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INFORMATIONAL ROUTING

Memorandum
Chief, Hydraulics Branch

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Head, Hydraulics Research Section JAS 9/19/78

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Research on Abrasive Materials in Stilling Basins

PURPOSE

To report work I have done on the hydraulic research project "Abrasive Materials in Stilling Basins." After you read this memorandum progress report and see a slide presentation I will prepare, you can then decide if a more formal report should be made, and also what the scope of the report should be.

INTRODUCTION

When assigned this project I thought there might be a specific model study in mind. However, there was not and thus I tried to determine if the Bureau had a severe problem of abrasive materials in stilling basins, or only isolated occurrences. Thus, I made a literature search and afterwards a survey of Bureau stilling basin experience.

LITERATURE SEARCH

I contacted the library and had a computerized search made. It was very hard finding appropriate words from the thesaurus of Water Resource Terms that distinctively aimed the search at stilling basin abrasion. The thesaurus words have been cataloged from previous experience and the subjects of scour and erosion were very prominent (but not from the standpoint of abrasion damage). The lack of thesaurus words shows the relative newness of this research project.

I received 27 references (appendix Ia), none of which were helpful to me. In fact one reference (No. 23) was my own research project, which I am presently working on. Another reference description (No. 15) surmises that polymer-impregnated concrete is protecting against erosion. However, after reading this in the article, "Much of the damage is attributed by the Corps of Engineers to construction debris that could not be removed before water was released through the spillway," I feel that conditions causing abrasive damage have been alleviated. Undoubtedly the stronger concrete can withstand abrasion better and should not be overlooked, but I feel the hydraulic part of the problem should be pursued from our standpoint.

I also searched through literature listed in the Bureau library microfilm system (more than I have shown in appendix Ib) and scanned through numerous documents. Only one document was found that I believed relevant to this research, R202,506, Arthur, H. G. and Jabara, M. A., "Problems Involved in Operation and Maintenance of Spillways and Outlets at Bureau of Reclamation Dams," International Commission on Large Dams, Istanbul, Turkey, September 4-8, 1967. A generalization was given concerning the problem.

> "Bureau of Reclamation experience with spillway hydraulic jump basins has shown that considerable damage can occur to concrete surfaces from debris present in the hydraulic jump. This debris is mainly rock which has fallen into the basin from adjoining slopes, has been thrown in by visitors, or which has been drawn in from the outlet channel by the reverse currents present in the jump. The damage consists of erosion of the floor, walls, and of the dentates.
>
> The severity of damage depends on a number of factors, one of which is the frequency of use. For some projects the outlet works is designed to utilize the spillway stilling basin, to save the cost of a separate energy dissipator. This may result in frequent use of the spillway stilling basin and increase the changes of erosional damage if other unfavorable conditions exist."

The paper went on to report about combined outlets works and spillway stilling basins and big hollow-jet valve basins being susceptible to abrasion damage. However, there was not much information about Type II and III basins. Therefore, I decided a survey should be made for Bureau stilling basins, hopefully to give good definition to the problem and also cover a wider range of basins.

At first the approach was for an interdisciplinary team to make the survey. Sometime later I talked with Tom Rhone about this and the consensus was I should make the survey.

SURVEY QUESTIONS

To aid in making the survey I had a brief writeup telling what information would be useful (appendix II). I felt if this information could be obtained then management could better judge seriousness of the problem, have the cost information, and thus establish priority for funding research. Also some "common denominator" information may show up indicating "hydraulics" that should, or should not, be researched. While I had some inkling that obtaining answers to the survey questions might be difficult, I did not realize I was asking for the near impossible, or if not impossible certainly a much more expensive and time consuming effort.

ENDEAVORS RELATED TO THE SURVEY FORM

I gave the survey form to Ed Rossillon, Head of the Spillways and Outlets Section, requesting what help they could readily give me; and without using an excessive amount of their time. He gave a list of the following dams that have had stilling basin abrasion problems: Causey, Mason, Navajo, Tiber, Palisades, Ruedi, Trinity, Haystack, Wanship, and Yellowtail. Major or remedial repair work has been done on these structures. Mr. Rossillon thought a rock trap may be one possible solution to the problem. He believed most material was brought in by the hydraulic action of the water at the downstream end of the basin. Other than this list of dams he could not supply me with more specific information and suggested that I see Vern Yocom from the Division of Water O&M.

I gave Vern the survey form, Ed Rossillon's list, and asked if he could help. He looked in their O&M files and gave me further information, appendix III. While this was helpful it still was not conclusive, nor gave me a strong indication that our hydraulic design was inadequate (in the sense that hydraulic action pulled debris into the basin, excluding hollow-jet stilling basins). Also Vern brought out the factor about people throwing a large number of rocks into stilling basins.

I wanted a more inclusive survey of Bureau stilling basin experience. At this time I knew of the underwater diver reports which I had seen in the "Review of Maintenance Program" (you had routed these to me), and I asked Vern if he had these in their O&M files. They did; however, the diver reports were not in one single file, but were in individually bound files for each of the different dams. If possible I did not want to go through each of the files. With further questioning I found that Shirley Barnes could make a computer search for me, listing a short statement about the underwater/unwater examination of the basins for all the dams.

SEARCH OF THE O&M FILES

First I looked through the computer printout that Shirley gave me. (She had to modify their program to give me only the information I wanted so I would not have armloads of paper. At this point I want to acknowledge the cooperation and help that Shirley and Vern gave me.) The printout was of a brief nature and thus I used it to find out what individual dam files I should look at. There was a total of 300 facilities listed - storage dams, diversion dams, carriage systems, and others. I excluded diversion dams because they can have bedload diverted through them and felt they would not be indicative of the problem. There were 218 storage dams and of these the computer printout gave me reason to look at 114 files.

In looking through each file, there were different sources of information, Review of Maintenance Program reports (from both E&R Center and Regional level), underwater diver reports, travel reports, and correspondence. Needless to say, I did not find all the survey form information. In fact for some cases I had to search and read diligently, and felt like a detective in trying to make some determination of what happened. I was depressed and overwhelmed about the problem of rocks in stilling basins, especially in relation with my survey intent of providing good definition of the troublesome hydraulic flow conditions. At this point it was time consuming searching the files and I was wheel spinning. After some time it became evident I had to reevaluate information for my survey, lower my sights, and provide less.

I have presented the survey information in appendix IV and V. Appendix IV is a tabulation of the rock and abrasion survey made of USBR stilling basins. The intent was to briefly summarize and categorize abrasion experience of the stilling basins. Column headings indicate problem severity "Rocks" being considered the least severe, "Abrasion" more severe, and then increased severity of abrasion to "Exposed rebars," and then the necessity for "Repaired." However, there were three instances when repairs were made before the rebars were exposed, thus somewhat reducing the significance of the last column. Appendix V is an information brief providing more information about quantity of rocks, extent of the damage, and cleaning the stilling basins.

