Swan Lake playa in the month of March and is included in the volumes to mitigate for Swan Lake in Table 6, for existing and buildout conditions. A series of HEC-1 models was used to compute this volume and is described in Appendix I.

In summary, a flow to the playa from RSWRF of 1.85 million gallons per day (MGD) with an additional flow from LVWRF of 0.65 MGD in the month of March was used in the HEC-1 models. The 1.85 MGD was calculated from the fully permitted rate at RSWRF of 2.35 MGD, minus 0.50 MGD used for irrigation/reuse in 2006 (personal communication, City of Reno). Since the 2006 average treatment flow at RSWRF was 1.4 MGD, the 606 ac-ft used in our analysis is conservative. If additional sources of irrigation are developed and the amount of water diverted for irrigation/reuse is greater than 0.50 MGD, than the volume to mitigate would decrease.

10.1.3 Discussion of Volume Differences in Silver Lake and Swan Lake

As discussed in section 6.2.1 of Volume I, an analysis of the watershed boundary in the vicinity of Stead Blvd. resulted in re-directing a number of small subbasins from Swan Lake watershed to Silver Lake watershed. This increased the total acreage of the Silver Lake watershed and decreased the total acreage of the Swan Lake watershed, and hence re-directed the volume of water from this area from Swan Lake to Silver Lake. Based on the calibration of the hydrologic model to the 1986 storm with the new stage-storage relationship (discussed in section 6.0, Volume I), the constant loss rate for Swan Lake was increased from 0.072 to 0.080. The increase in loss rate reduces the volume that was directed to the lake in the 1987 Nimbus study. Additionally, the initial storage volume for the 25-year, 24-hour storm in Swan Lake was reduced from 4,004 ac-ft in the 1987 Nimbus study, to 1,930 ac-ft in this study. The main reason for this decrease of 2,089 ac-ft was the use of the SCS curve number model for carry-over storage in this study as opposed to the lumped parameter model used in the 1987 Nimbus study. As discussed in section 8.8.5 of Volume I, the lumped parameter model over-predicts volumes for the 24-hour storm since the loss rates calibrated to the 10-day storm were used in the 24-hour lumped parameter model. Without data to calibrate loss rates to a 24-hour storm, it was concluded that the curve number method better represents the losses for a 24-hour storm.

11.0 MITIGATION OPTIONS AND COST ESTIMATES

Flooding of closed basin playa lakes poses a very serious problem for property owners in the vicinity of the playas since the only outflow of flood water is evaporation or infiltration. This means flooded property can remain inundated and inaccessible for weeks or even months after flooding begins. This is in contrast to riverine flooding which typically lasts for hours or days as the flood waters recede when the peak flow of the flood event passes and the river returns to normal flows.

A number of alternatives exist to mitigate the volume of stormwater runoff in Silver and Swan Lakes in excess of the BFE. The mitigation options available consist of: 1) removal of material from the playa lake bottoms, 2) construction of levees to contain the current or projected increase in stormwater volume, 3) infiltration, 4) retention, 5) injection into the Vadose Zone, 6) Low Impact Development (LID) practices, 7) partial excavation of playa lake fringes, 8) drain flood waters from Silver Lake to Swan Lake, and 9) pump excess out of Swan Lake basin. A discussion of each of these options follows below. A summary of estimated costs were provided where appropriate.

11.1 Removal of Material from Playa Lake Bottoms

This option consists of excavating the bottom of the playa lake beds to a depth necessary to contain the entire excess volume of runoff in order to maintain the current BFE. This is a unique solution that would mitigate the entire excess volume computed for the playa lakes. Later in the report, partial excavation of select areas of the playas to mitigate a portion of the excess volume will be discussed.

The elevation from which to begin excavation was chosen based on the area identified as 'playa' in the NRCS publication *Soils of Southern Washoe County* (Ref. 21). Excavation was calculated below the 4,960' elevation in Silver Lake and below the 4,916' elevation in Swan Lake. Table 7 tabulates the estimated cost for excavation and removal of material for existing and buildout conditions.

Table 7. Volumes and Costs of Excavating Playa Lake Bottoms

Silver Lake

Development Conditions	Volume To Mitigate (AF)	Depth To Excavate (ft)	Yards To Remove & Transport	Est. Cost per Yard	Cost To Excavate
Existing Conditions	3,249	7.2	5,240,000	$10	$52,400,000
Buildout Conditions	6,893	15.2	11,120,000	$10	$111,200,000

Swan Lake

Development Conditions	Volume To Mitigate (AF)	Depth To Excavate (ft)	Yards To Remove & Transport	Est. Cost per Yard	Cost To Excavate
Existing Conditions	0	0	0	$10	$0
Buildout Conditions	1,102	3.1	1,778,000	$10	$17,780,000

Table 8. Estimated Costs for Excavation of Playa Lake Bottoms Option

	Silver Lake		**Swan Lake**
Item	Existing Conditions Estimated Cost	Buildout Conditions Estimated Cost	Buildout Conditions Estimated Cost
Material Excavation & Transportation	$52,400,000	$111,200,000	$17,780,000
Engineering & Design	$500,000	$500,000	$500,000
Land Acquisition & Permitting [1]	$23,322,000	$23,322,000	$5,000,000
Total	**$76,222,000**	**$135,022,000**	**$23,280,000**

1 Silver Lake land values assumed 30% commercial value and 70% open space value; Swan Lake used Open Space Value

The costs to acquire land for excavation were estimated for two types of land values, open space value and private/commercial value. Based on personal communication with City of Reno, an open space value of $10,000 per acre and a private/commercial land value of $100,000 per acre were used.

In Silver Lake, the amount of land to be purchased was estimated in ArcGIS based on the total acres of all parcels crossed by the 4960’ elevation. These parcels consist of approximately 70% open space and 30% private/commercial land. A weighted average value of $39,000 per acre was applied to the total acres crossed by the 4,960’ elevation.

In Swan Lake, when the volume to mitigate of 1,102 ac-ft at buildout conditions is applied to the area of the 4,916’ elevation (810 acres), excavation of only 1.4 feet would be required. To reduce the amount of impact and land acquisition, the area was reduced to 350 acres which results in an excavation depth of 3.1 feet. The amount of land to acquire was estimated in ArcGIS at approximately 500 acres. Although Swan Lake is primarily federally owned and cannot be purchased, for the purpose of cost comparisons, an open space value of $10,000 per acre was used for the estimated 500 acres in Swan Lake.

Advantages: Unique solution that mitigate entire excess volumes.
Disadvantages: Significant environmental impacts to wetlands and bird habitat; high cost; probable strong public opposition; costs to mitigate the opposition are difficult to calculate.

11.1.1 Excavation Considerations in Silver Lake
The area anticipated for excavation in this scenario is privately owned. To acquire the rights to excavate the lake bottom, the City would need to negotiate easements with the land owners, purchase the land or enact eminent domain. Since the land is all privately owned and no federal money or agencies would be involved, excavation in this playa would not fall under jurisdiction of the National Environmental Policy Act (NEPA). Enacting eminent domain is not considered a reasonable or necessary action since other mitigation alternatives exist.

11.1.2 Excavation Considerations in Swan Lake
The 500 acres needed for excavation would be partially or wholly located on federal land administered by the Bureau of Land Management (BLM). Since federal land would be involved in the process, NEPA provisions would be enacted and require and Environmental Impact Statement (EIS) or an Environmental Assessment (EA) which can take up to ten years to complete. It is Quad Knopf's opinion that the volume to mitigate can be addressed with other less time consuming alternatives that will be discussed further in this report.

11.2 Construction of Levees

Mitigation to the current BFE by construction of levees would require engineering, design, land acquisition, permitting, importation of material and construction. The levee heights below include the required three feet of freeboard and assume a 4:1 slope on the inside of the levee.

11.2.1 Levees in Silver Lake
The toe of levee elevation was assumed equal to the BFE. To mitigate the existing conditions excess volume in Silver Lake of 3,249 ac-ft, a levee height of approximately 6.5 feet would be required. To mitigate the buildout conditions excess volume in Silver Lake of 6,893 ac-ft, a levee approximately 10.3 feet high would be required. Riprap was included in the cost estimate to protect against erosion. An area of 6" minus riprap at 1-foot thick was calculated at a cost of $3.50 per square foot, as listed on the City of Reno's cost sheet for bonding purposes. For construction of a levee, an easement approximately 100 foot wide would be needed for the existing conditions and an easement approximately 130 foot wide would be needed for buildout conditions. The estimated costs for levees in Silver Lake are summarized below in Table 9.

Table 9. Estimated Costs for Construction of Levees Option

	Silver Lake	
Item	Existing Conditions Estimated Cost	Buildout Conditions Estimated Cost
Material Importation & Construction	$8,733,796	$17,314,815
Riprap	$2,598,750	$4,071,375
Engineering & Design	$1,000,000	$1,000,000
Land Acquisition & Permitting [1]	$40,638,000	$40,638,000
Total	**$52,970,546**	**$63,024,190**

1 Assumed purchase of entire parcel crossed by levee was necessary, estimated 30% commercial value and 70% Open Space value - equal to $39,000 per acre.

11.2.2 Levees in Swan Lake

The BFE in Swan Lake covers such a large surface area that a levee around the entire playa would only need to be 3.5 feet high. Such a levee would incur costs and environmental impacts disproportionate to the amount of mitigation that would be achieved. To reduce costs and impacts by reducing the perimeter of the levee, a portion of the levee would be required to cross the middle of the playa. Thus, a mitigation solution including a levee in Swan Lake is not considered a practical solution.

Advantages: Single solution option. Maintain existing wetlands.
Disadvantages: Environmental and visual impacts; high cost; probable strong public opposition and costs to mitigate the opposition are difficult to calculate; risk of levee failure; high cost and liability to maintain levees.

Levees require a significant amount of maintenance and are still subject to failure. The ongoing costs of maintenance and the liability risks associated with levee failure are not preferred by the City and thus construction of levees is not recommended as a viable option.

11.3 Low-Impact Development (LID) Practices

Low-Impact Development (LID) practices are design practices and landscaping features that mimic natural hydrologic functions. The City of Reno has developed a Regional Stormwater Quality Management Program to help protect the water quality of the Truckee Meadows and Truckee River. Within this program, Terri Svetich, Storm Water Coordinator has recently participated in a series of presentations to educate and inform the public and development community about LID practices. In a cooperative effort with Kennedy/Jenks Consultants and the UNR Cooperative Extension, a seminar (Seminar #2) was developed titled *Low Impact Development Practices & Benefits*, and is available on the City website www.tmstormwater.com (Ref. 48).

This seminar outlines a number of LID practices and their benefits. Some examples of LID practices are:

- Landscape Buffer Zones between lawns and sidewalks
- Xeriscape Swales and Flat Curbs
- Directing rooftop runoff into vegetation
- Grassy Swales
- Clustered Development
- Porous Pavement
- Landscape Detention and Bioretention

These practices are intended to intercept the "first flush", or first ½ inch of the more frequent rainfall events and infiltrate or filter and convey the flow in more natural condition. LID practices target water quality improvement and infiltration for small frequent storm events. Many of these features such as Landscape Buffer Zones, Grassy Swales and Bioretention basins are shallow structures which will fill quickly and overflow in the event of a 25-year or 100-year event.

The first ½ inch of rainfall in the North Valleys is roughly equivalent to a 2-year, 2-hour storm event and is approximately 5% of 100-year, 10-day event. To estimate the maximum reduction in volume that could be achieved with LID practices, the curve number model used to calculate the 25-year, 24hour storm carry-over storage volumes was adjusted for a 2-year, 2-hour storm. Since LID practices are typically designed and installed during construction they would not provide any reduction in volume for existing conditions excess volumes above the BFE. The existing conditions volume for Silver Lake from the 2-year, 2-hour storm is 61 ac-ft and 86 ac-ft for buildout conditions. The existing conditions volume for Swan Lake from the 2-year, 2-hour storm is 105 ac-ft and 180 ac-ft for buildout conditions. If LID practices were employed by all future development were designed to infiltrate or retain 100% of the 2-year, 2-hour storm volume, the maximum reduction in volume for Silver Lake would be 25 ac-ft and 75 ac-ft for Swan Lake.

In summary, it is difficult to evaluate to what extent LID practices would ultimately be employed in future development and to determine what percent of the "first flush" is infiltrated versus conveyed downstream to the playa lakes. This coupled with the maximum volume reduction of 100 ac-ft lead us to conclude that while LID practices can provide significant benefits to water quality in the North Valleys, they would not have a measurable impact on reducing the excess volumes for the 100-year event in the North Valleys.

<u>Advantages</u>: Low cost. Water quality benefits to surrounding rivers, lakes and streams.
<u>Disadvantages</u>: Maximum volume reductions are a very small amount of the total volume to mitigate.

11.4 Injection of Stormwater into Vadose Zone

Working concurrently with Quad Knopf's stormwater mitigation analysis, ECO:LOGIC Engineering in Reno, NV, is evaluating effluent disposal options for effluent generated from additional development in the Silver Lake and Swan Lake watersheds. One of the disposal options investigated by ECO:LOGIC was injection of treated effluent into the Vadose Zone. ECO:LOGIC prepared a Memorandum to the City of Reno titled *Washoe County Site, Water Injection Testing Memo*, February 10, 2006 (Ref. 42).

