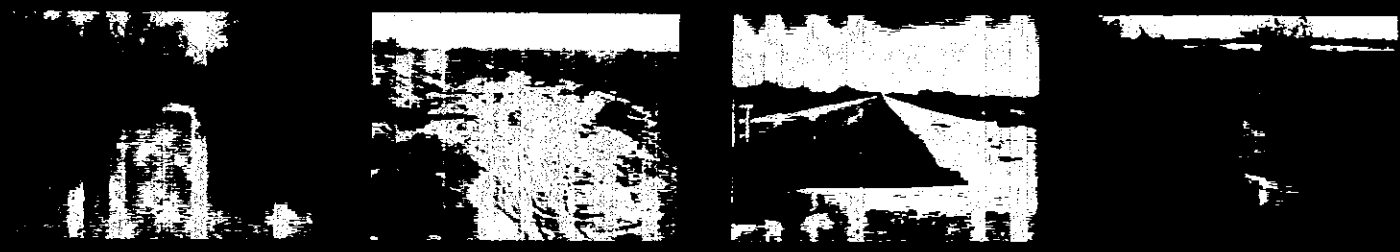
North Inlet Channel Design Data Report

May 2007



Prepared For

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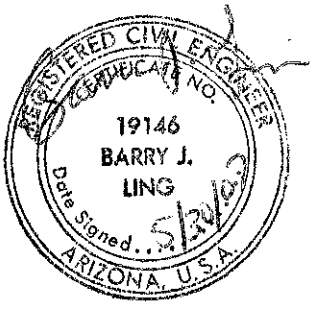


1. INTRODUCTION

1.1 DESCRIPTION

This report documents the analysis, calculations and results for the design of channel improvements for the White Tanks Flood Retarding Structure #3 North Inlet Channel North (NIC North) (see the "North Inlet Channel Pre-Design Study Report" completed by Kirkham Michael and Associates in November of 2004 for background information on both the project and the design alternatives not included in this report). Other reports to be used in conjunction with this report include the "Geotechnical Evaluation North Inlet Channel White Tanks Flood Retarding Structure No.3 Maricopa County, Arizona" completed by Ninyo & Moore on March 2, 2005, the "Phase I Environmental Site Assessment North Inlet Channel White Tanks FRS No.3 Maricopa County, Arizona" completed by Ninyo & Moore on January 28th, 2005 and the "Final Technical Memorandum Fissure & Subsidence Analysis White Tanks FRS#3 North Inlet Channel Maricopa County, Arizona" completed by Geological Consultants Inc. on February 14, 2005.

1.2 PURPOSE

The purpose of this report is to document the analysis, calculations and results for the design of the North Inlet Channel and associated structures. Structures included in the first phase of the project, NIC North (north of Northern Avenue), consist of a side weir, boulder drop structures, meandering channel, reno mattress lined channel, large box culverts and an interim channel south of Northern.

An earthen channel, stepped concrete drop structure, several protected sidewashes and two boulder drop structures will be constructed in conjunction with the NIC South project south of Northern as the second phase of construction to be constructed at the same time as the FRS #3 mitigation project is underway.

1.3 AGENCIES

The partnering agencies on this project are the Flood Control District of Maricopa County (FCDMC) and the Maricopa Water District (MWD). FCDMC is the lead agency and reviewer for the project. Other agencies contributing to cost and review are the Natural Resources Conservation Service (NRCS) and the Maricopa County Department of Transportation (MCDOT).

1.4 LOCATION AND EXISTING FEATURES

The project is located in Maricopa County east of the White Tanks Mountains (Township 2 North, Range 2 West, Section 4 and Township 3 North, Range 2 West, Sections 28 and 33). The project site begins just north of Olive Avenue and ends at the Flood Retarding Structure #3 (FRS#3) located ¾ of a mile south of Northern Avenue. The project corridor runs north-south along the Beardsley Canal, which is located ½ mile west of Perryville Road and 3 miles west of the Loop 303. It is bordered by the Sonoran Ridge Estates on the west between Olive Avenue and Northern Avenue and by undeveloped Arizona State Land between Northern Avenue and the FRS#3. The project is bordered on the east by undeveloped lands owned by MWD. Northern Avenue right-of-way ends to the east of the project site at Perryville Road. The existing channel south of Northern Avenue is contained within a 250-foot FCDMC-owned right-of-way corridor extending nearly ¾ of a mile south to the impoundment area for the FRS#3.