NOTES CONCERNING THE SEARCH

In starting the search I came across information which I did not believe too meaningful. However, at a later time I changed my mind and used this information to make judgements. There were interesting circumstances which I found and also some questions formed in my mind. Thus, this section of the memorandum may ramble but should provide background information.

In some instances when the diving inspections were made the water was clear with good visibility. In many instances, though, the water was murky with very poor visibility and the inspection was made by feeling the surface. Thus, it is difficult to measure the erosion depth of concrete. Generally, the diving reports describe rock shape characteristics. An angular or sharp cornered rock is one that has not been subjected to excessive tumbling or "ball milling" action. For some reports subangular was used and I was not sure whether partial abrasion of the rock corners was implied. Well-rounded rocks generally implied considerable grinding movement of the rocks. Yet this term cannot be considered "all inclusive" because I saw some photographs where these rounded rocks were available to be thrown into the basin.

Location of the rock in the basin can be indicative of how the rock entered the basin. Rock at the upstream end of the basin near the toe of the spillway chute, rock resting below the water surface on the chute, and rock resting on top of the chute blocks probably entered from the spillway chute, and not from hydraulic action of the water pulling it in from the downstream end. (This observation may be invalid for a combined outlets works - spillway stilling basins and hollow-jet valve basins.) There were photographs where it appeared rock at the upstream end of the basin had been moved by a small or medium discharge to an orderly deposit downstream from the chute toe. Other photographs indicated a somewhat larger discharge may have moved and deposited rock at the downstream end of the basin but had not been great enough to flush the rock out of the basin. This rock was not considered to have been hydraulically pulled into the basin because riprap immediately downstream from the basin was in place. The term "scattered rock" was considered to mean that the rock was probable thrown into the basin and was not moved to an organized deposit by hydraulic action of the water. Also, there were instances where rock deposits were greater near sides of the stilling basin, suggesting that these rocks were thrown in by people.

Factors of the "rock in stilling basin" problem as mentioned in Arthur's and Jabara's paper were strongly supported by the search. Indeed, spillway chutes proved effective for collecting sloughing rock and funneling it down into the basin. In addition, the location of these chutes are locked into foundation requirements that place them adjacent to cliffs and steep slopes. Also, people are attracted to the rolling of rocks down these inclined planes.

PEOPLE are another strong contributing factor of abrasive material (rocks and metal construction debris) entering stilling basins, and over the years the Bureau has built fences trying to keep rocks from being thrown into the basins. However, the inherent character of people causes them to accept these fences as a challenge and rocks are still thrown into the basins. One diver report remarked that because of the height of the fence and the size of the rock it must have taken a joint effort to heave it into the basin. Even "do not throw rock" signs are ignored and people still throw rocks into basins and chutes. One facility removed their sign because they thought it gave people the idea, and believed no more rocks were thrown in than before.

Frequency of basin use was another important factor concerning abrasion damage. Note for the table of appendix IV and the "Exposed Rebars" and "Repaired" columns that the basins are predominantly outlets works or combined spillway-outlets works basins. Generally, outlet works operate a much greater time than spillways and thus experience more damage.

For outlets works stilling basins the most extensive concrete abrasion occurred on the floor, on the walls in the immediate vicinity of the floor, but not on the walls at any appreciable distance above the floor (Trinity and Navajo hollow-jet basins excluded). Also, the most extensive abrasion could occur at different locations within the basin, depending upon the quantity of discharge (this was a conclusion I made, but without definite records of basin discharge). At small discharges abrasion was found on the chute floor, at slightly greater discharges the abrasion could be in the vicinity of the chute toe (both on the chute and stilling basin floor), and with progressively higher discharges the most extensively damaged area would be located further downstream in the basins. Judging from the photographs I saw in the O&M files many basins do not operate at a conjugate depth tailwater condition, but in the lower range, discharges have a much higher tailwater condition. For nonoperating conditions many of the basins had an appreciable water depth pool. Also, the diver reports listed 3- to 6-m water depths when making their examinations. (This figure I came up with by "recall" and I am sure there are basins with greater and lesser depths). Possibly the submerged hydraulic jump operating conditions may be conducive to abrasive action in the stilling basins.

Silt and sand deposits were found in many basins. In one instance the silt entered directly from the intake, another instance it was from water surface runoff carrying silt into the basin, another of windblown sediment, and for others I believe it could be from water currents generated by an outlet works carrying the small particles into the adjoining spillway basin. If the deposits become too deep there is a question whether flow will overtop the basin walls. The designers would like to see the basins cleaned out. The users say it costs too much, the deposits will form again, and anyway a good spill will flush it out. The operations people are caught in the middle. Silt flushing tests were made for the outlet works basin of Twitchell Dam. There was a 10-m (30-ft) thick deposit of firm clay. Flushing tests started with a low discharge and progressed to higher discharges, with each discharge held for a period of 30 minutes. Also, some material was removed with a clamshell equipped crane. Just a little more than half the deposit length was flushed out and a 34-m (110 ft) length of the deposit remained at the downstream end of the basin. Looking at photographs of the turbulent basin flow I wondered why more of the sediment was not removed because downstream from the hydraulic jump the water appeared fast flowing. Evidently considerable energy is required for eroding firm clay deposits. The region reviewed these tests and decided operating restrictions were not necessary. They felt the 30-minute gate opening time would be adequate for flushing future deposits without flow overtopping the walls. My point in bringing all this up is maybe there is a danger of damage to these silt deposit basins of having a floodflow released too quickly into the basin?

In reading the underwater diver reports I found a diversity of style among the regions. My preference was for the MP Region reports. In my estimation they gave the most information. They were the first to provide sketches of the basins which give a quick and more easily understood summary of their inspection. There were more detailed measurements concerning deposit size in the basins; contour lines in some cases. They tried to analyze how the rock entered the basin and hydraulic action that did the abrasion damage. In some of their later reports they added some operating information such as discharges the basin experienced since the last inspection (this can be helpful in trying to reason about debris movement and basin damage), and they made comments concerning their recommendations. However, I came to the conclusion that the MP Region spent more money than the other regions for their inspection program. It would be advantageous if some of the other regions upgraded their underwater diving inspections and reports, but these regions probably do not want to spend the money.

COMPLETENESS OF THE SURVEY

This was not a complete survey of all Bureau stilling basins. The computer printout listed 218 storage dams, I looked at 114 of these, and listd 96 of them in the survey tables. The 18 (114 minus 96) that were not in the table were basins I did not consider appropriate (flip buckets, flat concrete slabs, on rock foundations, etc.). Also, there is another example of incompleteness. When talking to Mike Colgate about this problem, he pulled a photograph from his files showing repair of Fontenelle Dam stilling basin. I did not find a record of this in the O&M file. Thus, the O&M files may have some gaps or I missed the material. I do not know how many stilling basins the

Bureau has. A 1967 map and list of Federal Reclamation Dams shows 232 storage dams. While I have not looked at that many records, I believe I have a good survey of Bureau experience, especially so since I have included the damaged stilling basins listed by Mr. Ed Rossillon.