The memorandum summarizes the geology of the study area, the injection methods and procedures used and test results. The study includes an estimate of Vadose Zone storage potential based on an a possible array of eight injection sites (Figure 16) and concludes that the Vadose Zone in the study area could store up to 3 MGD for a six-month period of injection pumping (Ref. 42). Effluent generation occurs on a relatively continuous basis with predictable daily flows, whereas stormwater occurs over a very short period of time with unpredictable high flows. Hydrologic modeling carried out for infiltration testing determined that this area could receive up to 1,360 ac-ft in one day during a 100-year storm. The 3 MGD is equivalent to 9.2 acre-feet per day which is far short of what would be needed for stormwater infiltration. Thus, injection of stormwater does not appear to be a practical solution to mitigate the relatively instantaneous volumes associated with stormwater flows.

Additionally, per communication with the Nevada Department of Environmental Protection (NDEP), "the state of Nevada discourages injection of water into vertical wells that could potentially impact the water quality of an aquifer". Nevada Revised Statute 445A.490 (Ref. 45) states "*No permit may be issued which authorizes any discharge or injection of fluids through a well into any waters of the State: which would result in the degradation of existing or potential underground sources of drinking water*". Thus, injection of water into underground wells is feasible if the water meets drinking water quality standards. In order to inject stormwater the water would need to be retained temporarily, tested and treated to meet drinking water standards and then injected. This option would be very expensive and still not dispose of stormwater at an adequate rate. Based on the above discussion, this option is not considered a feasible solution.

Advantages: Storage of stormwater in an aquifer for later use as groundwater.
Disadvantages: Cannot dispose of stormwater at an adequate rate; NRS 445A.490 prohibits injection of water that has the potential to degrade underground sources of drinking water.

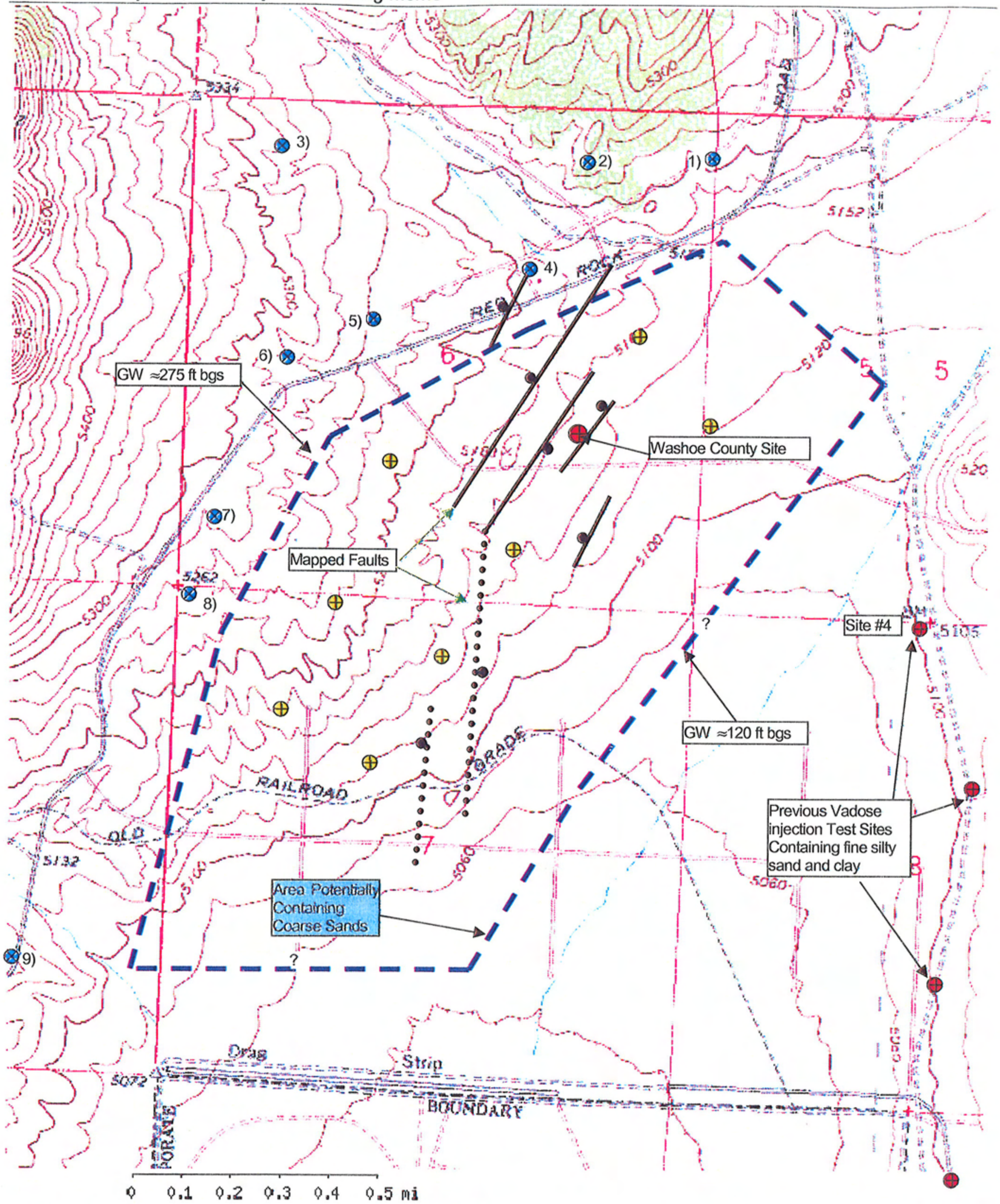


Figure 1: Showing Washoe County Well Site, existing domestic wells (see Table 3), potential injection sites area potentially containing coarse sands, and mapped faults.

FIGURE 16

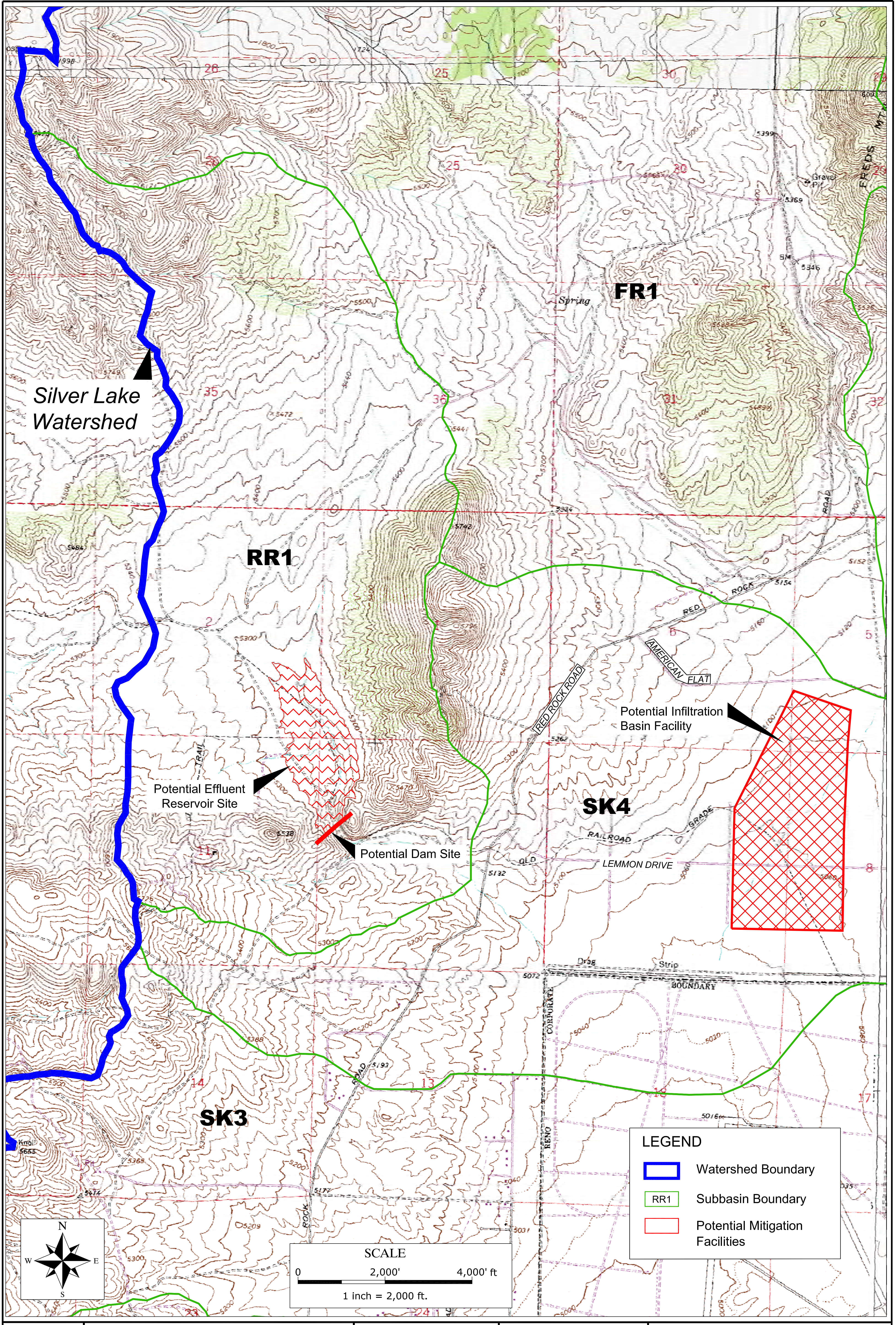
11.5 Retention in Effluent Storage Reservoir in Silver Lake Watershed

ECO:LOGIC, Reno, NV prepared Technical Memorandum No. 4 (Ref. 43) as part of their study on the Reno-Stead Wastewater Reclamation Facility (RSWRF) expansion to 4.5 MGD. The memorandum evaluates effluent disposal options in the North Valleys and includes an option for an Effluent Storage Reservoir in the northwest portion of the Silver Lake watershed. The proposed reservoir would include construction of a dam near the outflow point of subbasin RR1 (Figure 17). The primary purpose of the reservoir would be for storage of effluent during winter months for withdrawal during summer months for irrigation (Ref. 43). The secondary purpose of the reservoir would be for retention of stormwater generated during a 100-year, 10-day storm event to reduce the volume of stormwater that reaches the Silver Lake playa.

In the Technical Memorandum No. 4, ECO:LOGIC calculated a preliminary maximum storage capacity for the reservoir of 3,735 ac-ft with a dam height of 60 feet (Ref. 43). The volume and estimated dam height includes capacity for a preliminary design flow of 4.5 MGD from RSWRF and the volume generated by subbasin RR1 of 718 ac-ft at buildout conditions. ECO:LOGIC is in the process of revising the storage capacity and dam height estimates based on a new topographic survey of the reservoir area. Preliminary results from the new topographic data indicate less available storage than originally calculated. A new capacity of 3,013 ac-ft, a dam height of 90 feet and 603 ac-ft of storage available for stormwater runoff were calculated from this new data by ECO:LOGIC (personal communication, 2007). These new data were not available in time to include in this report, but for the objective of comparing mitigation options costs, the relative estimates calculated with 718 ac-ft of stormwater capacity included herein are considered adequate.

To estimate the cost of this facility that could be attributed to stormwater mitigation, the ratio of the volume contribution from stormwater to the estimated total volume of the reservoir was applied. The volume generated by subbasin RR1 was calculated to be 718 ac-ft at buildout conditions and the total estimated capacity of the reservoir is 3,735 ac-ft. Based on the preliminary reservoir volume, stormwater would account for 19% of the total capacity needed in the reservoir. ECO:LOGIC estimated the cost of the reservoir and dam to range from $7,300,000 to $13,300,000 (Table 4-2, Ref. 43); thus, the cost attributable to stormwater mitigation would range from $1,387,000 to $2,527,000. Section 11.11 discusses cost comparisons of different options and the $2,527,000 amount was used to be conservative.

<u>Advantages</u>: Dual purpose facility – will retain treated effluent and retain the stormwater volume generated by subbasin RR1. Stormwater can be re-used for irrigation with effluent. Provides open space and recreation opportunity to the area.
<u>Disadvantages</u>: Some environmental impact to reservoir area.



Sheet 1 of 1	Figure 17	Scale: 1" = 2,000'	References:	Quad Knopf
Quad Knopf Job: 050665	Location Map of Potential Effluent Reservoir	CI: 20 foot	* Parcels and Ownership Designation from 2005 TMRPA Regional Land Use Model.	9600 Prototype Ct. Reno, Nevada 89521
Date: Feb. 2007	North Valleys Stormwater Project	File Name: LV4-LV5 Retention Options.dwg	* Subbasin & Watershed Boundaries from 2000 Stantec, Drainage Master Plan, Stead, NV	TEL: (775) 324-1212 FAX: (775) 324-2311
	City of Reno & RWPC	Drawn By: GH	* Topographic Maps from USGS.	WEB: www.quadknopf.com
	Reno Nevada	Designed By: GH	* Location of Effluent Reservoir From Eco:Logic, March, 2006.	050665

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11.6 Retention Basins in Swan Lake Watershed

Potential exists in the Swan Lake watershed to retain flows from subbasins LV4 and LV5 (Figure 18) to help mitigate excess runoff volume at Swan Lake playa.

For 2005 existing conditions, no excess runoff volume was calculated for Swan Lake playa and thus no mitigation would be necessary to maintain the current FEMA BFE. However, for buildout conditions and including 1.85 MGD of net inflow from RSWRF, an excess volume of 1,102 ac-ft was calculated which could be mitigated with a combination of any two of three potential retention pond sites.