Beardsley Canal Wash, formed by the west leveed maintenance road of the Beardsley Canal, does not have the capacity to contain the 100-year flows. Beardsley Canal Wash is a densely vegetated natural wash with Sonoran Ridge Estates encroachments between Olive Avenue and Cholla Wash along the west side. The Beardsley Canal is the boundary restricting the movement of the wash to the east. The thalweg of the wash is located adjacent to the toe of the canal maintenance road, with some smaller natural wash braids confluencing along its west bank and extending into the floodplain.

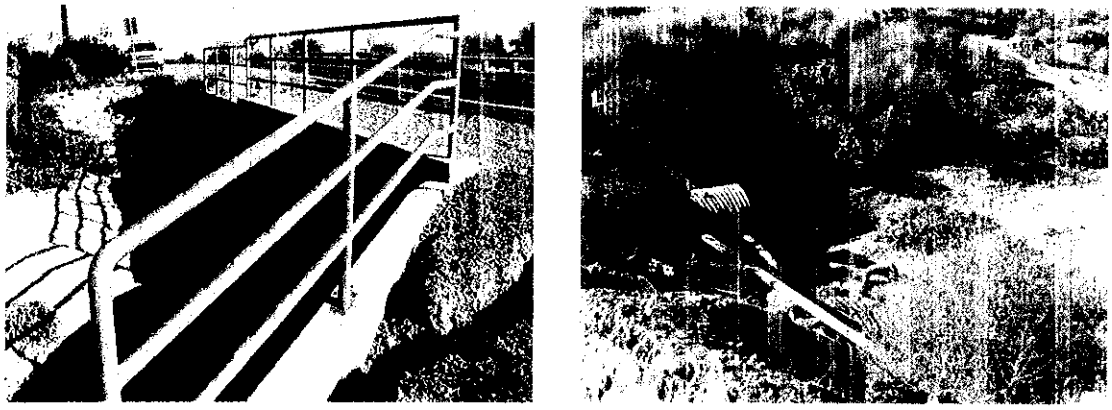
Beardsley Canal Wash and Waterfall Wash confluence just north of Olive Avenue and cause overtopping at the intersection of Olive Avenue and the Beardsley Canal. Sonoran Ridge Estates was directed to construct additional box culverts at this location along with their roadway improvements to Olive Avenue as the only access into the development.

Cholla Wash joins Beardsley Canal Wash approximately halfway between Olive Avenue and Northern Avenue and is the primary source of flow which causes overtopping of the canal between Cholla Wash and Northern Avenue.

MWD currently owns and maintains the Beardsley Canal within a 75-foot right-of-way. MWD owns the land located along the east side of the canal for the entire project corridor and is donating the land to be used as the site for the North Inlet Channel (NIC) diversion channel.

There are existing culverts at both the Northern and Olive Avenue crossings. The Olive Avenue crossing consists of two sets of culverts: one 7-foot and one 8-foot corrugated metal pipe (CMP) and one recently constructed two-barrel 10'x6' concrete box culvert. All culverts have one to two feet of silt and sand. There are two 60-inch CMP culverts located at crossing of Beardsley Canal Wash at Northern Avenue. These CMP culverts do not contain significant amounts of sediment.