DAMAGED STILLING BASINS

One purpose of the survey was that some common denominator type of information would appear and would be useful in directing us in our future research. Thus, I looked at the damaged stilling basins which have required repairs to cover the exposed rebars, appendix IV; I have categorized these basins not as type I, type II, etc., but as spillway or outlet works basins.

Note: S = Spillway
OW = Outlet Works
HHSG = High-head Slide Gate

Dam	Category of basin
Anderson Ranch	Combined S & OW
Pineview	Combined S & OW
Echo	Combined S & OW
Fontenelle	Similar to combined S & OW
Wickiup	Tube valve OW
Trinity	Hollow-jet OW
Navajo	Hollow-jet OW
Mason	HHSG OW
Wanship	HHSG OW
Tiber	HHSG OW
Merritt	HHSG OW
Causey	HHSG OW

None of these basins were for singular spillway use. The category of combined spillway and outlet works basins and hollow-jet valve basins was susceptible to abrasion damage, as pointed out previously in Arthur's and Jabara's paper. However, I believe one new bit of information appeared, the number of high head slide gate outlet works stilling basins that have been damaged. In bringing this to Tom Rhone's attention, he mentioned that this was the Bureau's "meat and potatoes" type basin. The Bureau has quite a few basins of this type, and many of those listed in the "Exposed Rebars" column of appendix IV are probably of this type. (When making the survey I did not categorize the HHSG OW basins, but did afterwards, and only for the repaired basins.) The HHSG OW basins can be considered somewhat similar to the hollow-jet valve stilling basin. Both have a concentrated jet of water entering a deep basin that may produce eddies with velocities sufficient to move large abrasive material. I feel this survey brings out the need for further hydraulic model research of HHSG OW stilling basins and close attention to tendencies for damage to be caused by abrasive material.

At the beginning of the survey I did not recognize a simple and obvious generality about abrasion damage. It is the high water velocity that can bang rocks the hardest against concrete and produce the most abrasion. The high entrance velocity stilling basins experienced the most severe damage, both in extent and short-time duration. Also combined basins (spillway with a slide entry outlet works) brought out the velocity-abrasion relationship. Combined basins with gated high-velocity flows could have more severe damage than basins where the velocity was slower and entered by a gravity flow channel. Thus, a rock entrained in high-velocity flow and "banging" against the concrete can be worse than a rock in low-velocity flow rolling around on the bottom of the concrete surface.

HYDRAULIC ACTION PULLING ABRASIVE DEBRIS INTO THE STILLING BASINS

One survey objective was to find flow situations where water brought abrasive debris from downstream of the stilling basin into the basin. The MP Region made field tests for the Trinity hollow-jet basin. They completely cleaned the basin, placed painted rocks downstream from the basin at different locations, operated the basin, and found some painted rocks in the basin afterwards. Also, I believe your model studies of the Navajo Dam basin confirmed the transport of material and retention of material in hollow-jet basins.

Combined spillways and outlet works basins can also possess this fault. The outlet works high-velocity jet can create a strong eddy with a backflow component to sweep material into the basin. Rye Patch Dam was a vivid example of this, and Canyon Ferry Dam.

The HHSG OW stilling basin is suspected of pulling debris into the basin. I use the word suspected because the survey did not convince me beyond a shadow of a doubt that this occurs. There were only a few instances in the literature I surveyed where hydraulic action was believed responsible for drawing abrasive material into the basin.

1. Tiber Dam outlet works. - "The riprap in the outlet channel appeared stable and in good condition. It could be possible that some of the smaller rocks were washed into the basin during the time of discharge which would be one source of the rocks in the hole." (Hole was an eroded hole in and below the concrete floor extending 1.2 m deep). Another quote "It was determined that the cause of the damage was due to tumbling rocks that were thrown into the basin by visitors or drawn into the basin from the riprap stilling pool by water action."

2. Stampede Dam outlet works. - In July 1971, the underwater diving team removed 23 kg of miscellaneous metal construction debris. Near the abrasion area the metal objects were shiny, with no rust, indicating they had been tumbled recently. Further downstream the metal objects were rusty with rust stains underneath on the floor, and had not been tumbled recently. Near the downstream end of the basin the divers carried some rock and metal pieces past the basin and dumped them in the riprap below the basins. In the divers report it was noted:

> "that the 2-1/2 inch deep erosion found in the outlet works basins following a single year of normal releases points up the tremendously erosive potential of only a very small amount of abrasive material. It also illustrates that despite all of the precautionary correspondence that has flowed from Denver over the years concerning the dangers of placing into operation new stilling basins that have not been adequately checked and cleaned, it still happens. We also feel it points up the value of underwater examinations."

The following year, July 1972, the divers again examined the basin and found 7 kg of material, some rocks and some metal, and from their report:

> "We are not sure how the material got into the basins between the two checks which were roughly one year apart. The outside training walls are well fenced and the area is not open to the general public. Fishermen and others can reach the area by foot but vehicular traffic for the public is not permitted closer than about 3/8 of a mile from the outlet works basins. There is a considerable amount of metal debris in the rocks below the basins and we wonder whether or not at certain fairly high discharges a hydraulic roller action pulls the material back into the basin. We think this situation should be checked again next year, and if more debris is found in the basin it would be a pretty good indication material is being pulled back into the basins. In that event, all small material likely to be impelled by a reverse roller should be cleaned from the area."

I still feel it was possible for the metal objects to be thrown into the stilling basin. People could pick this material from the riprap and throw it in, unless these metal objects were below the water surface and not obtainable. Also I did not recall any later diver reports addressing this problem.

There was another flow situation I came across. In Hydraulic Model Studies of Causey Dam Outlet Works - Weber Basin Project, Utah (Report No. HYD 496), a test was made with the right gate 100 percent open and the left gate closed. "Material was deposited on the downstream side of the dentated end sill and inside the left half of the basin." Wanship Dam Outlet Works operated under similar circumstances. Besides breaking two panels of the center wall considerable abrasion damage occurred. A large amount of debris was in the basin, some which appeared to be construction debris (cables, pipe, and angle iron). While it can be questioned whether hydraulic action or man brought material into the basin, there is still the possibility it entered by hydraulic action. Since that time efforts have been made to make the operating procedures more forceful to prevent single bay operation of that magnitude.