11.6.1 Curve Number Model for Subbasin Volumes

To determine the volume available for mitigation at specific subbasin locations, the new curve numbers determined in Volume I of this report were adjusted to 10-day curve numbers using Table 2-3b in SCS TR-60 (Ref. 19). These curve numbers were entered into the curve number model used to determine carry-over storage volumes for the 25-year, 24-hour storm. To allow the model to run for a 10-day storm, the routing routines developed by Stantec were omitted as the model was only used to evaluate volumes produced by particular subbasins and not to identify peak flows. This model is included digitally in Appendix M. As anticipated, based on previous discussion in Section 6.1 of the tendency of the curve number model to over-predict volumes for a 10-day storm, the 100-year, 10-day curve number model predicts more volume than lumped parameter volume at the playa lakes. Table 10 below compares the volumes generated at the playa lakes for the curve number model versus the lumped parameter model.

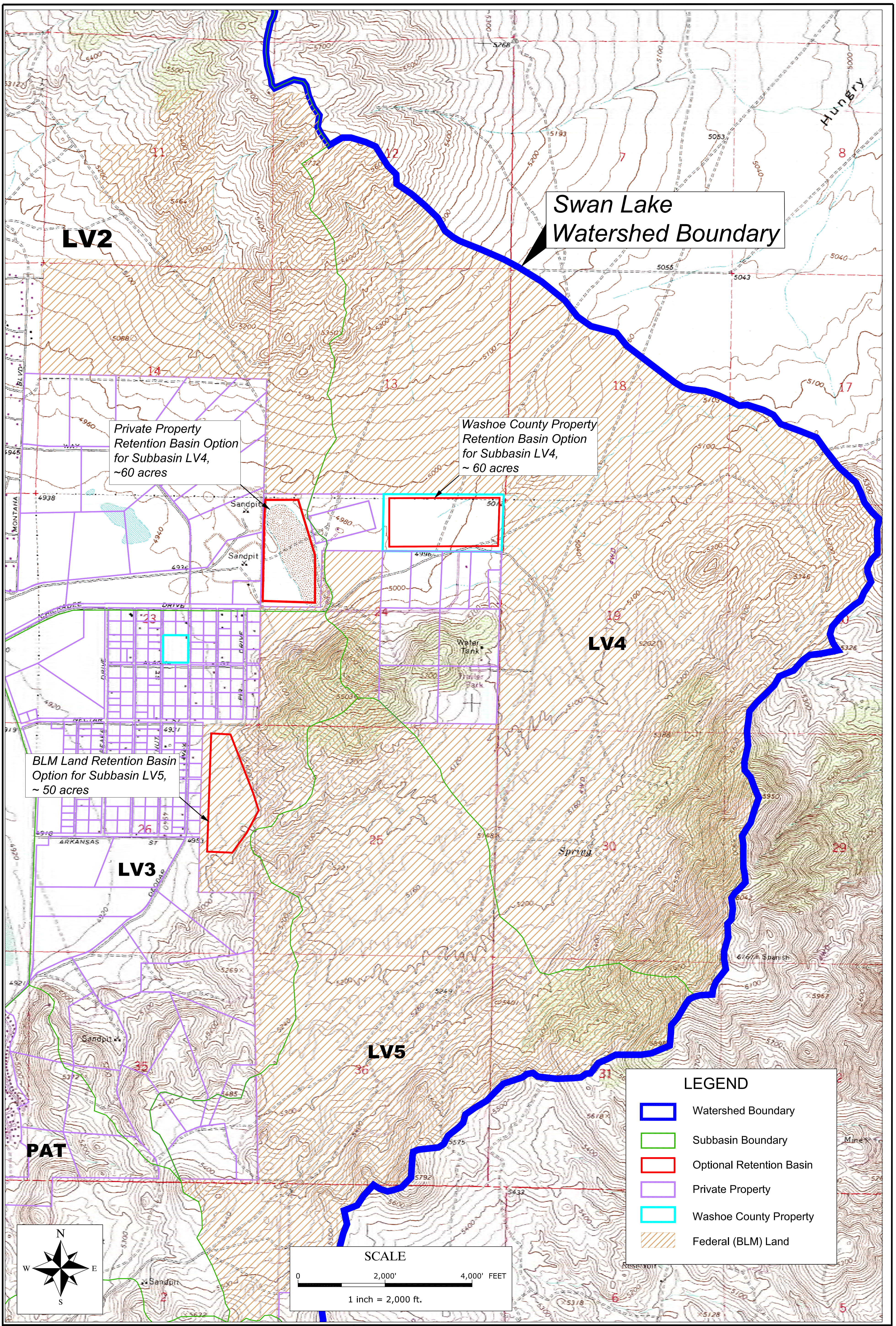
Table 10. Comparison of 100-year, 10-day Curve Number Model versus Lumped Parameter Model

WATERSHED	Existing Conditions			Buildout Conditions		
	Lumped Parameter Volume (ac-ft)	Curve Number Volume (ac-ft)	Ratio of Lump to CN models	Lumped Parameter Volume (ac-ft)	Curve Number Volume (ac-ft)	Ratio of Lump to CN models
SILVER LAKE	7,210	13,372	0.54	10,098	15,404	0.66
SWAN LAKE	6,956	8,902	0.78	8,299	10,049	0.83

Note: All volumes do not include carry-over storage volumes from the 25-year, 24-hour storm

11.6.2 Retention Ponds in Swan Lake Watershed

At buildout conditions the curve number model generates 383 ac-ft of runoff from subbasin LV5. If we reduce this volume by the ratio of the lumped parameter volume to the curve number volume (0.83), a volume of 318 ac-ft is available for mitigation at subbasin LV5 at buildout conditions. A 50-acre retention pond could be constructed on BLM land west of the range front and east of existing development (Figure 18). If the basin were constructed with the required two feet of freeboard, a pond depth of 8.1 feet would be necessary to store 318 ac-ft from



Sheet 1 of 1	Figure 18	Scale: 1" = 2,000'	References:
Quad Knopf Job: 050665	Retention Basin Options for Subbasins LV4 and LV5	CI: 20 foot	* Parcels and Ownership Designation from 2005 TMRPA Regional Land Use Model.
	North Valleys Stormwater Project	File Name: LV4-LV5 Retention Options.dwg	* Subbasin & Watershed Boundaries from 2000 Stantec, Drainage Master Plan, Stead, NV
Date: Feb. 2007	City of Reno & RWPC — Reno, Nevada	Drawn By: GH	* Topographic Maps from USGS.
		Designed By: GH	

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subbasin LV5. Since very minor future development is planned in subbasin LV5, essentially the same volume would be available for mitigation at any stage of development through buildout conditions.

Using the same adjustment ratio of 0.83 for subbasin LV4, the curve number volume of 852 ac-ft at buildout conditions would represent 707 ac-ft of water available for mitigation in subbasin LV4. Two potential retention pond sites exist to retain flows from subbasin LV4. Both sites are could host retention ponds approximately 60 acres in size. One is located on private land owned by Hungry Valley Enterprises LLC at the site of the inactive Sha-Neva sand and gravel operation and the other is located on a Washoe County parcel (Figure 18). To mitigate the 707 ac-ft volume, with two feet of freeboard using only one of these sites, a pond depth of 13.8 feet would be required. To mitigate the entire 707 ac-ft using two 60-acre retention ponds, a pond depth of 7.9 feet would be required for each pond. Table 11 compares the estimated costs of the possible retention ponds in Swan Lake watershed described above.

Table 11. Estimated Costs of Possible Retention Ponds in Swan Lake Watershed

Subbasin	LV5	LV4			
Site & Property Owner	50 ac Site on BLM Land	60 ac Site on Private Land	60 ac Site on Private Land	60 ac Site on Washoe County Land	60 ac Site on Washoe County Land
Depth of Excavation	8.4 ft	13.8 ft	7.9 ft	13.8 ft	7.9 ft
Material Excavation & Transportation [1]	$6,776,000	$13,310,000	$7,663,333	$13,310,000	$7,663,333
Engineering & Design	$200,000	$200,000	$200,000	$200,000	$200,000
Land Acquisition & Permitting [2]	$250,000	$7,000,000	$7,000,000	$0	$0
Total	**$7,226,000**	**$20,510,000**	**$14,863,333**	**$13,510,000**	**$7,863,333**

1 Calculated with excavation & transportation cost $10 per cubic yard.

2 Calculated with $100,000 per acre for private land; Cost estimated for EA study on BLM land.

Advantages: Stormwater can be re-used for irrigation. Mitigates nearly all (1,025 ac-ft of 1,102 ac-ft) of the excess stormwater volume in Swan Lake watershed.
Disadvantages: The parcel located on BLM land would require an EIS or EA.

11.7 Partial Excavation of Playa Lakes and Playa Fringes

Excavation of select areas within and around the fringes of the playa lakes can be used to add storage capacity to the existing playa lakes. Both Silver Lake and Swan Lake have areas which may be either purchased or permitted for excavation for storage of excess runoff. A total of eight areas have been identified for partial excavation, four in Silver Lake and four in Swan Lake. Since the size of these areas are not large enough to mitigate the entire volumes of excess stormwater presented in Table 6, the amount of excavation needed and the cost of the excavation will depend on which additional options are implemented. The costs for land acquisition and engineering for each of the eight areas can be estimated on the size of the areas and are tabulated in Table 12. These costs will be added to the costs of the amount of excavation required with combinations of other options to be discussed in Section 11.11.

Table 12. Estimated Costs for Engineering and Land Acquisition for Select Areas In and Around Playa Lakes

	Silver Lake			
Cost Item	Area 0	Area 1	Area 2	Area 3
Engineering & Design	$300,000	$2,000,000	$300,000	$200,000
Land Acquisition & Permitting [1,2]	$2,930,000	$70,000,000	$32,500,000	$0
Subtotal	**$3,230,000**	**$72,000,000**	**$32,800,000**	**$200,000**

	Swan Lake			
Cost Item	Area 4	Area 5	Area 6	Area 7
Engineering & Design	$200,000	$200,000	$200,000	$200,000
Land Acquisition & Permitting [1]	$11,700,000	$1,340,000	$750,000	$750,000
Subtotal	**$11,900,000**	**$1,540,000**	**$950,000**	**$950,000**

1 Land value of $100,000 per acre was used for Area 4; Open space value of $10,000 per acre for Area 0 & Area 5; estimate for EIS in Areas 6 & 7 on BLM land.

2 Land Acquisition cost for Area 2 includes Area 3.

11.7.1 Silver Lake Playa

The four areas in Silver Lake identified for partial excavation are Areas 0, 1, 2, and 3 and are shown in Figure 19. The estimated costs to acquire these areas are listed above in Table 12. Area 0 is the most attractive area for partial excavation in Silver Lake if an open space land value of $10,000 per acre is used to estimate to cost to acquire this land. This parcel is owned by the Moya Lear Foundation and could possibly be traded for land elsewhere. In addition, Area 0 would not require any excavation above the BFE since it lies within the center and lowest portion of the playa and would have the least amount of impact on vegetation and wildlife.

Area 1 was identified with an analysis of parcels classified as "Vacant Land" in the assessors' database as of November, 2005. Approximately 700 acres were identified on the fringe of the existing BFE which could be excavated to allow flood waters to expand rather than rise. Additional criteria used to identify the 700 acres were: 1) parcels contiguous with the existing BFE of 4968.7' (NAVD 1988), 2) small groups of parcels or large parcels within close proximity to the BFE and to each other (~200'), and 3) assumed that excavation would not occur on the west side of Red Rock Road.

A less extensive excavation option would be to deepen the existing low-lying area on the north side of Silver Lake playa. This area is shown on Figure 19 and referred to as Area 2 and consists of one large parcel and a number of smaller parcels all in direct proximity to the BFE. The southern boundary of this area, shown as Area 3 in Figure 19, is a west-northwest trending ridge which separates the main playa from the low-lying Area 2 to the north. Excavation of Area 3 could be considered, but due to the relatively high elevation of this area it would incur a very high cost relative to the amount of mitigation it would provide. A cost option of excavating Area 2 and Area 3 together is considered in section 11.11 of this report.

11.7.2 Swan Lake Playa

Four areas in and around the Swan Lake playa were evaluated for partial excavation. The area east of the playa, between the north trending sand dune and Lemmon Drive is referred to as Area 4. The north trending sand dune proper is referred to as Area 5, and two large parcels of BLM land on the west side of the playa are referred to as Area 6 and Area 7 (Figure 20).

Area 4 is mostly private land owned by the Lemmon Valley Land Company (LVLC) with a lesser portion of BLM land. This area becomes inundated with lake waters when the water level in Swan Lake is high and therefore provides a practical location to add volume without having to remove excess material. LVLC is in the currently evaluating this area for mitigation of stormwater volume generated from proposed development east of Lemmon Valley Drive. Coordination with LVLC could enable use of this area for volume storage in addition that generated from their proposed development.

Area 5 could also be excavated, but as with Area 3 in Silver Lake, the relatively high elevation would incur significant excavation costs just to get down to the BFE. In addition, this area is a preferred location to maintain for wildlife habitat and is not a recommended area to pursue. Areas 6 and 7 are predominantly low-lying ground which could be partially or wholly excavated to provide additional storage volume. As discussed Section 11.1.2, since the land in these areas are administered by the Bureau of Land Management (BLM), NEPA provisions would be enacted and require and Environmental Impact Statement (EIS) or an Environmental Assessment (EA) which could take a significant amount of time.

Advantages: These areas can mitigate a large portion of the excess volume.
Disadvantages: Environmental impact to existing wetlands. Excavation on federal land would enact a possibly lengthy environmental permitting process.