Figure 1 - Inlet of wash culverts at Olive Avenue crossing (left) and Northern Avenue (right)



1.5 PROPOSED DESIGN

The proposed design includes a 150-foot long concrete lateral weir as the inlet to a 331-foot box culvert to divert 1600 cfs from Beardsley Canal Wash north of Olive Avenue to a new, earthen trapezoidal channel (North Inlet Channel) located along the east side of the Beardsley Canal. The flow in the North Inlet Channel will be diverted back to the west side of the Beardsley Canal into a continuation of the North Inlet Channel via a 388-foot box culvert crossing Northern Avenue. The

North Inlet Channel is an earthen, trapezoidal channel with varying side slopes that produce a meandering bottom. 15-foot maintenance roads are located on either side with access ramps into the channel. The new channel will include eight, grouted boulder drop structures to drop the channel 36 feet in elevation while maintaining a flat slope (S=0.00075'/ft) and non-scouring velocities of less than 4 feet per second. Undiverted flows in Beardsley Canal Wash will continue under Olive Avenue through the existing culverts to accumulate with flows from Cholla Wash a ½ mile downstream. Potential bank erosion occurring at the Cholla Wash - Beardsley Canal Wash confluence will be mitigated by using soil cement bank protection on the east bank of the Beardsley Canal Wash at this location. The flows will continue in Beardsley Canal Wash to Northern Avenue where the existing corrugated metal pipe culverts will be replaced with a large concrete box culvert and sloping concrete drop inlet. This box culvert will have a conjoined headwall with the box culvert conveying flows from the North Inlet Channel under Northern Avenue. The outlet of this conjoined box culvert structure will reunite flows from Beardsley Canal and the North Inlet Channel.

The existing channel of the NIC South project downstream of Northern Avenue will be improved to handle the increased flows coming from both the NIC diversion channel and from Beardsley Canal Wash. The channel will be deepened and widened downstream of Northern Avenue to the FRS#3. Some issues regarding the channelization improvements downstream of Northern Avenue include: 1) meandering the channel to the east to utilize existing FCDMC right-of-way; 2) meandering the channel back to the west around the proposed FRS#3 dam extension (which ends approximately 2400' south of Northern Avenue); 3) removal of collapsible soils forming the east bank of the channel adjacent to the dam extension and 4) accomodating flows from defined washes coming in from the west by protecting the banks with grouted rip rap and grout cut-off walls as well as maintenance road scour protection (for side wash flows allowed to come over the proposed west bank maintenance and into the channel).

2. HYDROLOGY

2.1 INTRODUCTION

The hydrologic evaluations completed for the Loop 303 Corridor/White Tanks Area Drainage Master Plan Update (Contract FCD 99-40, May 2003) and FRZR Basin Outlet Channel (Contract FCD 2004C009, January 10, 2005) were provided by the FCDMC for the project. The FRZR hydrology was based on the Loop 303 hydrology incorporating the latest changes to the upstream watershed. The FRZR hydrology was updated by Kirkham Michael to account for design changes in the side weir diversion at Olive Avenue. The updated FRZR HEC-1 and Loop 303 model output summaries are located in the North Inlet Channel Design Calculations and Analyses Notebook (NIC DC&AN).

2.2 HYDROLOGY SOFTWARE

US Army Corps of Engineers, Hydrologic Engineering Center Flood Hydrograph Package (HEC-1) Version 4.1 (June, 1998) was used for the hydrologic analyses to update the FRZR Basin Outlet Channel hydrology to obtain the peak discharges along the project corridor.

2.3 HYDROLOGIC MODELS

Hydrology provided by the County was used and updated to obtain peak discharges along the project corridor that would reflect the new overall project conditions (see Appendix A), these conditions included:

No breakouts over Olive Avenue at Beardsley Canal.
A controlled diversion of 1600 cfs at Olive Avenue into the new NIC diversion channel.
Reduction in flow in Beardsley Canal Wash from Olive Avenue to Cholla Wash.
New peak flow at Beardsley Canal Wash and Cholla Wash.
No breakouts at Northern Avenue at Beardsley Canal.
Return of the diversion flows (1600 cfs) into the proposed channel south of Northern Avenue.

The assumption was made that the diversion flows in the proposed North Inlet Channel combine directly with the flows routed in Beardsley Canal Wash just south of Northern Avenue.