From my interpretation of the survey literature the preponderance of information suggested that abrasive material entered the HHSG OW basins by people, and not by hydraulic action. However, once in the basin the material was constantly circulated, banged on the basin floor, and would not flush out of the basin. I consider this to be a hydraulic deficiency of the basin. Hydraulic model studies should be made to investigate the "ball milling," flow conditions holding the abrasive debris in the basin, and hydraulic action pulling debris into these stilling basins.

PREVIOUS HYDRAULIC STUDIES

I looked at some previous Hydraulic Laboratory studies concerning outlet works stilling basins. Only one report dealt with the abrasion problems (Hyd-573, Hydraulic Model Studies of the Modified Outlet Works Stilling Basin, Navajo Dam, Colorado River Storage Project, New Mexico) and it was for a hollow-jet valve basin. However, my main concern was for high head slide gate outlet works basins (HHSG OW); therefore, I went back to Engineering Monograph No. 25. The HHSG OW basin is a type II basin. In looking at a graph of type II basin data (figure 1) I noticed that the existing basins were shorter than verification tests of the design curve. For a standard in making the verification tests the toe of the hydraulic jump was established at the chute toe, figure 2a. However, for the existing basins some of the chute length is used and possibly all of the hydraulic jump was not contained entirely within the basin, figure 2b. Earlier in my investigation I wondered if we had economized the length of the basin at the expense of the abrasion problem and pulling debris into the basin.

Next, I looked at the list of damaged HHSG OW basins that Ed Rossillon gave me and then if we had model studied any of these structures. We had, Tiber (Hyd-402), Causey (Hyd-496), and Ruedi (Hyd-534). While scour tests were made hydraulic action of pulling debris into the basin or the "ball milling" was not extensively studied and what was studied was for limited discharge and tailwater conditions.

Another hydraulic study, somewhat more generalized was done, Hyd-544, Progress Report VII - Research Study on Stilling Basins, Energy Dissipators, and Associated Appurtenances - Section 13, Stilling Basins for High Head Outlet Works with Slide-Gate Control (Preliminary Studies). While this was a preliminary study the results are somewhat different than Engineering Monograph No. 25 (compare figure 3 to figure 1). To me this suggests that there may be some question concerning the design of HHSG OW stilling basins. Also, conclusion No. 6 of the report gave me the impression more research needs to be done for these basins:

> "6. Future work should include (in addition to the proposals listed in the preceding paragraphs) determination of pressures on the training walls for both basin types, determination of optimum basin width, a study of the hydraulic characteristics of plunge basins with other than rectangular shapes, and refinement of the design curves for both basin types. Data presented in this report are preliminary. Final designs based on the data should be verified by hydraulic model studies of the particular installation being designed."

With the factors of the above paragraph, the fact that HHSG OW basins are susceptible to abrasion damage, and considering the number of these basins the Bureau has, I feel further model studies need to be made.