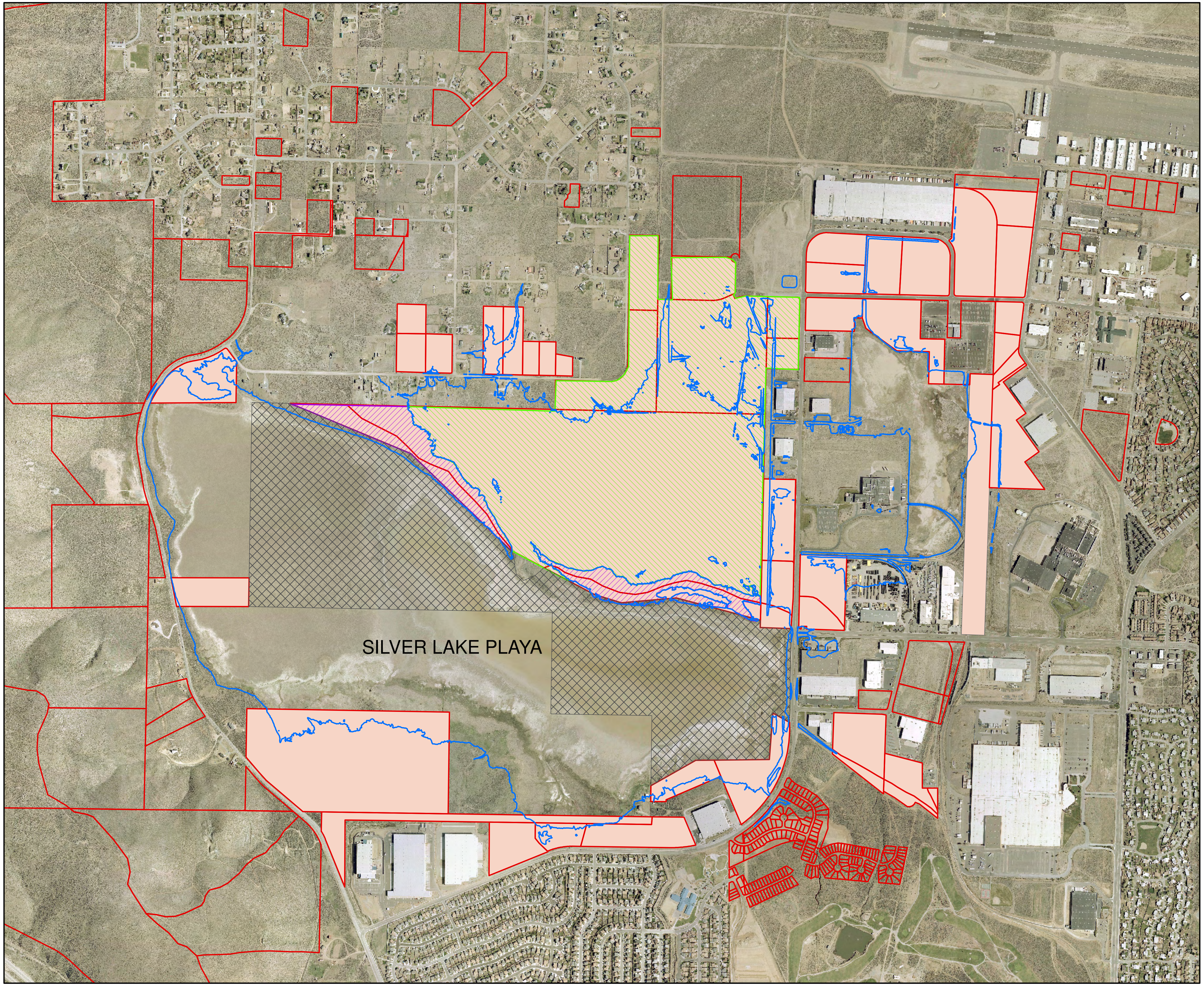

FIGURE 19

POSSIBLE EXCAVATION AREAS
SILVER LAKE PLAYA

North Valleys Flood Control Project

Quad Knopf

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Date: March 2007

LEGEND

- Silver BFE (4968.7' NAVD 1988)
- Area 0 - Playa Lake Parcel
- Area 1 - Parcels (within ~ 200' of BFE)
- Area 2 - Low-Lying Area North of Playa
- Area 3 - West-Northwest Ridge
- Parcels of 'Vacant Land' (Nov. 2005 Assessors Data)

N
W E
S

1,250 625 0 1,250 Feet

1 inch equals 1,250 feet

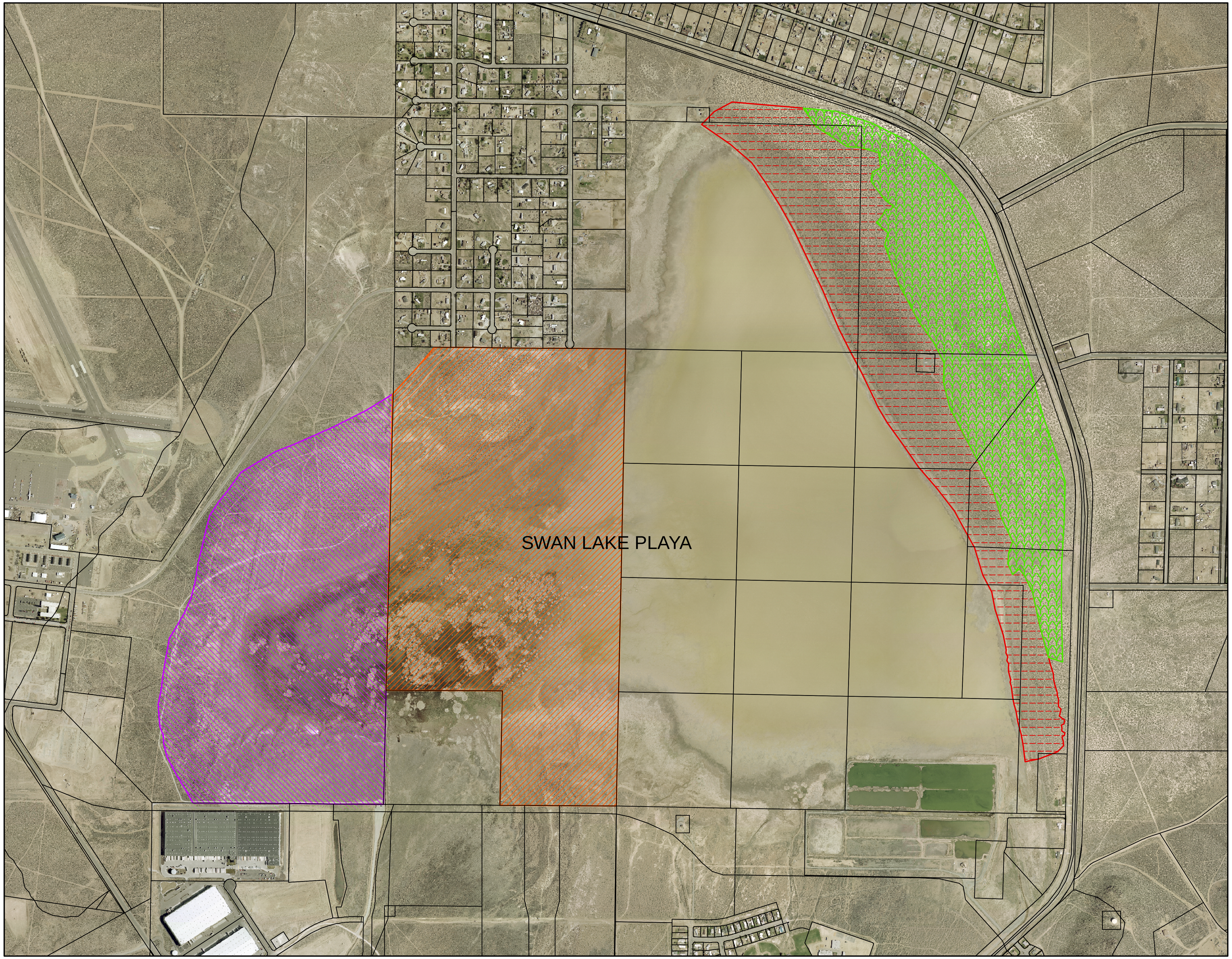

FIGURE 20

POSSIBLE EXCAVATION AREAS
SWAN LAKE PLAYA

North Valleys Flood Control Project

Quad Knopf

Quad Knopf Job: 050665

Date: February 2007

LEGEND

- Parcels - Swan Lake Playa
- Swan BFE (4924' NAVD 1988)
- Area 4 - East of Dune
- Area 5 - North Trending Dune
- Area 6 - Portion of BLM Parcel
- Area 7 - Portion of BLM Parcel

1,100 550 0 1,100 Feet

1 inch equals 1,100 feet

11.8 Drain Excess Volume from Silver Lake to Swan Lake

Silver Lake generates all the excess stormwater volume for existing conditions and the vast majority of the total excess volume of Silver and Swan Lakes combined above the BFE's (Tables 5 & 6). One option would be to drain the excess volume from Silver Lake into Swan Lake and pump it out of the North Valleys basins from a central pumping facility located in Swan Lake.

Silver Lake is approximately 50 feet higher in elevation than Swan Lake which provides adequate slope to make draining Silver Lake to Swan Lake possible. A total of four possible combinations of open channels and a concrete box culvert were considered and are located on Figure 21. The preferred combination includes an open channel extending due south into Silver Lake playa, approximately 3,000 feet in length, from the end of the Stantec channel. Water from Silver Lake would then enter a concrete box culvert extending east underneath Lear Blvd. Water would enter the concrete box culvert by flowing over a U-shaped concrete weir positioned in Silver Lake at the west end of Lear Blvd. The concrete box culvert would extend approximately 8,700 feet east to a small open channel adjacent to Lear Blvd.; the small channel flows from east to west along the southern boundary of RSWRF. From this point, an open channel would extend approximately 5,200 feet east and northeast to Swan Lake (Figure 21).

One of the channel/culvert options considered consists of a channel extending southeast from the end of the Stantec channel to Lear Blvd. (Figure 21). This alternative was discarded due to the extensive length and width of the channel in addition to the number of railroad and road crossings that would be need to be reconstructed. Another alternative considered was extending the box culvert to the downstream end of RSWRF and beginning the open channel to Swan Lake at this location (Figure 21). This option was discarded since the small open channel along the southern boundary of RSWRF could be deepened at a lower cost than extending the concrete box culvert to the end of RSWRF.

The size of the concrete box culvert was based on the available slope and the size of the inlet weir in order to maintain the current BFE of 4968.75' (NAVD 1988) at peak stage. A flow of 5,500 cfs was determined necessary to maintain the BFE and to maximize the weir crest elevation. A U-shaped weir with a total length of 1,800 feet was used with a weir crest elevation of 4,968'. This length and elevation allow for a flow of 5,500 cfs while maintaining the water surface elevation below the BFE. Two 15.5' x 15.5' concrete box culverts with a 0.2% slope are required to handle this flow. Table 13 tabulates the estimated costs for the selected combination of open channels, concrete box culverts and weir dimensions. A summary of the dimensions used and assumptions made in the cost estimate in Table 13 is included in Appendix J. Worksheets with material and unit costs are also included in Appendix J.

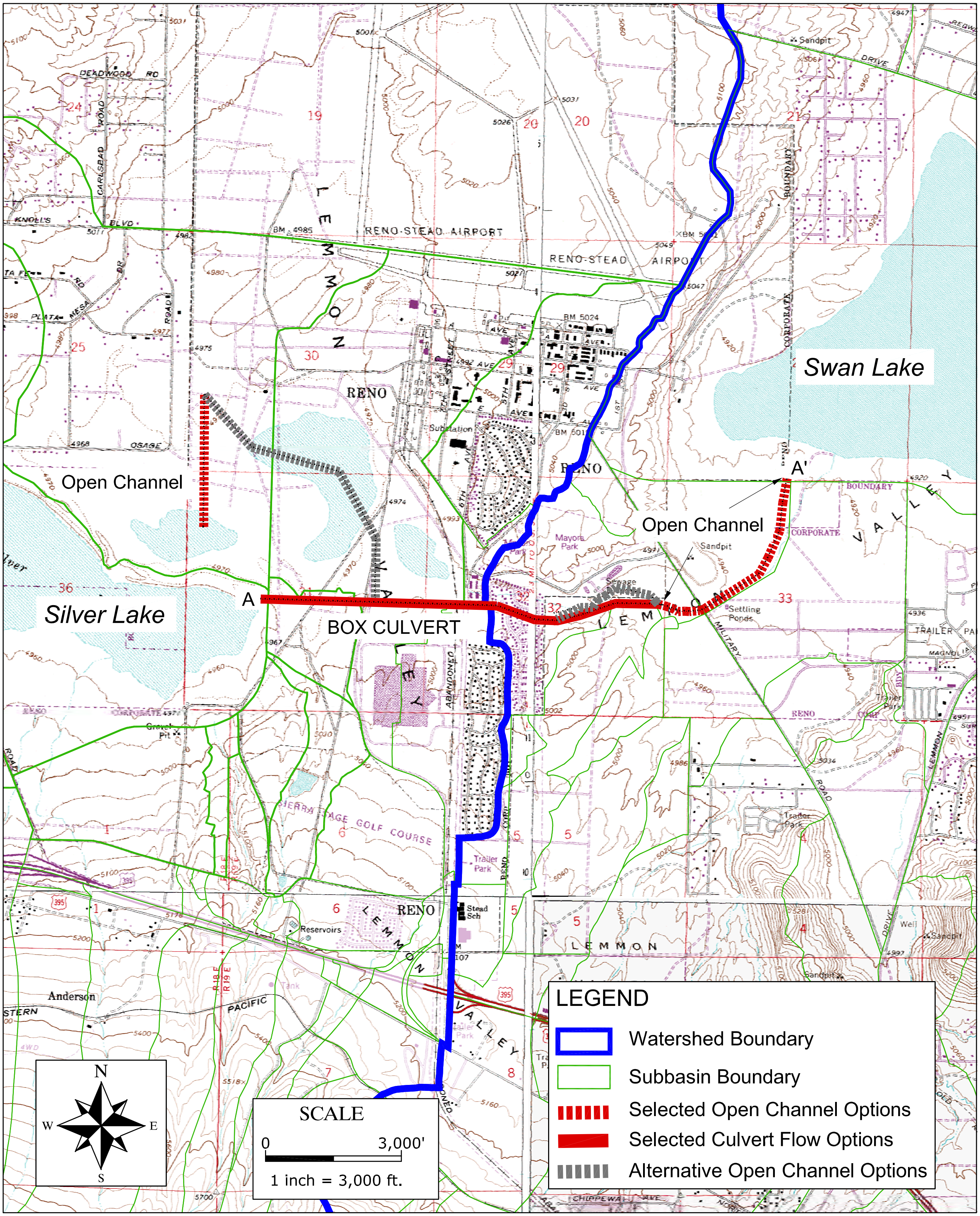

Figure 21
Open Channel & Pipe Options
North Valleys Stormwater Mitigation
City of Reno & RWPC