The peak flows are as follows:

At Olive Avenue – 2722 cfs
Diversion at Olive Avenue – 1600 cfs
Olive Avenue to Cholla Wash in Beardsley Canal Wash – 1043 cfs
Cholla Wash – 4877 cfs
Cholla Wash to Northern Avenue in Beardsley Canal Wash– 5678 cfs
Northern Avenue to 1200 feet south of Northern Avenue – 7132 cfs
1200 feet south of Northern Avenue to FRS#3 Structure in FRS#3 Channel – 7572 cfs

These flows were used consistently for all inputs into weir calculations, HEC-RAS, CulvertMaster and FlowMaster for evaluation and design of proposed features.

3. HYDRAULICS

3.1 INTRODUCTION

Hydraulic analyses were performed in order to determine the design of the structures and channels comprising the project including:

Side weir and drop inlet structure at Olive Avenue
Diversion box culvert at Olive Avenue
North Inlet Channel (NIC North) diversion channel from Olive Avenue to Northern Avenue
Eight grouted boulder drop structures in the NIC North
Soil cement bank protection at the confluence of Cholla Wash and Beardsley Canal Wash
Diversion box culvert at Northern Avenue
Box culvert for undiverted Beardsley Wash flows crossing under Northern Avenue
An 8 foot concrete drop structure at the outlet of the box culverts at Northern Avenue
Two grouted boulder drop structures in the NIC South
Six grouted boulder side washes flowing into NIC South

3.2 HYDRAULIC SOFTWARE

U.S. Army Corps of Engineers HEC-RAS River Analysis System v.3.1, ADWR State Standard 5-96 – Guideline 2, Haestad Methods CulvertMaster v.3.0, FlowMaster v.7.0, various hand calculations using standard hydraulic equations and methodologies were implemented to determine culvert sizes, toe-down depths for bank protection, water surface profiles and weir dimensions.

3.3 HYDRAULIC MODELS

The HEC-RAS model "NICDSGNDTDY.prj" contains the steady state analysis of the side weir, channels, culverts and drop structures of the NIC North project design. The geometries and flow data represent the proposed design for the project. Table 1 below documents the plans contained within NICDSGNSTDY.prj (these models are included on CD in the NIC North DC&AN).

Table 1 – Project Hydraulic Models

PLAN NAME	USE
NIC Steady01	Design model documenting proposed design from Olive Avenue to FRS#3 including side weir, culverts, drop structures and culverts.
KM Dsgn Existing Wash (KM Base)	Documents existing conditions under proposed flow rates.
Fpfw 072902 Olive Ave CBC	Original Sonoran Ridge Estates model with updates to culverts at Olive and Northern based on as-built info.

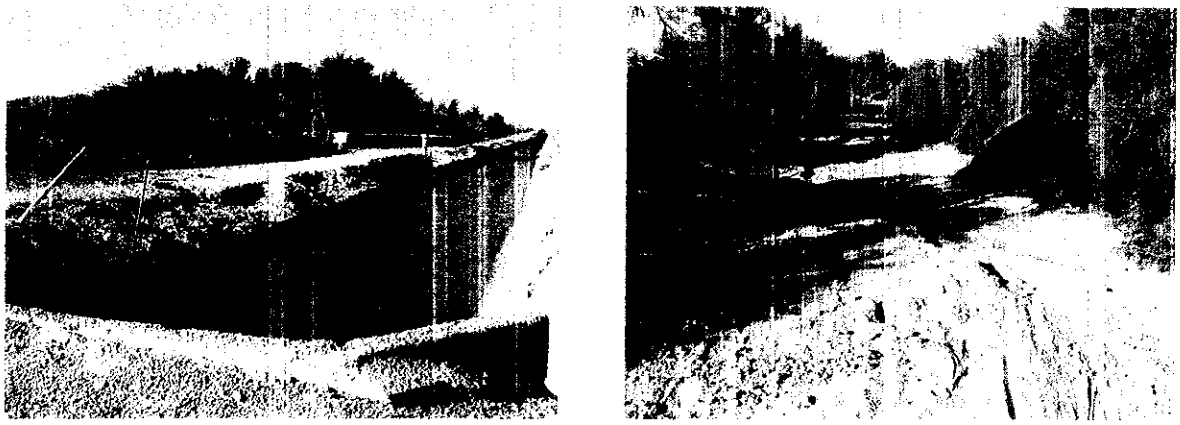
The HEC-RAS model "NIC_FinalDesign.prj" contains the steady state analysis of the NIC South design, including an 8 foot concrete drop structure, two grouted boulder drop structures and several grouted boulder side wash structures, combined through a junction to the NIC North design.