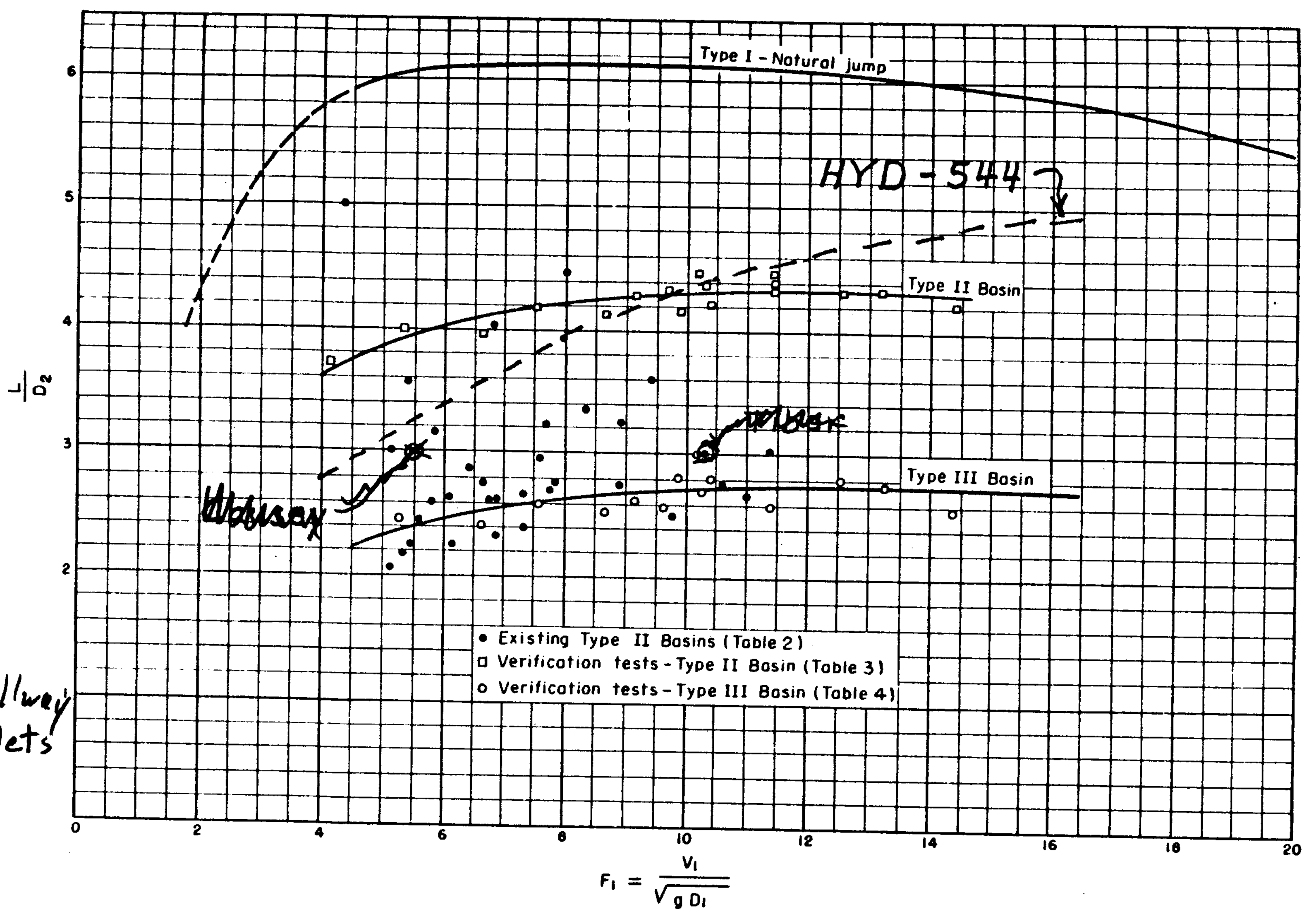


FIGURE 1 —*Length of jump on horizontal floor (Basins I, II, and III).*

Causey - Wrong F_1

Tiber - Spillway & not outlets works

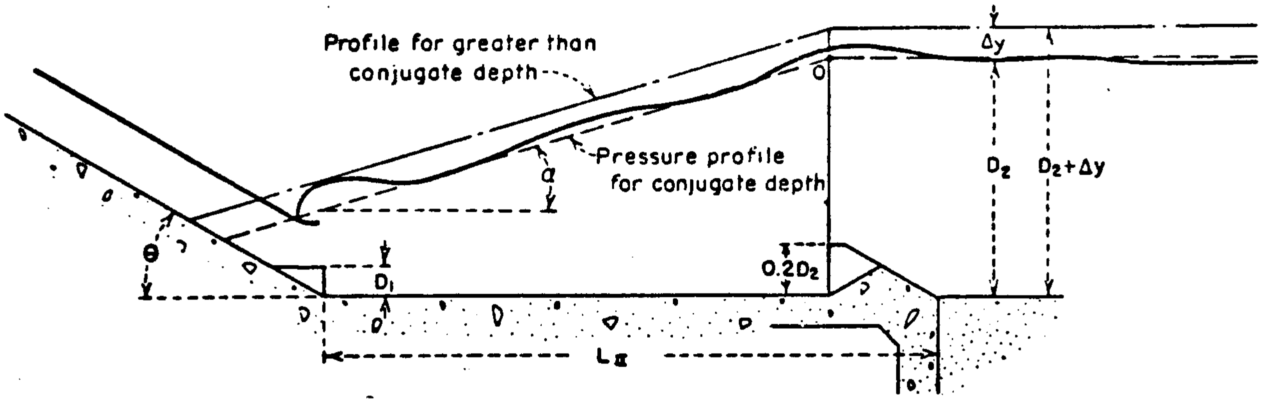


Figure 2a. Shape of jump for verification tests.

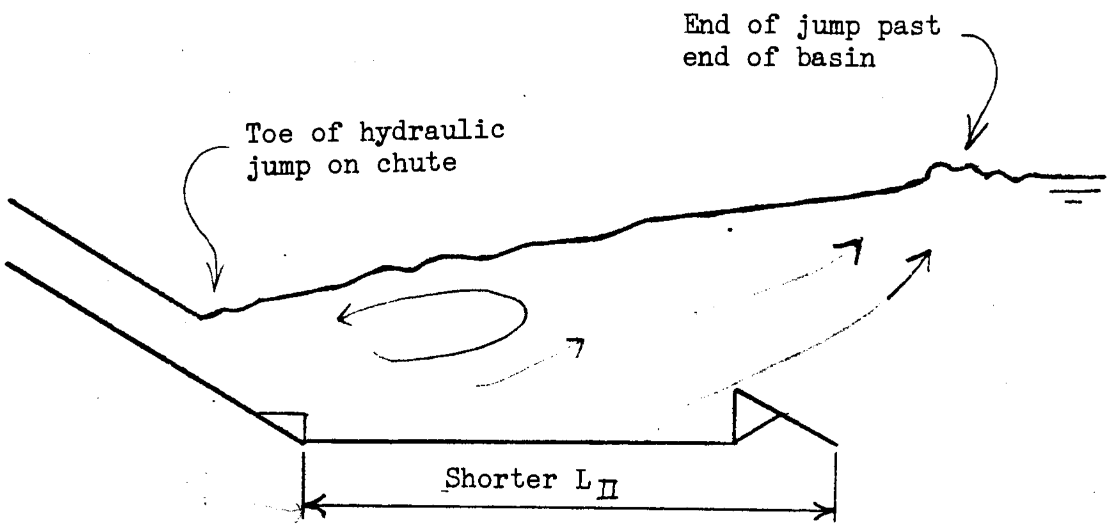


Figure 2b. Possible shape of jump for model tests of protype basin.

Figure 2. Difference in length of basin between verification tests and existing type II Basin data points as shown in Figure 1.