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Date: February 2007

Table 13. Estimated Costs for Open Channels and Concrete Box Culvert from Silver to Swan Lake

5,500 cfs to mitigate to BFE = 4968.75'

Structure	Item	Material Volumes	Units	Unit Costs	Estimated Cost
Channel 1 (3,000' Length)					
	Excavation & Construction[1]	32,888	yds^3	$10	$328,880
	Riprap[1]	270,000	sf	$3.5	$945,000
	Land Acquisition & Permitting [3]	10	acre	$100,000	$1,000,000
	Subtotal Channel 1				$2,273,880
Weir (1800' Length)					
	Concrete	2,463	yds^3	$750	$1,847,250
	Excavation	11,679	yds^3	$20	$233,580
	Drain Rock Backfill	2,042	yds^3	$30	$61,260
	Structural Backfill	2,939	yds^3	$25	$73,475
	Land Acquisition & Permitting [3]	11	acre	$10,000	$110,000
	Subtotal Weir				$2,325,565
Concrete Box Culvert (7,300' Length)					
	Excavation	472,300	yds^3	$15	$7,084,500
	Concrete 2 - 16'x16' boxes	32,750	yds^3	$750	$24,562,500
	Drain Rock Backfill	23,800	yds^3	$20	$476,000
	Structural Backfill	439,600	yds^3	$20	$8,792,000
	Shoring (see Appendix J)				$7,294,242
	Replace Road & Utilities	547,500	sf	$5	$2,737,500
	Subtotal Concrete Box				$50,946,742
Channel 2 (5,240' Length)					
	Excavation & Construction[1]	263,400	yds^3	$5	$1,317,000
	Land Acquisition & Permitting [3]	50	acre	$100,000	$5,000,000
	Subtotal Channel 2				$6,317,000
Engineering & Design (5%)					$3,093,159
20% Contingency					$12,991,269
Total					**$77,947,616**

Advantages: Reduces the severity of the mitigation necessary in Silver Lake. Provides a regional solution for Silver and Swan Lake watersheds combined. Enables use of lower cost BLM land in Swan Lake for excavation of additional storage volume.
Disadvantages: Requires Swan Lake land owners to be responsible for mitigation needs in Silver Lake watershed. Significant disruption to infrastructure along Lear Blvd.

11.9 Pump Excess Volume out of Swan Lake Basin

ECO:LOGIC prepared a memorandum for the City of Reno summarizing a planning level evaluation of stormwater disposal options in Swan Lake (Ref. 44). This evaluation includes an opinion of estimated costs to pump excess stormwater from Swan Lake playa to a disposal site in Hungry Valley via a pipeline beginning at a pumping facility located on the east side of Swan Lake. The opinion of estimated costs and map of possible pipeline, prepared by ECO:LOGIC, are attached in Appendix K.

Cost estimates for four scenarios were tabulated by ECO:LOGIC and include pumping of an existing conditions volume of 1,384 ac-ft over a 30-day period and 60-day period, and a buildout conditions volume of 6,700 ac-ft over a 30-day period and 60-day period. The highest flow rate evaluated was 50,534 gallons per minute (gpm), for the buildout conditions volume of 6,700 ac-ft pumped over a 30-day period, and required a 60-inch pipe. When converted to cubic feet per second (cfs) the 50,534 gpm equals a rate of 113 cfs. As noted in Section 11.9, a flow of 5,500 cfs was required to drain Silver Lake to Swan Lake and maintain the water surface elevation at or below the BFE in Silver Lake. Thus, it is not feasible to construct a pump facility capable of maintaining the BFE in both Silver Lake and Swan Lake.

In order to use a pump facility, a large detention basin would need to be constructed to hold the water until it was pumped out of the basin. If a pump facility with a capacity to pump 113 cfs was constructed, it would pump approximately 2,233 ac-ft out of the basin by the end of a 10-day storm, leaving the need for approximately 4,600 ac-ft of temporary storage capacity. Paying for excavation of 4,600 ac-ft of additional storage in addition of the pump facility would defeat the purpose of the pump facility option, and thus it is not recommended.

<u>Advantages</u>: Environmental impact is limited to pipeline; maintains existing wetlands. Consolidates excess volume of both playas into one location.
<u>Disadvantages</u>: Some environmental impacts to rangeland for pipeline construction. Requires Swan Lake land owners to be responsible for mitigation needs in Silver Lake watershed.

11.10 Infiltration Facility on Airport Authority Property

Phase II of this study included two amendments to the Scope of Work to carry out field investigations evaluating a site for a potential infiltration facility on Reno/Stead Airport Authority property, north of the Reno/Stead Airport. The first amendment consisted of an exploratory drilling program (Phase I) consisting of 35 shallow, 2 to 12 foot deep drill holes to identify favorable (permeable) material for the site of a proposed infiltration facility. Following success in the exploratory phase of drilling, the second amendment to the Scope of Work (Phase II) targeted specific areas for more detailed infiltration testing and included testing of four Pilot Infiltration Basins. A detailed discussion of the methodology and results obtained from these additional studies is attached as Appendix L.

The costs of construction for an infiltration facility on Airport Authority property are estimated in Table 14 below. Worksheets on the material volumes and unit costs are also attached in Appendix L.

Table 14. Estimated Costs for Construction of Infiltration Basin and Channels

Item	Material Volumes	Units	Unit Costs	Estimated Cost
Material Importation & Construction[1]				
Debris Basin	255,475	yds^3	$5	$1,277,375
Basins 1-3	1,608,012	yds^3	$5	$8,040,060
West Channel	115,845	yds^3	$5	$579,225
Riprap[1]	1,455,164	sf	$5	$7,275,820
Ridge & Furrow Structures [2]				$50,000
Engineering & Design (5%)				$1,411,124
Land Acquisition & Permitting [3]				$11,000,000
Contingency @ 20%				$5,926,721
Total				**$35,560,325**

1 See Appendix L for material calculations

2 Estimated from personal communication with Sediment Solutions, Inc.

3 Cost assumes 110 acres of Airport Authority property is needed at a land value of $100,000 per acre.

11.11 Costs of Combined Solutions to Mitigate to Existing BFE in Silver Lake Watershed

Various combinations of the mitigation options described above, in Sections 11.1 through 11.10, could be used to mitigate the excess stormwater volumes to maintain the current BFE. A planning level comparison of estimated costs and mitigated volumes of twelve combinations of these mitigation options and are presented in Table 15. Scenarios 1 through 8 evaluate playa-by-playa solutions and the associated costs of mitigating the required volume within each watershed, for existing and buildout conditions. Scenarios 9 through 12 include transfer of the excess volume from Silver Lake to Swan Lake via open channels and a concrete box culvert and evaluate the excess volumes of Silver Lake and Swan Lake watersheds combined.

For existing conditions, the ‘Total Estimated Cost’ listed in Table 15, for playa-by-playa Scenarios 1 through 6 can be compared to the ‘Total Estimated Cost’ of the combined playa Scenarios 9 through 12. For buildout conditions, the value for the ‘Total Estimated Cost’ in Swan Lake for Scenario 8b was added to the ‘Total Estimated Cost – Silver Only’ to determine the total cost for the playa-by-playa solutions. These values are listed in the far right column of Table 15 and can be compared to the ‘Total Estimated Cost’ of the combined playa Scenarios 9 through 12. Scenario 8b was selected due to the low cost and ability to utilize Washoe County land.

TABLE 15 - MITIGATION OPTION COST COMPARISON WORKSHEET

To Mitgate Silver Lake to Current Base Flood Elevation = 4968.75' (NAVD 1988)

March 2007

Bold Numbers are Scenario Totals

Italicized cells are linked

$10 Cost per cubic yard for Excavation and Transportation

PLAYA BY PLAYA SOLUTIONS

SILVER LAKE

Scenario	Solutions	Existing Conditions, (3,249 AF) Volume to Mitigate (Ac-Ft)	Depth to Excavate	Excavation Costs	Other Costs - Land, Design, Permitting	Total Estimated Cost	Buildout Conditions, (6,893 AF) Volume to Mitigate (Ac-Ft)	Depth to Excavate	Excavation Costs	Other Costs - Land, Design, Permitting	Total Estimated Cost -Silver Only	Total Estimated Cost - Silver + Scenario 8b for Swan Lake
1	Remove Material from Playa Lake Bottoms	3249	7.2	*$52,400,000*	*$23,822,000*	**$76,222,000**	6893	15.2	*$111,200,000*	*$23,822,000*	$135,022,000	**$155,758,000**
2	Construct Levee around Playa Lake	3249	NA	NA	*$52,970,546*	**$52,970,546**	6893	NA	NA	*$63,024,190*	$63,024,190	**$83,760,190**
3	***Partial Excavation***											
a	Area 1 (All 700 Acres)	*3249*	*4.7*	*$84,025,170*	*$72,000,000*	**$156,025,170**	*6893*	*9.9*	*$142,815,037*	*$72,000,000*	$214,815,037	**$235,551,037**
b	Area 2 (low-lying area)	*3249*	*11.4*	*$55,126,050*	*$32,800,000*	**$87,926,050**	*6893*	*24.3*	*$113,915,917*	*$32,800,000*	$146,715,917	**$167,451,917**
c	Area 2 & Area 3 (low-lying area + Ridge)	*3249*	*9.9*	*$58,926,050*	*$33,000,000*	**$91,926,050**	*6893*	*21.0*	*$117,715,917*	*$33,000,000*	$150,715,917	**$171,451,917**
d	Area 0 (Silver lake playa parcel)	*3249*	*11.1*	*$52,417,200*	*$3,230,000*	**$55,647,200**	*6893*	*23.5*	*$111,207,067*	*$3,230,000*	$114,437,067	**$135,173,067**
4	***Retention in Effluent Reservoir + Partial Excavation***											
	Silver Lake - Effluent Reservoir	623	NA	NA	$2,527,000		718	NA	NA	$2,527,000		
a	Area 1 (All 700 Acres)	*2626*	*3.8*	*$73,974,103*	*$72,000,000*	**$148,501,103**	*6175*	*8.9*	*$131,231,303*	*$72,000,000*	$205,758,303	**$226,494,303**
b	Area 2 (low-lying area)	*2626*	*9.2*	*$45,074,983*	*$32,800,000*	**$80,401,983**	*6175*	*21.7*	*$102,332,183*	*$32,800,000*	$137,659,183	**$158,395,183**
c	Area 2 & Area 3 (low-lying area + Ridge)	*2626*	*8.0*	*$48,874,983*	*$33,000,000*	**$84,401,983**	*6175*	*18.8*	*$106,132,183*	*$33,000,000*	$141,659,183	**$162,395,183**
d	Area 0 (Silver lake playa parcel)	*2626*	*9.0*	*$42,366,133*	*$3,230,000*	**$48,123,133**	*6175*	*21.1*	*$99,623,333*	*$3,230,000*	$105,380,333	**$126,116,333**
		3249					6893					
5	***Infiltration Facility + Partial Excavation***											
	Infiltration Basin Facility at Airport Authority	1757	NA	NA	*$35,560,325*		1757	NA	NA	*$35,560,325*		
a	Area 1 (All 700 Acres)	*1492*	*2.1*	*$55,678,903*	*$72,000,000*	**$163,239,228**	*5136*	*7.4*	*$114,468,770*	*$72,000,000*	$222,029,095	**$242,765,095**
b	Area 2 (low-lying area)	*1492*	*5.3*	*$26,779,783*	*$32,800,000*	**$95,140,108**	*5136*	*18.1*	*$85,569,650*	*$32,800,000*	$153,929,975	**$174,665,975**
c	Area 2 & Area 3 (low-lying area + Ridge)	*1492*	*4.5*	*$30,579,783*	*$33,000,000*	**$99,140,108**	*5136*	*15.6*	*$89,369,650*	*$33,000,000*	$157,929,975	**$178,665,975**
d	Area 0 (Silver lake playa parcel)	*1492*	*5.1*	*$24,070,933*	*$3,230,000*	**$62,861,258**	*5136*	*17.5*	*$82,860,800*	*$3,230,000*	$121,651,125	**$142,387,125**
		3249					6893					
6	***Infiltration Facility + Retention in Effluent Reservoir + Partial Excavation***											
	Infiltration Basin Facility at Airport Authority	1757	NA	NA	*$35,560,325*		1757	NA	NA	*$35,560,325*		
	Silver Lake - Effluent Reservoir	623	NA	NA	$2,527,000		718	NA	NA	$2,527,000		
a	Area 1 (All 700 Acres)	*869*	*1.3*	*$45,627,837*	*$72,000,000*	**$155,715,161**	*4418*	*6.4*	*$102,885,037*	*$72,000,000*	$212,972,361	**$233,708,361**
b	Area 2 (low-lying area)	*869*	*3.1*	*$16,728,717*	*$32,800,000*	**$87,616,041**	*4418*	*15.6*	*$73,985,917*	*$32,800,000*	$144,873,241	**$165,609,241**
c	Area 2 & Area 3 (low-lying area + Ridge)	*869*	*2.6*	*$20,528,717*	*$33,000,000*	**$91,616,041**	*4418*	*13.4*	*$77,785,917*	*$33,000,000*	$148,873,241	**$169,609,241**
d	Area 0 (Silver lake playa parcel)	*869*	*3.0*	*$14,019,867*	*$3,230,000*	**$55,337,191**	*4418*	*15.1*	*$71,277,067*	*$3,230,000*	$112,594,391	**$133,330,391**
		3249					6893					