4. SUMMARY OF RESULTS

4.1 SIDE WEIR AT OLIVE AVENUE

A side weir is proposed to intercept the flows coming from Beardsley Canal Wash and Waterfall Wash immediately upstream of Olive Avenue. The weir will be configured into the existing west bank of the Beardsley Canal maintenance road (which serves as the east bank of Beardsley Canal Wash). The figure below shows the existing Beardsley Canal Wash approximately where the weir will be placed.

Figure 2 - Approximate location of proposed lateral weir



The side weir was analyzed using the standard weir equation. A range of weir coefficients were evaluated. Due to the ponded condition behind the existing culverts at Olive Avenue, a weir coefficient of 3.0 was selected. Headwater at the weir was determined from the HEC-RAS analysis of the existing culverts at Olive Avenue.

The weir is sized to limit the diversion flow to 1600 cfs. The weir crest will be set at elevation 1275.00 and will have a crest length of over 216 feet (see HEC-RAS output in the NIC North DC&AN). Some channel grading will be needed around the weir structure. Behind the weir, a concrete apron leading to a sloping drop inlet will direct flows into a box culvert (see Conceptual Sketch provided in the NIC North DC&AN). Due to the backwater effects from the existing Olive Avenue roadway embankment and culverts, the velocities at the weir slow down to less than 4 fps. The head over the weir is assumed to be at the water surface elevation (as opposed to the energy grade line).

4.2 DIVERSION CULVERT AT OLIVE AVENUE

The diversion culvert at Olive Avenue is sized to keep the headwater elevation below the side weir crest. A CulvertMaster analysis determined that a 2-barrel, 10'x5' box culvert would be sufficient to keep the headwater low enough (1270.62) so as not to impede flow over the side weir (see NIC North DC&AN for calculations). It should be noted that this size box culvert is able to pass more flow than the pre-determined diversion flow of 1600 cfs. The weir crest serves to restrict the diversion flow to 1600 cfs during a 100-year flow. A smaller culvert can pass the diversion flow, but would not maintain the headwater elevation needed to keep the side weir flowing free. The diversion culvert is 331 feet long and outlets into the proposed North Inlet Channel.

4.3 NIC NORTH (FROM OLIVE AVENUE TO NORTHERN AVENUE)

4.3.1 CHANNEL

The diversion channel is an unlined, trapezoidal, earthen channel with meandering side slopes and 15-foot maintenance roads on each side of the channel. The slope of the channel is 0.00075 ft/ft with side slopes varying from 4:1 to 8:1 creating a meandering channel bottom of constant width. The dimensions and flow were analyzed in FlowMaster to obtain the 100-year flow depth of 5.5 feet. The total channel depth will be set at 7.5 feet, allowing a 2-foot freeboard to ensure that the banks will not be overtopped if the channel becomes vegetated. To prevent erosion the channel slope was flattened to insure the velocities will be no greater than 4 feet per second. The maximum capacity of the channel was calculated to be 3025 cfs, meaning that the NIC could contain all of the flow from Beardsley Canal Wash. Calculations and HEC-RAS output for the channel can be found in the NIC North DC&AN.

4.3.2 DROP STRUCTURES

Eight grouted boulder drop structures are used along the proposed channel to maintain the flat channel slopes and drop the 36 feet of elevation difference from Olive Avenue to Northern Avenue. Three different drop heights are used: five structures have a 3.50' drop, two structures have a 4.50' drop and one structure has a 6.25' drop. All of the drop structure heights were analyzed in HEC-RAS at 400 cfs, 800 cfs, 1200 cfs and 1600 cfs to determine the constriction width needed to prevent draw down over the drop structure crest and for hydraulic jump analysis to determine the length needed for downstream aprons.