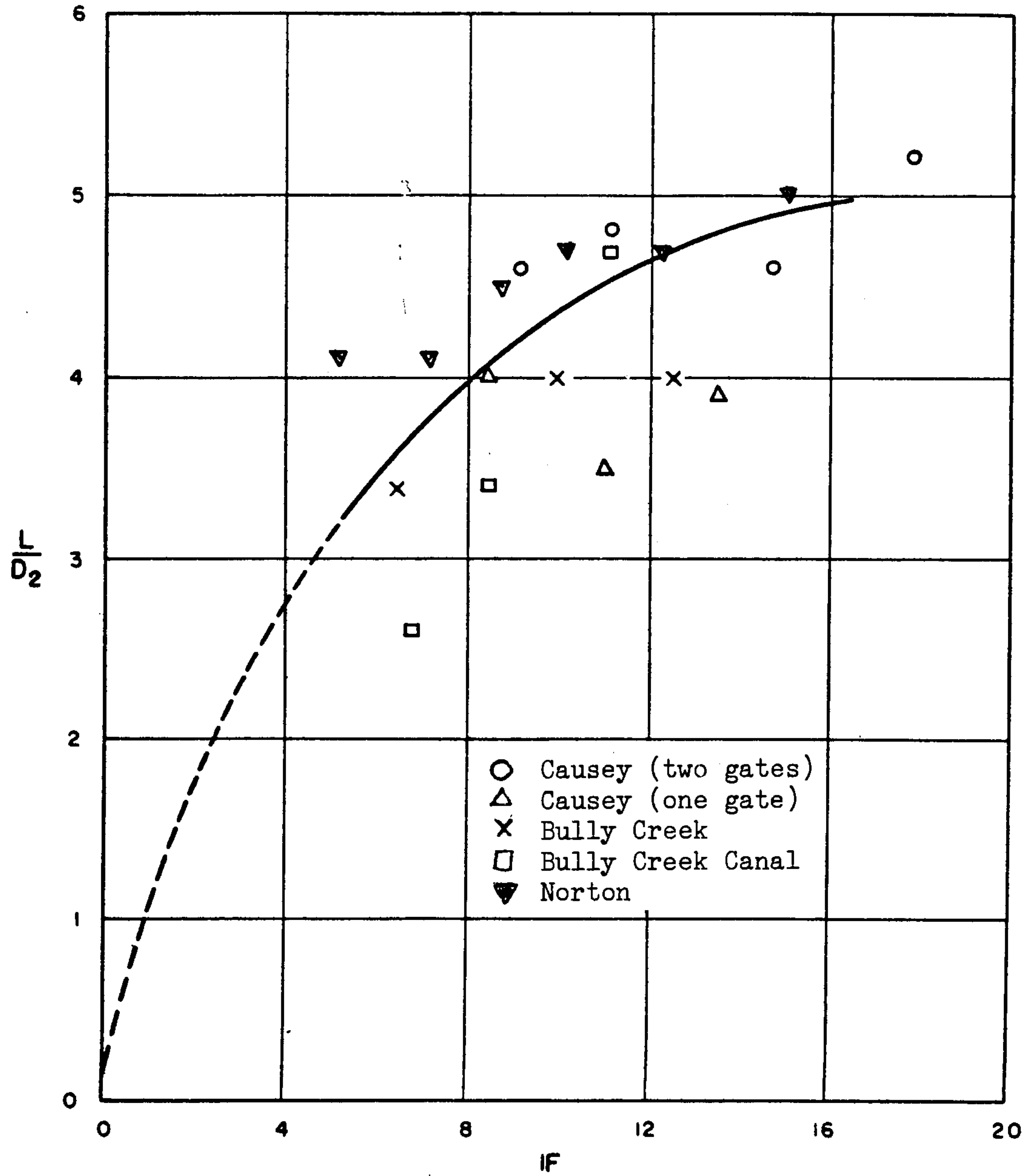


Figure 3. **SLIDE GATE STILLING BASIN STUDIES**

LENGTH OF HYDRAULIC JUMP--HYDRAULIC JUMP BASIN

FURTHER CONTACT WITH MR. ED ROSSILLON

After making the survey I met with Mr. Ed Rossillon for some questions and discussion. He was aware of the hollow-jet valve basin abrasion problems. I asked him if the Bureau has any future plans for using these type valves and basins; because if they do, we should do some model research studies. He did not foresee any use of the hollow-jet valves and said the trend has been toward high head slide gate valves. The slide gate valves are cheaper.

Next, I commented about the Tiber Dam outlet works and auxiliary outlet works basins. The outlet works basin had a greater flare of the chute sidewalls leading into the basin than most other basins. This basin experienced abrasion damage and there was an eroded hole near each side wall and near the end of the basin. I felt that flow separation of the entering jet could produce strong eddies at location of the eroded holes. If there were future basins with this much divergence in the entry walls, then they should be model tested. He said this was an old design where the valve jet was angled into the chute floor to help spread the jet. Presently, their basins have less diverging entry walls. I noticed that the newer Tiber Dam auxiliary outlet works basin was longer than the older basin and asked if the designers tended to make these basins longer than in the 1950 to 1960 era. He said yes they do.

Briefly, other points of our discussion were:

1. He was interested in a model testing a rock trap.

2. Some structural covering of basins has been done but not necessarily for the purpose of preventing people from throwing rocks in. There is a valid apprehension about covering the whole basin. I mentioned the possibility of placing a series of light-type polymer concrete covers on and which could be removed by a crane. We did not know if the cost was justified.

3. I mentioned in my survey about construction debris damaging basins and asked about post-construction cleanup. They require clean out and proof of cleanliness.

4. Do they provide help for dewatering the stilling basins in their design? Provision for stoplogs is nearly 100 percent for outlet works basins but spillway basins are generally too wide and, thus, no provision.

5. I asked about a stilling basin appurtenance used at Cheney Dam, a large deflector-type baffle located between the floor blocks and the dentated end sill. He said these deflectors were to maintain a tailwater elevation in the basin in the event serious erosion occurred in the downstream channel. Cheney, Foss, and Cutter Dams have these appurtenances, and I later found they were model tested for Foss Dam (Hyd-466).

In closing I asked him if he was satisfied with their present design information, or would he like to see some further research, and if so in what direction. Earlier I mentioned that the survey pointed out abrasion problems for HHSG OW basins, and these basins had a high velocity jet as did the hollow-jet valve basins. He replied:

1. That he wanted to talk with Mike Colgate about pulling the walls and chute floor away from the jet so as to prevent cavitation, but would this reduce effectiveness of the basin.

2. Whether the shorter basin turns out to be cheaper or if damageable, then more expensive than a longer basin, and

3. A big model (Navajo-Hyd-573) should be used instead of a small model for testing.

RESPONSE TO YOUR SEPTEMBER 19, 1977 MEMORANDUM

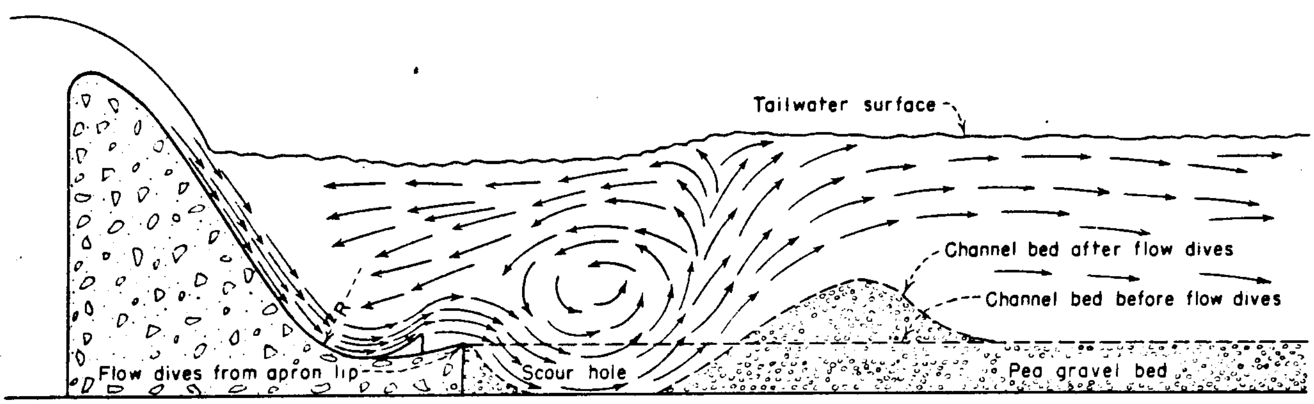
After I gave a Thursday morning seminar about my work concerning abrasive materials in stilling basins you sent me a memorandum with four comments. Following I will list each comment and my thoughts about the comment.

"1. You mentioned the fact that we often overlook the partial flows in our model studies. I agree, and have tried to make this point before. Perhaps model tests as part of your research could determine if there are certain ranges of percent of design flow in our standard basins which tend to pull material upstream."

Yes, hydraulic model tests need to be made for the full discharge range. The survey indicated damage occurred at low, medium, and maximum discharges. Also, the survey indicated that for low discharges the tailwater depth can be considerably higher than the conjugate hydraulic jump depth. I am still not convinced that the material is hydraulically pulled in, but once the material is in, it continually circulates and is not swept out. I feel that the scope of the above comment is too wide, and only one standard-type basin should be tested to begin with, i.e., the high head slide gate basin.

"2. Perhaps we need to examine the basic fluid mechanics of flow in stilling basins. From a theoretical point of view, can we identify combinations of Q, tailwater, etc., which cause adverse conditions?"