SWAN LAKE

Scenario	Solutions	Existing Conditions, (-690 AF) Volume to Mitigate (Ac-Ft)	Depth to Excavate	Excavation Costs	Other Costs - Land, Design, Permitting	Total EstimatedCost	Buildout Conditions, (1,102 AF) Volume to Mitigate (Ac-Ft)	Depth to Excavate	Excavation Costs	Other Costs - Land, Design, Permitting	Total EstimatedCost
7	***Partial Excavation***										
a	Area 4 (east of sand dune)	0	0	0	0	0	*1102*	*9.4*	*$17,818,863*	*$11,900,000*	$29,718,863
b	Area 6 (BLM parcel central)	0	0	0	0	0	*1102*	*4.0*	*$19,605,223*	*$950,000*	$20,555,223
c	Area 7 (BLM parcel west)	0	0	0	0	0	*1102*	*5.3*	*$37,346,159*	*$950,000*	$38,296,159
8	***Retention from Subbasins LV4 & LV5***										
	LV5 - Pond on BLM land	0	0	0	0	0	318	8.4	*$6,776,000*	*$450,000*	
a	with 1 Pond in LV4 on Private Land	0	0	0	0	0	*707*	*13.8*	*$13,310,000*	*$7,200,000*	$27,736,000
b	with 1 Pond in LV4 on County Land	0	0	0	0	0	*707*	*13.8*	*$13,310,000*	*$200,000*	$20,736,000
c	with 2 (both) Ponds in LV4	0	0	0	0	0	*707*	*7.9*	*$15,326,667*	*$7,000,000*	$29,552,667
							1025				

Quad Knopf, LLC

Options_Combos_Master_NC.xls

TABLE 15 - MITIGATION OPTION COST COMPARISON WORKSHEET - continued

SILVER & SWAN LAKES COMBINED SOLUTIONS

Open Channels and Pipe Flow from Silver to Swan Lake

Bold Numbers are Scenario Totals

Italicized cells are linked

Scenario	Solutions	Existing Conditions, (3,249 AF) Volume to Mitigate (Ac-Ft)	Depth to Excavate	Excavation Costs	Other Costs - Land, Design, Permitting	Total EstimatedCost	Buildout Conditions, (7,995 AF) Volume to Mitigate (Ac-Ft)	Depth to Excavate	Excavation Costs	Other Costs - Land, Design, Permitting	Total EstimatedCost
9	***Infiltration Facility in Silver + Piping to Swan + Partial Excavation in Swan***										
	Infiltration Basin Facility at Airport Authority	1757	NA	NA	*$35,560,325*		1757	NA	NA	*$35,560,325*	
	Pipe and Channel Structures (~5500 cfs)	0	NA	NA	*$77,947,616*		0	NA	NA	*$77,947,616*	
	Use excess capacity available in Swan (~690 AF)	690	NA	NA	$0		690	NA	NA	$0	
a	Swan Lake - Area 4 (east of sand dune)	802	6.9	$12,978,863	*$11,900,000*	**$138,386,804**	5348	*45.7*	*$86,320,997*	*$11,900,000*	**$211,728,937**
b	Swan Lake - Area 6 (BLM parcel east)	802	2.9	$14,765,223	*$950,000*	**$129,223,164**	5348	*19.5*	*$88,107,357*	*$950,000*	**$202,565,297**
c	Swan Lake - Area 7 (BLM parcel west)	802	3.9	$32,506,159	*$950,000*	**$146,964,100**	5348	*26.0*	*$105,848,293*	*$950,000*	**$220,306,233**
		3249					7795				
10	***Infiltration Facility in Silver + Piping to Swan + Retention from Subbasins LV4 & LV5 + Partial Excavation in Swan***										
	Infiltration Basin Facility at Airport Authority	1757	NA	NA	*$35,560,325*		1757	NA	NA	*$35,560,325*	
	Pipe and Channel Structures (~5500 cfs)	0	NA	NA	*$77,947,616*		0	NA	NA	*$77,947,616*	
	Use excess capacity available in Swan (~690 AF)	467	NA	NA	$0		690	NA	NA	$0	
a	Retention - LV4 & LV5 (avg of scenario 8)	1025	NA	NA	*$26,008,222*	**$139,516,163**	1025	NA	NA	*$26,008,222*	
b	Swan Lake - Area 4 (east of sand dune)	0	0	0	0	0	4323	*36.9*	*$69,784,330*	*$11,900,000*	**$221,200,493**
c	Swan Lake - Area 6 (BLM parcel east)	0	0	0	0	0	4323	*15.8*	*$71,570,690*	*$950,000*	**$212,036,853**
d	Swan Lake - Area 7 (BLM parcel west)	0	0	0	0	0	4323	*21.0*	*$89,311,626*	*$950,000*	**$229,777,789**
		3249					7795				
11	***Infiltration Facility + Retention in Effluent Reservoir + Piping to Swan + Partial Excavation in Swan***										
	Infiltration Basin Facility at Airport Authority	1757	NA	NA	*$35,560,325*		1757	NA	NA	*$35,560,325*	
	Silver Lake - Effluent Reservoir	623	NA	NA	$2,527,000		718	NA	NA	$2,527,000	
	Pipe and Channel Structures (~5500 cfs)	0	NA	NA	*$77,947,616*		0	NA	NA	*$77,947,616*	
	Use excess capacity available in Swan (~690 AF)	690	NA	NA	$0		690	NA	NA	$0	
a	Swan Lake - Area 4 (east of sand dune)	179	*1.5*	*$2,927,797*	*$11,900,000*	**$130,862,737**	4630	*39.6*	*$74,737,263*	*$11,900,000*	**$202,672,204**
b	Swan Lake - Area 6 (BLM parcel east)	179	*0.7*	*$4,714,157*	*$950,000*	**$121,699,097**	4630	*16.9*	*$76,523,623*	*$950,000*	**$193,508,564**
c	Swan Lake - Area 7 (BLM parcel west)	179	*0.9*	*$22,455,093*	*$950,000*	**$139,440,033**	4630	*22.5*	*$94,264,559*	*$950,000*	**$211,249,500**
		3249					7795				
12	***Infiltration Facility + Retention in Effluent Reservoir + Piping to Swan + Retention from Subbasin LV4 & LV5 + Partial Excavation in Swan***										
	Infiltration Basin Facility at Airport Authority	1757	NA	NA	*$35,560,325*		1757	NA	NA	*$35,560,325*	
	Silver Lake - Effluent Reservoir	623	NA	NA	$2,527,000		718	NA	NA	$2,527,000	
	Pipe and Channel Structures (~5500 cfs)	0	NA	NA	*$77,947,616*		0	NA	NA	*$77,947,616*	
	Use excess capacity available in Swan (~690 AF)	690	NA	NA	$0		690	NA	NA	$0	
a	LV5 - Pond on BLM land	179	*5.6*	*$4,501,200*	*$450,000*	**$120,986,140**		see Scenario 8 above			
b	with 1 Pond in LV4 on Private Land	179	*5.0*	*$4,840,000*	*$7,200,000*	**$128,074,940**		see Scenario 8 above			
c	with 1 Pond in LV4 on County Land	179	*5.0*	*$4,840,000*	*$200,000*	**$121,074,940**		see Scenario 8 above			
d	Retention - LV4 & LV5 (avg of scenario 8)	0	0	0	0	0	1025	see Scenario 8 above		*$26,008,222*	
e	Swan Lake - Area 4 (east of sand dune)	0	0	0	0	0	3605	*30.8*	*$58,200,597*	*$11,900,000*	**$212,143,759**
f	Swan Lake - Area 6 (BLM parcel east)	0	0	0	0	0	3605	*13.2*	*$59,986,957*	*$950,000*	**$202,980,119**
g	Swan Lake - Area 7 (BLM parcel west)	0	0	0	0	0	3605	*17.5*	*$77,727,893*	*$950,000*	**$220,721,055**
		3249					7795				

11.11.1 Observations of Total Estimated Costs for Existing Conditions

Scenario 2, construction of a levee around Silver Lake playa, is on of the lowest cost options at approximately $53 million. However, as discussed in Section 11.2, the ongoing costs of maintenance and the liability risks associated with levee failure are not preferred by the City of Reno and thus, construction of levees is not recommended as a viable option.

The highest cost of Scenarios 1 through 12 are Scenarios 3a, 4a, 5a and 6a, averaging approximately $156 million each. This can be attributed to the high cost to acquire 700 acres of private and commercial land around Silver Lake at an estimated cost of $100,000 per acre.

Of the combined playa solutions for existing conditions (page 2 of Table 15), Scenarios 9 through 12, range from $121 million to $147 million. The next lower cost options are Scenarios 1, 3b&c, 4b&c, 5b&c and 6b&c average approximately $88 million. The lowest cost options are 3d, 4d, 5d, and 6d which average $55.5 million since they utilize excavation of Area 0 which has the lowest land cost as discussed in section 11.7.1. These are the preferred options due to the relatively low cost and the lesser impact they would impose on vegetation and wildlife. The cost of $55.5 million provides a target benchmark for a planning level estimated cost to mitigate the existing conditions 100-year volume to the current BFE of 4968.75' (NAVD 1988). However, if Area 0 is not attainable and purchase of private land is required for excavation, the benchmark cost could be closer to $88 million.

The difference in water surface elevation of the current BFE (4968.75' NAVD 1988), set by the Federal Emergency Management Agency (FEMA) in 1994, and the new calculated existing conditions water surface elevation of 4971.8' determined in this study, is approximately three feet. The three foot rise in water surface can be attributed to using the 25-year storm versus the 5-year storm volume for carry-over storage (used to set the current BFE), development that has progressed in the Silver Lake watershed since 1987, and the new precipitation data released by NOAA (the Atlas-14 precipitation dataset). The City of Reno recommended to FEMA to have the 100-year BFE set to the current elevation based on the best available data at the time of the 1994 Schaff & Wheeler study.

11.11.2 Cost Assessment Options for Existing Conditions

It is difficult to assess how to fairly distribute the cost to mitigate the excess volume above the current BFE. There are two general approaches to be considered. The first approach is to assess all the property owners in the Silver Lake watershed by their relative contribution to the stormwater volume. In this case the assessment could be derived from the number of impervious acres per parcel. The second approach would be to assess only the property owners which would benefit by maintaining the current BFE; mainly those with existing development or parcels with development potential within the three foot difference in elevation. A third approach could also be derived by a combination of the first two.

Assuming similar precipitation patterns in the developed area, the increase in volume of water in the playa is directly related to the acres of impervious area in the watershed, i.e. pavement and rooftops which result in an increase in runoff to the playa lake. If the $55.5 million cost is divided by the total number of impervious acres from existing conditions development, as of November, 2005 (1,535 acres), a cost of $36,156 per acre of impervious area could be assessed. To calculate the cost for a particular parcel, a percent impervious value per existing land use type could be applied to the parcel acreage. For example, a 1-acre residential parcel is approximately 20% impervious and thus contains approximately 0.2 acres of impervious area; this would equal a cost of $7,231 for this parcel. Another example would be a commercial parcel, such as the O'brien Middle School, which is 34 acres in size; at 70% impervious this parcel contains 23.8 acres of impervious area and would thus be assessed $860,513 using this method.

For the second approach, a cursory review of the parcels that intersect the area between the current BFE and the 4,972' elevation identifies roughly 90 parcels that total approximately 1,090 acres of land. If the $55.5 million cost were divided by the 1,090 acres of land, the cost per acre to each parcel owner would equal $50,917. A residential land owner with a 2-acre parcel would have pay $101,835; a commercial property with a 12-acre parcel would have to pay $611,004. With this approach, these land owners would incur significant financial hardships. An analysis of options on how to fund this significant cost could be addressed with further study.

<u>11.11.3 Observations of Total Estimated Costs for Buildout Conditions</u>

Scenario 2, construction of a levee around Silver Lake playa is also the lowest cost option for buildout conditions, at approximately $84 million. The highest cost of Scenarios 1 through 12 for buildout conditions are Scenarios 3a, 4a, 5a and 6a, which average approximately $235 million each. Besides construction of levees, the most attractive option is Scenarios 4d at a cost of approximately $126 million. This scenario includes excavation of Area 0 and retention in the Effluent Storage Reservoir proposed by ECO:LOGIC which combine to provide the best relative cost per acre-foot of mitigation. Options 3d, 5d and 6d are the next lowest cost options averaging $137 million. The combined playa scenarios 9 through 12 cost significantly more due to the added cost of constructing the facilities to transfer water from Silver to Swan Lake in addition to excavation costs.