The drop structures include concrete cutoff walls at the beginning of the top apron and the end of the bottom apron. A channel constriction to 25 foot width at the top of the drop is incorporated to prevent the water surface from drawing down over the drop crest and thereby increasing the velocities upstream of the crest. The channel expands back to the full channel width at the end of the downstream apron (apron lengths vary from 30' for the 3.50' drop structure to 31' for the 4.50' drop structure to 36' for the 6.25' drop structure). The drop structures are comprised of large grouted boulders. The drop face is a 4:1 slope and the side slopes for the entire structure are 4:1 on both sides. The transition of the side slopes from 6:1 to 4:1 and back to 6:1 occur within 15 feet upstream of the constriction and 15 feet downstream of the expansion. The HEC-RAS showing the hydraulic characteristics as well as typical drop structure drawings can be found in the NIC North DC&AN.

4.4 DIVERSION CULVERT AT NORTHERN AVENUE

The diversion culvert at Northern Avenue, though passing the same diversion flow of 1600 cfs, has one more barrel than the Olive Avenue diversion culvert. This is due to the fact that the Olive Avenue diversion culvert has much more head on the upstream inlet (and therefore more capacity). A CulvertMaster analysis determined that a 3-barrel, 10'x5' box culvert would be needed to keep the headwater (1227.66) below Northern Avenue (elev =1230 approximately 200' east of the canal) (see the NIC DC&AN for culvert calculations). This analysis accounts for the channelization and tailwater conditions in the NIC South as modeled in HEC-RAS.

4.5 WASH CROSSING CULVERT AT NORTHERN AVENUE

4.5.1 CULVERT

A HEC-RAS analysis determined that a 4-barrel, 12'x6' box culvert is needed at the location where Beardsley Canal Wash crosses Northern Avenue (see the NIC DC&AN for HEC-RAS output). The new culvert is to be centered nearly 75 feet west of the existing culvert (two 60-inch CMP's). The new location is to be aligned with the channelization and alignment of the NIC South. Some channelization and re-direction of the low flow of the existing wash are proposed to route low flows directly into the culvert. The culvert was sized to prevent overtopping of the Beardsley Canal and Northern Avenue.

4.5.2 DROP INLET STRUCTURE

The inlet to the culvert will be a sloping, concrete drop inlet. The upstream end will consist of an apron and curb-type apron lip to prevent gravel from being carried down into the bottom of the drop inlet. The drop inlet and culvert experience high velocities (21 fps) and will be self-cleaning. Just downstream of the culvert in the NIC, the sediment will settle out and maintenance may be required. Outlet protection is required at the outlet. The drop inlet is completely inundated in the 100-year storm event.

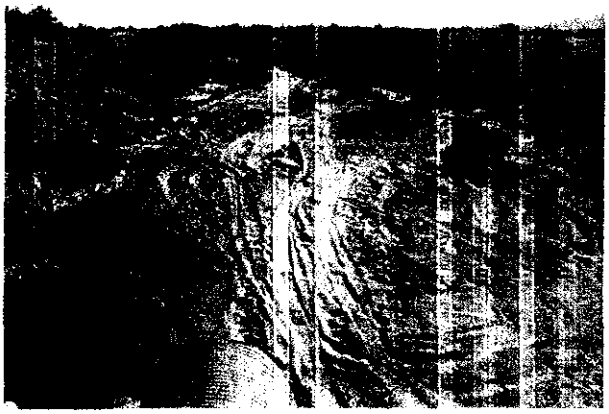
4.6 NIC SOUTH (FROM NORTHERN AVENUE TO FRS#3)

4.6.1 CHANNELIZATION

An interim channel will be constructed with the NIC North project which daylights the channel downstream of the Beardsley Wash and Northern Avenue Diversion Culverts

The NIC South channelization is proposed to begin immediately downstream of Northern Avenue and extend ¾ mile to the FRS#3 impoundment area. The combined flows from Beardsley Canal Wash, the NIC and unimproved lands west of the channel south of Northern Avenue (7572 cfs) will be conveyed to the FRS#3. The channel will consist of an unlined, varying side slopes, earthen trapezoidal channel with varying west bank and levee east bank. Some channel meanders are proposed. The channel will have a 150-foot bottom width with 4:1 to 6:1 side slopes and a longitudinal slope of 0.0004'/ft. The channel was analyzed using HECRAS. The NIC DC&AN contains HEC-RAS model outputs for the proposed channelization.