From a theoretical standpoint, I could not begin to identify adverse hydraulic conditions for a stilling basins. I have not worked that much with the theory, and even if I took more time I think it would be a dead end for me. However, I do have another thought which may have a theoretical aspect, and that is do we have a true hydraulic jump in these HHSG OW basins for many of their flow conditions? A hydraulic jump is a physical phenomenon of nature, fast supercritical flow changing to slower subcritical flow. Nature needs a given jump length for this intrinsic process to occur, and for a given inflow condition, the natural process works best with a downstream water depth ascribed the conjugate or sequent depth. Yet because of economy we alter the process, we force and constrain the jump to occur in a shorter length. Furthermore, because of field conditions beyond our control, I believe these basins seldom operate with the conjugate tailwater depth. Thus, we have a water pool that is agitated by a high velocity entrance jet and may be more similar to flow conditions of a slotted bucket energy dissipator, figure 4.



Note: The diving flow condition occurs with the slotted bucket only when the tailwater depth becomes too great.

FIGURE 4 —*Diving flow condition—slotted bucket.*

Possibly the above flow conditions are conducive to "ball milling" of abrasive debris, while a hydraulic jump has a better flushing process. This flushing process may be of a probability nature, whereby, there is churning of the debris but eventually it is caught in a downstream current and swept away from the jump.

I do think we need to examine the basic fluid mechanics of flow in stilling basins, but from the physical approach, and not the theoretical approach. Hydraulic model tests should be made, both in a cursory and detailed pragmatic manner. We need to ask ourselves some perceiving questions concerning the hydraulic jump and its likeness in HHSG OW basins. One such question which came to my mind was, does a hydraulic jump have a continuous "ball milling" action with rocks. Cursory model tests could be made in a type I basin (natural hydraulic jump). Sand, gravel, and rocks could be placed at different locations and their action observed. Maybe we could answer some questions about "ball milling" or "flushing" properties of the jump, where it occurs, and under what tailwater depths. Afterwards we may want to proceed with the more pragmatic tests of detailed depth, velocity, and location measurements to obtain better definition. Then if indeed the jump is capable of flushing, try to obtain this flushing in the HHSG OW basin, using cursory and, if necessary, pragmatic tests. What I am suggesting may at first glance appear a quicky-type program, but it is not, if one is to truly obtain some perception about "mechanics of flow in stilling basins." I believe the testing will be a long drawn out process. Much care and thought will be required to design knowledge-gaining test programs and then the persistence to overcome the normal setbacks while making the tests and analyzing the data.

> "3. Your consideration of basin placement with respect to side-slopes and other sources of loose material should be pursued, as well as the effects of outlets discharging into very large basins."

At the present time I am not sure what further work I could do to accomplish a solution of the above two problems. My intention for making a strong emphasis about basin placement was to show that the hydraulic design criteria was not at fault for pulling debris into the basins, but that there was another valid and documented reason why debris is in the basins. Also, I hope my strong emphasis did not inadvertently belittle the designers for placing spillway chutes and stilling basins at these bad locations. Because of firm foundation requirements these structures are placed away from the earth dams which can settle. Thus, I believe the designers are forced to use these poor locations. I suppose one desirable pursuit would be to furnish the designers a nonabradable or self-cleaning basin. Possibly the necessity of poor basin placement, accompanied by the ready entry of abrasive debris, could provide justification why the Hydraulics Branch should make model tests.

Concerning combined stilling basins, I do not propose any future research. Presently, Phil Burgi is doing research on one such basin, Canyon Ferry. I just wanted to reiterate that these can be abrasion problem basins. I believe the designers recognize this, and thus want to reinforce their wise policy of model testing (Perry Johnson's Navajo stilling basin tests). I feel there is a large combination of inflow conditions the designers might want to use. Thus, the study would be difficult to generalize, and more suited to individual model tests. Also, I believe the combined basin design is not as prevalent as the before 1950 era, and we should concentrate on more frequently used designs. (This was one question I was going to ask Ed Rossillon but forgot). However, there is one point I think needs consideration, and that is the adequacy of the hydraulic model for this type study. I plan to comment further about this in my slide presentation.

> "4. Our philosophy has been to minimize basin length. Is this wrong? What is the trade-off between the additional cost of a longer basin and the costs of repairing abrasion damage? Are there other basic changes in design philosophy which we should consider?"

My first thinking was that our basins were too short and debris was pulled in, and by making the basins longer abrasion damage could be stopped. I had hoped that repair costs would give information showing whether it was more economical to make repairs or to make the basin longer. I could not find very many records of the repair costs. After making the survey I found abrasion damage also occurred at the upper and middle areas of the basins, and I believed this damage occurred for discharges considerably below the maximum design discharge. Thus, it seemed damage could still occur even if the basins were longer, and thus, a longer basin (by itself) was not the answer. In addition, the survey indicated that debris in the basins did not readily flush out. It was trapped in the basin, continually circulated, and abraded the concrete. Again, for this situation a longer basin would not have solved the problem. Therefore, at the present time, I am not sure that our philosphy of a minimum basin length is wrong.

I do believe there is a change in design philospphy we should consider, and that is our basins should operate with a tailwater elevation nearer the conjugate depth. One such method to do this would be raising the basin floor elevation and having conjugate depth control piers in the basin. However, while this might allow a better flushing basin, it gives the designers a problem of the basin being undercut at the downstream end.

CONCLUSIONS

1. The underwater diving teams have performed an invaluable service for the Bureau. They initially alerted us to the abrasion damage problems, provided information for taking countermeasures to lessen the problem, helped gain additional information for coping with the abrasion problem, and made periodic inspections of abrasion damage and debris deposits in the basins.

2. The Bureau has experienced considerable abrasive material entering stilling basins. Most of the material is in the form of rocks with some steel construction debris, such as pipes, rebars, bolts, cable, angle iron, and other miscellaneous items.

3. Most abrasive material enters the basins either by people throwing it in or from basins and spillway chutes being near steep slopes, where material may slough into the basin.

4. Once the material is in the basins the Bureau relies upon reports of their diving teams whether the basin should be cleaned. If damage appears critical, the basin is cleaned and, if necessary, repaired. The tendency has appeared that the material is allowed to remain in spillway basins with infrequent use but can require cleaning from the frequently operated outlet works basins.

5. The survey showed combined spillway and outlet works basins, hollow-jet valve basins, and high head slide gate basins are susceptible to abrasion damage. Thus, these three general basins can be considered as having an abrasion weakness in their design. Earlier Bureau literature documented the first two designs, but to the best of my knowledge the high head slide gate basin has not been questioned as having an insufficiency in its design.

6. Hydraulic model tests should be made investigating abrasion damage characteristics of the high head slide gate outlet works stilling basin.