To assess the cost to mitigate the BFE for buildout conditions, it would make sense to first assess the cost to mitigate to the current condition as described above in Section 11.11.2. The cost to mitigate from current development conditions to buildout conditions could be assessed with an impact fee on future development, which will be discussed in the following section.

12.0 RECCOMENDED MITIGATION OPTIONS

12.1 Apply for LOMR for Silver Lake playa.

The exorbitant costs of thousands, to perhaps millions, of dollars that would need to be assessed to property owners in the Silver Lake watershed to mitigate to the current BFE would be very difficult to impose and could result in costly legal action to the City of Reno and Washoe County. An alternative to mitigating the excess volume of 3,249 acre-feet in Silver Lake to the current BFE, is to apply to FEMA for a Letter of Map Revision (LOMR) to raise the BFE to 4972' (NAVD 1988), rounded up to the nearest foot from the elevation determined in this study of 4,971.8' (NAVD 1988). If the BFE was raised to this elevation, the cost to mitigate existing conditions would be eliminated or drastically reduced.

<u>12.1.1 Considerations to Raising the Base Flood Elevation in Silver Lake</u>
FEMA has developed the National Flood Insurance Program (NFIP) which offers flood insurance to properties within a Special Flood Hazard Area. Special Flood Hazard Areas are delineated on Flood Insurance Rate Maps (FIRM's), which are generated by FEMA, and outline zones of relative risk of flood related damage. The area delineated by an established BFE is referred to as Zone AE and is associated with higher insurance premiums than those seen in a Zone X, or area outside the 500-year floodplain. A property owner can reduce their flood insurance premiums by setting the finished floor elevation of their building a designated height, determined by FEMA, above the BFE.

Based on a cursory review of Elevation Certificates of select parcels adjacent to Silver Lake playa, most of the buildings within or adjacent to Zone AE (below 4968.75', NAVD 1988) had finished floor elevations set two or more feet above the FEMA regulatory BFE at the time of construction. Thus, these property owners are typically not required by their lenders to carry flood insurance or have very low premiums if they do carry the insurance. If the BFE is raised three feet, a number of buildings will have their finished floor elevations below the new Zone AE (BFE), and may be required by their lenders to purchase flood insurance at the higher Zone AE rates.

Based on information from the FEMA website, annual flood insurance premiums for a residential unit valued at approximately $250,000 with $100,000 of contents would be expected to almost double if the area where the unit was located was re-zoned from a Zone X to a Zone AE. Annual premiums for a non-residential use property, with a building value of approximately $500,000 and contents valued at $500,000, would be expected to more than double if the area where the building was located was re-zoned from a Zone X to a Zone AE. The costs to obtain flood insurance, while not convenient for property owners, will be substantially lower (at least in the short term) than the costs discussed above to mitigate the excess volume of 3,249 ac-ft to the current BFE.

In addition to purchasing flood insurance through the NFIP, property owners can lessen the impacts of flooding with an Emergency Action Plan that includes flood proofing techniques appropriate for their building or home. These techniques consist of actions such as sandbagging and moving expensive equipment to higher elevations, or products such as temporary flood walls which can be implemented at a minimal to reasonable cost.

12.2 Observations of Total Estimated Costs to Mitigate Future Development Only

As performed in Section 11.11, a comparison of estimated total costs for various combinations of mitigation options was made to mitigate the excess volume calculated as the difference in volume from existing to buildout development conditions in each watershed. The total volume to mitigate at buildout conditions in Silver Lake is 3,644 ac-ft; the volume to mitigate in Swan Lake remains 1,102 ac-ft. Table 16 compares the planning level estimated total costs for an additional 12 Scenarios of combinations of mitigation options, Scenarios 13 through 22. For Scenarios 7 & 8 in Swan Lake, since no excess volume was calculated for existing conditions, the buildout conditions estimated costs are the same as in Table 15. Scenarios 13 through 18 compare the playa-by-playa solutions which evaluate the cost of mitigating the required volume within each watershed for future development. Scenarios 19 through 22 include transfer of the excess volume from Silver Lake to Swan Lake via open channels and a concrete box culvert, evaluating the excess volumes of Silver Lake and Swan Lake watersheds combined.

As carried out in section 11.11, the cost of Scenario 8b was added to all Scenarios 13 through 18 to arrive at a minimum Total Estimated Costs for the playa-by-playa solutions. These values are listed in the far right column of page 1, Table 16 and can be compared to the 'Total Estimated Cost' of the combined playa Scenarios 19 through 22.

Similar to the analysis in section 11.11, construction of a levee around Silver Lake is also one of the lowest cost options but as previously discussed is not preferred by the City.

The most attractive options are Scenarios 15d, 16d, 17d & 18d which range from approximately $74 to $90 million. All these scenarios include utilizing Area 0 for excavation of additional storage volume in Silver Lake playa. The next lowest cost options are playa-by-playa scenarios 13, 15b&c, 16b&c, 17b&c and 18b&c which range in cost from $106 to $126 million.

Scenarios 15a, 16a, 17a, and 18a are the highest cost Scenarios averaging $182 million each, largely due to excavation of 700 acres of private land (Area 1). The estimated costs of the combined playa solutions, Scenarios 19 through 22, range from $127 to $154 million with the exception of Scenario 21b at $118 million. Thus, for the combined playa options, the already high cost to construct open channels, a weir, and a box culvert to transfer water from Silver Lake to Swan Lake does not provide a cost benefit since excavation will have to take place in Swan Lake as opposed to Silver Lake. In Scenario 21b, the cost of the transfer facilities are somewhat compensated for by the lower cost of utilizing BLM land as opposed to private land for excavation of additional volume in Silver Lake.

The recommended option from this analysis is playa-by-playa Scenario 18d with a planning level estimated total cost of approximately $81 million. Scenario 16d is the lowest cost option at $74 million but requires Area 0, in the center of Silver Lake playa, to be excavated to a depth of ten feet; Scenario 18d only requires an excavated depth of four feet. The depth calculations were made assuming vertical walls where actual design will include transitional slopes and require a deeper depth in the center of the area to obtain the same volume of storage. Scenario 18d is recommended since the four foot depth will blend in with the natural topography and is more likely to be accepted and approved by the land owner and the community.

For Silver Lake, this scenario also includes an infiltration facility on Airport Authority property and retention in the Effluent Reservoir proposed by ECO:LOGIC. For Swan Lake, Scenario 18d includes Scenario 8b for Swan Lake mitigation needs. Scenario 8b includes construction of one retention basin on a Washoe County parcel to capture flows from subbasin LV4, and/or a second retention basin on BLM land to capture flow from subbasin LV5.

<u>12.2.1 Assessment of Estimated Cost for Recommended Options</u>

To assess the $81 million estimated cost to construct the facilities necessary to mitigate the increase in stormwater volume from future development an impact fee could be developed. A formula could be constructed based on the cost, per acre of impervious area to be added, by any future development. Since the costs and volumes are different for each watershed, a unique cost factor could be developed for each watershed. An increase of 3,130 acres of impervious area is projected from existing to buildout conditions in Silver Lake (see Appendix F). An increase of 1,965 acres of impervious area is projected from existing to buildout conditions in Swan Lake. If the estimated cost of Scenario 18d for Silver Lake of $60 million, is divided by the 3,130 acres of impervious area, a cost factor of $19,169 could be assessed per acre of impervious area added to Silver Lake watershed through buildout conditions. If the estimated cost of Scenario 8b for Swan Lake, of $21 million, is divided by the 1,965 acres of impervious area, a cost factor of $10,687 could be assessed per acre of impervious area added to Swan Lake watershed.

Using the examples in Section 11.11.2, a 1-acre residential lot at 20% impervious, which equals 0.20 acres of impervious area, would be charged an impact fee in Silver Lake of $3,834 and $2,137 in Swan Lake. A commercial property equal in size to the O'Brien Middle School, approximately 34 acres in size with 70% impervious and approximately 23.8 acres of impervious area, would be charged $456,222 in Silver Lake, and $254,351 in Swan Lake watershed.

Bold Numbers are Scenario Totals

Italicized cells are linked

$10 Cost per cub. yd. for Excavation and Transportation

March 2007

PLAYA BY PLAYA SOLUTIONS

SILVER LAKE

Scenario	Solutions	Buildout Conditions, (3,644 AF)					
		Volume to Mitigate (Ac-Ft)	Depth to Excavate	Excavation Costs	Other Costs - Land, Design, Permitting	Total Estimated Cost - Silver Only	Total Estimated Cost - Silver + Scenario 8b for Swan Lake
13	Remove Material from Playa Lake Bottoms	3644	8.0	$58,789,867	*$23,822,000*	$82,611,867	**$103,347,867**
14	Construct Levee around Playa Lake	3644	NA	NA	*$63,024,190*	$63,024,190	**$83,760,190**
15	***Partial Excavation***						
a	Area 1 (All 700 Acres)	*3644*	*5.3*	*$90,397,837*	*$72,000,000*	$162,397,837	**$183,133,837**
b	Area 2 (low-lying area)	*3644*	*12.8*	*$61,498,717*	*$32,800,000*	$94,298,717	**$115,034,717**
c	Area 2 & Area 3 (Ridge)	*3664*	*11.1*	*$65,621,383*	*$33,000,000*	$98,621,383	**$119,357,383**
d	Area 0 (Silver lake playa parcel)	*3644*	*12.4*	*$58,789,867*	*$3,230,000*	$62,019,867	**$82,755,867**
16	***Retention in Effluent Reservoir + Partial Excavation***						
	Silver Lake - Effluent Reservoir	718	NA	NA	$2,527,000		
a	Area 1 (All 700 Acres)	*2926*	*4.2*	*$78,814,103*	*$72,000,000*	$153,341,103	**$174,077,103**
b	Area 2 (low-lying area)	*2926*	*10.3*	*$49,914,983*	*$32,800,000*	$85,241,983	**$105,977,983**
c	Area 2 & Area 3 (low-lying area + Ridge)	*2926*	*8.9*	*$53,714,983*	*$33,000,000*	$89,241,983	**$109,977,983**
d	Area 0 (Silver lake playa parcel)	*2926*	*10.0*	*$47,206,133*	*$3,230,000*	$52,963,133	**$73,699,133**
		3644					
17	***Infiltration Facility + Partial Excavation***						
	Infiltration Basin Facility at Airport Authority	1757	NA	NA	*$35,560,325*		
a	Area 1 (All 700 Acres)	*1887*	*2.7*	*$62,051,570*	*$72,000,000*	$169,611,895	**$190,347,895**
b	Area 2 (low-lying area)	*1887*	*6.6*	*$33,152,450*	*$32,800,000*	$101,512,775	**$122,248,775**
c	Area 2 & Area 3 (low-lying area + Ridge)	*1887*	*5.7*	*$36,952,450*	*$33,000,000*	$105,512,775	**$126,248,775**
d	Area 0 (Silver lake playa parcel)	*1887*	*6.4*	*$30,443,600*	*$3,230,000*	$69,233,925	**$89,969,925**
		3644					
18	***Infiltration Facility + Retention in Effluent Reservoir + Partial Excavation***						
	Infiltration Basin Facility at Airport Authority	1757	NA	NA	*$35,560,325*		
	Silver Lake - Effluent Reservoir	718	NA	NA	$2,527,000		
a	Area 1 (All 700 Acres)	*1169*	*1.7*	*$50,467,837*	*$72,000,000*	$160,555,161	**$181,291,161**
b	Area 2 (low-lying area)	*1169*	*4.1*	*$21,568,717*	*$32,800,000*	$92,456,041	**$113,192,041**
c	Area 2 & Area 3 (low-lying area + Ridge)	*1169*	*3.6*	*$25,368,717*	*$33,000,000*	$96,456,041	**$117,192,041**
d	Area 0 (Silver lake playa parcel)	*1169*	*4.0*	*$18,859,867*	*$3,230,000*	$60,177,191	**$80,913,191**
		3644					

SWAN LAKE

Scenario	Solutions	Buildout Conditions, (1,102 AF)				
		Volume to Mitigate (Ac-Ft)	Depth to Excavate	Excavation Costs	Other Costs - Land, Design, Permitting	Total Estimated Cost
7	***Partial Excavation***					
a	Area 4 (east of sand dune)	*1102*	*9.4*	*$17,818,863*	*$11,900,000*	$29,718,863
b	Area 6 (BLM parcel central)	*1102*	*4.0*	*$19,605,223*	*$950,000*	$20,555,223
c	Area 7 (BLM parcel west)	*1102*	*5.3*	*$37,346,159*	*$950,000*	$38,296,159
8	***Retention from Subbasins LV4 & LV5***					
	LV5 - Pond on BLM land	318	8.4	*$6,776,000*	*$450,000*	
a	with 1 Pond in LV4 on Private Land	*707*	*13.8*	*$13,310,000*	*$7,200,000*	$27,736,000
b	with 1 Pond in LV4 on County Land	*707*	*13.8*	*$13,310,000*	*$200,000*	$20,736,000
c	with 2 (both) Ponds in LV4	*707*	*7.9*	*$15,326,667*	*$7,000,000*	$29,552,667
		1025				

Quad Knopf, LLC

Options_Combos_Master_NC.xls

TABLE 16 - MITIGATION OPTION COST COMPARISON WORKSHEET

To Mitgate Silver Lake to New Base Flood Elevation set by LOMR = 4972' (NAVD 1988)