Figure 3 - Existing FRS#3 Channel



4.6.2 DROP STRUCTURES

The NIC South project proposes one 8' concrete drop structure immediately downstream of the conjoined culvert outlet passing under Northern Avenue, and two 3' grouted boulder drop structures midway along the proposed channel to maintain the flat channel slope and drop the fourteen feet of elevation difference from Northern Avenue to the FRS#3.

The concrete drop structure was sized as a straight drop weir. The drop design has 2-foot high steps that will produce a cascade effect for low flows through the structure. The drop structures include concrete cut off walls at the beginning of the top apron and the end of the bottom apron. The downstream apron of the outlet at the Northern Avenue culverts includes a cut off wall, where the concrete drop structure begins.

For the two boulder drop structures, an iterative HEC-RAS analysis was performed to determine that a 65' constriction was needed to eliminate draw down and increasing velocities upstream of each drop crest. A hydraulic jump analysis was performed to determine the bottom apron lengths of the two drops, and a scour analysis was conducted to determine the upstream and downstream cut off wall depths and volumes of rip rap needed for protection. The drop face is a 4:1 slope and the side slopes for the entire structure are 4:1 on both sides. The HEC-RAS model showing the hydraulic characteristics as well as typical drop structure drawings can be found in the NIC South DC&AN.

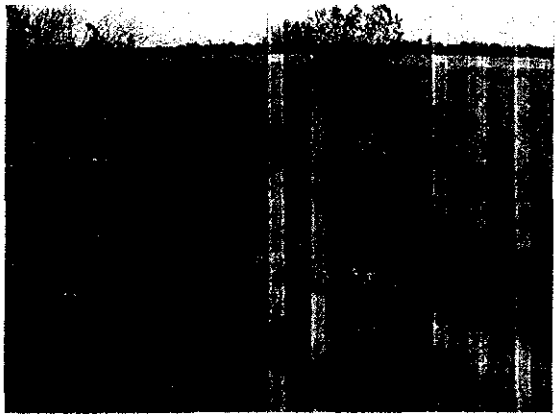
4.6.3 SIDE WASHES

Six drainage areas were identified as flowing into the South Channel from the west, from undeveloped land. Due to the depth of the proposed channel, structures were needed to safely convey flows from these side washes into the South Channel without causing side wall or channel bottom erosion. Grouted boulder drop structures were sized to have a total flow depth of 2-feet, 4:1 side slopes, rip rap areas at the top and toe of slope, and grout cut off walls sized from the scour analysis surrounding the perimeter of the structures to prevent South Channel flows from undermining them. The NIC South DC&AN contains supporting data for the design of these six side washes.

4.7 SOIL CEMENT BANK PROTECTION AT CHOLLA-BEARDSLEY WASH CONFLUENCE

Bank protection was placed along Beardsley Canal Wash at the Cholla Wash confluence to reduce erosion of the Beardsley Canal maintenance road. A photo below shows the east bank of the Beardsley Canal Wash before the soil cement was placed..

Figure 4 - East bank of Beardsley Canal Wash



Soil cement was placed along 900-feet of the east bank of Beardsley Wash in approximately 6-inch lifts and included a top width of 8-feet being placed from the top of bank to thalweg of the wash at a 2:1 slope. The height of the exposed soil cement ranges from 4 to 11-feet, increasing from upstream to downstream. A toe down is included having a 6.0' to 8.5' foot depth. The toe-down depths were determined using ADWR State Standard 5-96 (see the NIC DC&AN for scour calculations in Beardsley Canal Wash).

5. REFERENCES

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