March 2007

SILVER & SWAN LAKES COMBINED SOLUTIONS

Open Channels and Pipe Flow from Silver to Swan Lake

Bold Numbers are Scenario Totals

Italicized cells are linked

Scenario	Solutions	Buildout Conditions, (4,746 AF) Volume to Mitigate (Ac-Ft)	Depth to Excavate	Excavation Costs	Other Costs - Land, Design, Permitting	Total EstimatedCost
19	***Infiltration Facility in Silver + Piping to Swan + Partial Excavation in Swan***					
	Infiltration Basin Facility at Airport Authority	1757	NA	NA	*$35,560,325*	
	Pipe and Channel Structures (~2405 cfs)	0	NA	NA	*$51,546,013*	
	Use excess capacity available in Swan (~690 AF)	690	NA	NA	$0	
a	Swan Lake - Area 4 (east of sand dune)	2299	*19.6*	*$37,130,463*	*$11,900,000*	**$136,136,801**
b	Swan Lake - Area 6 (BLM parcel east)	2299	*8.4*	*$38,916,823*	*$950,000*	**$126,973,161**
c	Swan Lake - Area 7 (BLM parcel west)	2299	*11.2*	*$56,657,759*	*$950,000*	**$144,714,097**
		4746				
20	***Infiltration Facility in Silver + Piping to Swan + Retention from Subbasins LV4 & LV5 + Partial Excavation in Swan***					
	Infiltration Basin Facility at Airport Authority	1757	NA	NA	*$35,560,325*	
	Pipe and Channel Structures (~2405 cfs)	0	NA	NA	*$51,546,013*	
	Use excess capacity available in Swan (~690 AF)	690	NA	NA	$0	
a	Retention - LV4 & LV5 (avg of scenario 8)	1025	NA	NA	*$26,008,222*	
b	Swan Lake - Area 4 (east of sand dune)	1274	*10.9*	*$20,593,797*	*$11,900,000*	**$145,608,357**
c	Swan Lake - Area 6 (BLM parcel east)	1274	*4.6*	*$22,380,157*	*$950,000*	**$136,444,717**
d	Swan Lake - Area 7 (BLM parcel west)	1274	*6.2*	*$40,121,093*	*$950,000*	**$154,185,652**
		4746				
21	***Infiltration Facility + Retention in Effluent Reservoir + Piping to Swan + Partial Excavation in Swan***					
	Infiltration Basin Facility at Airport Authority	1757	NA	NA	*$35,560,325*	
	Silver Lake - Effluent Reservoir	718	NA	NA	$2,527,000	
	Pipe and Channel Structures (~2405 cfs)	0	NA	NA	*$51,546,013*	
	Use excess capacity available in Swan (~690 AF)	690	NA	NA	$0	
a	Swan Lake - Area 4 (east of sand dune)	1581	*13.5*	*$25,546,730*	*$11,900,000*	**$127,080,068**
b	Swan Lake - Area 6 (BLM parcel east)	1581	*5.8*	*$27,333,090*	*$950,000*	**$117,916,428**
c	Swan Lake - Area 7 (BLM parcel west)	1581	*7.7*	*$45,074,026*	*$950,000*	**$135,657,364**
		4746				
22	***Infiltration Facility + Retention in Effluent Reservoir + Piping to Swan + Retention from Subbasin LV4 & LV5 + Partial Excavation in Swan***					
	Infiltration Basin Facility at Airport Authority	1757	NA	NA	*$35,560,325*	
	Silver Lake - Effluent Reservoir	718	NA	NA	$2,527,000	
	Pipe and Channel Structures (~2405 cfs)	0	NA	NA	*$51,546,013*	
	Use excess capacity available in Swan (~690 AF)	690	NA	NA	$0	
	Retention - LV4 & LV5 (avg of scenario 8)	1025	see Scenario 8		*$26,008,222*	
a	Swan Lake - Area 4 (east of sand dune)	556	*4.8*	*$9,010,063*	*$11,900,000*	**$136,551,623**
b	Swan Lake - Area 6 (BLM parcel east)	556	*2.0*	*$10,796,423*	*$950,000*	**$127,387,983**
c	Swan Lake - Area 7 (BLM parcel west)	556	*2.7*	*$28,537,359*	*$950,000*	**$145,128,919**
		4746				

13.0 CONCLUSION

New information including one-foot topographic data, NOAA Atlas 14 precipitation data, up-to-date land use information and future land use projections from TMRPA, enable Quad Knopf to update the hydrologic models and calculate new 100-year lake levels for Silver and Swan Lake playas. Water surface elevations were calculated for existing and buildout development conditions for the 100-year, 10-day storm event, with a 25-year, 24-hour storm event used to calculate carry-over storage volumes. An additional volume of treated effluent, from RSWRF and LVWRF, was included in the water surface elevations calculated in Swan Lake.

The existing development condition water surface elevations were calculated to be 4,971.8 feet (NAVD 1988) for Silver Lake playa, and 4923.3 feet for Swan Lake playa. The buildout development condition water surface elevations were calculated to be 4,974.4 feet (NAVD 1988) for Silver Lake playa, and 4924.4 feet for Swan Lake playa. The above water surface elevations computed for Swan Lake playa include treated effluent inflow from RSWRF equal to 1.85 MGD and from LVWTP equal to 0.65 MGD for the month of March only.

The updated hydrologic models calculate a volume of stormwater runoff of 3,249 acre-feet in excess of the current FEMA Base Flood Elevation of 4968.74 feet (NAVD 1988) for existing development conditions in Silver Lake playa. This volume can be mitigated with a combination of facilities costing an estimated $55.5 million dollars. Alternatively, and recommended by Quad Knopf, the Base Flood Elevation can be raised 4,972 feet, the nearest foot to the existing conditions water surface elevation calculated in this study of 4971.8 feet (NAVD 1988). Raising the Base Flood Elevation will impose costs to some property owners by way of increased or added flood insurance premiums and should be considered further.

Once the BFE is raised to the 4,972 elevation, the increase in stormwater runoff from existing to buildout development conditions will need to be mitigated. The updated hydrologic models project an increase of 3,644 acre-feet in Silver Lake and 1,102 acre-feet in Swan Lake playas. These volumes can be mitigated for a planning level estimated total cost of approximately $81 million dollars. Recommended facilities include an infiltration facility on Reno/Stead Airport Authority property, added storage capacity in an Effluent Reservoir, excavation in the center of Silver Lake playa, and retention ponds in Swan Lake watershed. An impact fee based on the number of impervious acres added to the watershed is one method to assess this cost.

14.0 – REFERENCES

1. California, State of, Department of Water Resources, Division of Planning, Rainfall Depth-Duration-Frequency for California, Revised November 1982.

2. Chow, Ven Te, Handbook of Applied Hydrology, McGraw Hill, Inc. 1964.

3. Cochran, G.F., J.M. Barry, M.W. Dale, P.R. Sones, Water Harvest From Peavine Mountain With Artificial Recharge in Golden Valley, Nevada: Hydrologic Feasibility and Effects, Desert Research Institute Publication #41103, October 1986.

4. Crowe, Leonard E., Jr., Storm Amounts Recorded During the February 1986 Flooding, Washoe County Department of Comprehensive Planning, Memo dated April 3, 1986.

5. Federal Emergency Management Agency, Flood Insurance Study, Washoe County, Nevada, Unincorporated Areas, February 1984.

6. Harrill, James R., Evaluation of the Water Resources of Lemmon Valley, Washoe County, Nevada, with Emphasis on Effects of Groundwater Development to 1971, US Geological Survey and the State of Nevada, Department of Conservation and Natural Resources, Division of Water Resources, Bulletin No. 42, 1973.

7. Great Basin Aerial Survey, Spot Elevation Map of Lemmon Valley Playa, Scale: 1”=400’, June 1987.

8. Linsley/Kohler/Paulhus, Hydrology for Engineers, McGraw Hill, Inc. 1982.

9. Millard Spink Assoc. Inc., Lear Reno, Reno/Stead Development Company, Topographic Base Maps, Scale: 1”=100’, Undated.

10. Pyramid Engineers and Land Surveyors, North Reno Business Center, Moya Boulevard Improvements, “As Built” plans dated February 1987.

11. City of Reno, Department of Public Works, Engineering Division, Public Works Design Manual, July 1, 1985.

12. Reimer and Associates, Request for a Letter of Map Revision for North Reno Business Park, Reno, Nevada, July 1985.

13. SEA Engineers/Planners, Flow Profile Investigations on the North Truckee Drain East Prater Way to Interstate 80 Sparks, Nevada, July 13, 1981.

14. Schaaf andWheeler, Consulting Civil Engineers, Hydrology Report for Silver Lake in Reno, Nevada, March 1985.

15. The Spink Corporation, Lear Reno, Reno/Stead Development Company, Topographic Base Maps, Date unknown, From photos dated Aug. 1968.

16. Tipton and Kalmback, Inc., Consulting Engineers, Denver Colorado, Rainfall-Runoff Modeling, (Short Course), February 1985.

17. U.S. Department of Agriculture, Soil Conservation Service, SCS National Engineering Handbook, Section 4, Hydrology, August 1972.

18. U.S. Department of Agriculture, Soil Conservation Service, TSC Technical Note – Hydrology – PO-6 (Rev. 2), Use of National Weather Service Revised Precipitation-Frequency Maps and Estimation of 10-Day Precipitation Values, October 1975.

19. U.S. Department of Agriculture, Soil Conservation Service, Engineering Division, Earth Dams and Reservoirs, Technical Release No. 60, Revised October 1985.

20. U.S. Department Agriculture, Soil Conservation Service, Engineering Division, Urban Hydrology for Small Watersheds, Technical Release 55, June 1986.

21. U.S. Department of Agriculture, Soil Conservation Service, Soil Survey of Washoe County, Nevada, South Part, August 1983.

22. U.S. Department of the Army, Corps of Engineers, Hydrologic Engineering Center, Computer Program 723-X6-L2010, HEC-1, Flood Hydrograph Package, January 1985.

23. U.S. Department of the Army, Corps of Engineers, Engineering and Design, Flood Hydrograph Analysis and Computations EM-1110-2-1405, August 31, 1959.

24. U.S. Department of the Army, Corps of Engineers, Engineering and Design, Routing of Floods Through River Channels EM-1110-2-1408, March 1, 1960.

25. U.S. Department of the Army, Corps of Engineers, Sacramento District, Truckee River, California and Nevada, Hydrology, February 1980.

26. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, NOAA Atlas 2, Precipitation – Frequency Atlas of the Western United States, Volume VII – Nevada, 1973.

27. U.S. Department of Commerce, National Weather Service, Two to Ten-Day Precipitation for Return Periods of 2 to 100 years in the Contiguous United States, Technical Paper No. 49, 1964.

28. U.S. Department of Commerce, National Weather Service Forecast Office, Reno, Nevada Report on the February 1986 Flood in Western Nevada, March 1986.

29. University of California, Davis, University Extension, Flood Plain Hydrology Using HEC-1 on the IBM PC (Short Course), April 1986.

30. Winzler and Kelly Consulting Engineers, Reno Drainage Study, Preliminary Report: Analysis of Drainage Deficiency Areas Within the City Limits, December 1984.

31. Nimbus Engineers, Reno, NV, Hydrologic Analysis of Silver Lake and Lemmon Valley Playas, 1987.

32. Stantec Consulting, Inc., Reno, NV, Drainage Master Plan, Stead, Nevada, August, 2000.

33. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, NOAA Atlas 14 Precipitation Frequency Data Server, http://hdsc.nws.noaa.gov/hdsc/pfds/sa/nv_pfds.html, 2003

34. National Geodetic Survey, VERTCON – North American Vertical Datum Conversion Utility, http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl

35. Washoe County Department of Water Resources, Washoe County Hydrologic Criteria and Drainage Design Manual, 1996.

36. Truckee Meadows Regional Planning Agency, Regional Land Use Model, Draft Procedure Manual, November, 2005.

37. Walker & Associates, North Valleys' Hydrological Condition Rating Report, December, 2006.

38. Schaaf & Wheeler, Consulting Civil Engineers, 100 Year Water Surface Elevation in Silver Lake, 1994.

39. Washoe County Department of Water Resources, Water Resource Investigation for Lemmon Valley, Washoe County, Nevada, by Justin Huntignton February 25, 2005.

40. Washington State Department of Ecology, Water Quality Program, Stormwater Management in Western Washington – Volume III: Hydrologic Analysis and Flow Control Design/BMP's, February 2005, Publication No. 05-10-31

41. City of Portland, Stormwater Management Manual, adopted July 1999; revised September 2004.

42. ECO:LOGIC Engineering, Washoe County Site, Injection Test Results Summary, Memo to City of Reno, February 10, 2006

43. ECO:LOGIC Engineering, City of Reno RSWRF Expansion to 4.5 MGD, Technical Memorandum No. 4, Effluent Disposal Evaluation, Draft, March, 2006

44. ECO:LOGIC Engineering, Lemmon Lake Stormwater Pumping Evaluation, Planning Level Opinion of Probable Costs, September, 2005.

45. State of Nevada, Nevada Revised Statutes: NRS 445A.490, http://www.leg.state.nv.us/nrs/nrs-445a.html.

46. ECO:LOGIC Engineering, North Valleys Effluent Disposal, Draft, August, 2005.

47. Ron Olson, Mountain West Weather, Probability of Multiple Excessive Rainfall/Runoff Events in the Same Water Year in the Reno, Nevada North Valleys – Historical Analysis, September, 2006.