RECOMMENDATIONS

1. I, or someone else, should make some formal-type report about this research project and results of the survey. While I have spent considerable time and effort in making this survey it is not an "all inclusive" survey. Therefore, I believe the report should probably be somewhat generalized, or at least not give the reader an idea this was a complete survey of all Bureau basins. I have not shown photographs in this memorandum because I plan on giving a slide presentation. Afterwards, we can discuss and decide upon content of the report.

2. I strongly believe hydraulic model studies should be made for the high head slide gate stilling basin. After talking with Ed Rossillon and gaining his idea of using an air-slot and, thus, the possible change of entrance flow conditions into the basin, hydraulic model tests are warranted for adequate basin operation; especially so if this entrance is incorporated into a standardized Bureau design. Then when considering the past abrasion experience of this type basin there is further reason for model tests. These are my personal feelings; however, I have not had very much previous experience with stilling basins. (Only Palmetto Bend, and that was a low Froude number spillway stilling basin.) Therefore, people with more extensive experience should critically review my findings, conclusions, and recommendations. I recomend you, Tom Rhone, Mike Colgate, and Ed Rossillon meet and discuss the entrance flow conditions of an air-slotted high head slide gate stilling basin. Consider whether an air slot will change the entrance jet compared to that of previous hydraulic model studies and then come to a concensus whether or not new model studies are needed along this line. Next, decide whether or not abrasion tests should be made with the high head slide gate stilling basin.

3. The "Abrasive Materials in Stilling Basins" research project is at the point where it should be reviewed and reevaluated. I need some feedback whether my survey was adequate or if it is necessary to do more work. Also, future research work could progress along different lines. Thus, it is a very opportune time for management (you and the section heads) to determine priority of this research project concerning funding and manpower requirements. In the following section I will give some thoughts about future work for your consideration.

CONSIDERATIONS

1. Is the survey adequate for our purpose or is a more complete survey required? In using the computer printout as a guide I looked at slightly more than half the Bureau storage dams. After looking at these, I saw that if there were rocks near a stilling basin, and people could get there, then there would be rocks in the basin. Probably there are many more Bureau basins which have rock and my survey missed them. Another factor was size of the basin. You asked me about this some time ago. When starting the survey I came across so many different size and shape basins that I thought it would be too time consuming to sketch and dimension each basin. Also, I did not know how to make a meaningful and efficient categorization of the basins. Some I saw were in a category by themselves. Also in hindsighting I should have seen that the maximum design

discharge was a meaningful statistic. If it is decided a more complete survey is needed, and a good general categorization is decided upon, I could make the survey more efficiently than my past survey. Because in the past survey I did a lot of wheel spinning, especially for the first half of it. Also, I feel I have gained some familiarity with the O&M files and I was progressing faster near the latter part of the survey.

2. Make some abrasion tests with a basic hydraulic jump on a flat floor and no basin appurtenances. Test various Froude numbers with different tailwater depths and different size sand and gravel. Also, we may want to make a test with one consistent Froude number but varying the inflow conditions to investigate scaling characteristics of the different size sand and gravels. Afterwards the tests could progress to sectional model tests of spillway stilling basins.

3. If abrasion tests are made with a high head slide gate outlet works stilling basin, the tests should be made for the full range of discharge. Also, the influence of various tailwater elevations different from the conjugate depth for a given discharge needs to be tested. Some objectives of the model study should be to determine if the basin does hydraulically pull material in from the downstream end, gain some understanding of why the material is continually "ball milled" in the basin, and does not flush out. Probably the tailwater depth has a great influence upon flushing action of the basin. If the jump is submerged too much, the currents are conducive to "ball milling"; and maybe if the jump is at conjugate depth, or slightly lower, the downstream velocity components are great enough to sweep material away from the churning action of the jump. In mentally visualizing the hydraulic action of a hydraulic jump, some areas of the jump are more susceptible to churning than others. Also, it would appear there is some probability phenomenon of churning rock with respect to the rock's location in the jump. Thus, many visual observation model tests will need to be made in an effort to gain some understanding about "ball milling." One possible approach to the probability phenomenon is to make a large series of tests inserting different size rocks into the jump at different locations. The method would be to insert a given number of rocks, measure a time interval, and number of rocks flushed away. That is a lot of testing but may provide some measure to make judgments about the various flow conditions the Bureau stilling basins experience and point to us a way for less abrasion damage.

4. If hydraulic model tests showed a lower tailwater depth was essential for good flushing action, further model tests could be made with conjugate depth control piers (Hyd-466). These are deflectors placed upstream from the end sill for the purpose of holding an adequate water depth in the basin to prevent "sweepout." These appurtenances are somewhat analogous to a canal check structure; they are shaped to provide a range of given water depths over the range of structure discharges. The Bureau has built three basins with these appurtenances. The basin floor elevations were located at low elevations for safe tailwater conditions and the appurtenances were a safety factor in the event serious erosion occurred in the downstream channel during a large flood. My proposal is to raise the basin floor and use the appurtenances as a primary water depth control. This proposal has one very serious drawback in that it exposes the basin structure to erosion problems, and it may be economically unfeasible to overcome these erosion problems. We would have to check with Spillways and Outlets and get their concurrence before proceeding with this test program.

5. If these model studies do get underway there may be an excellent opportunity to use them as an educational aid. One of the Hydraulic Laboratory's strong points is the designers can see their ideas in action and therefore make judgments much better than computations on paper. Yet I question whether our strong point is used to its fullest advantage. In the past (1960 to 1975 era) it has appeared to me that mainly the "higher-ups" come over to view model operation. Occasionally they bring their rotation engineers to see the model and give them some instruction. The past few years many of the "higher-ups" have retired and I have wondered if a lot of Bureau expertise has not just walked out the front door. Thus, what I am suggesting is the designers use the models as a training aid. This may be more appropriate with a generalized model study. Can they use the models to show axioms of good and bad design features, can design practice described in the literature be effectively shown, and are there earlier design experiences that were somewhat a painful learning process which can be shown so we will not make the same mistakes again? In some part of the model testing program the designers could formulate an operation sequence for us to follow. We could organize ourselves to efficiently establish the desired flow conditions in the model while they gave a training lecture to their lesser experienced engineers. Maybe this is somewhat along the concept of the color slide seminars we gave in building 67, but in a reciprocal sense - they lecture in our building. You may wish to explore this consideration with Ed Rossillon.

6. These are some thoughts which I will give briefly. All of these considerations are ones that apply more toward a wider than Branch level approach to abrasive materials in stilling basins. If any of these ideas have merit you would need to discuss them further with the appropriate Bureau organization.

a. A brief writeup giving nomenclature of the stilling basin appurtenances. In some diving reports I read about upstream and downstream dentates, and in an operation report they used sharks teeth. This nomenclature information may be useful to some of the divers, region operation people who make unwatered inspections, and would give them the proper names for the different basin appurtenances.

b. Maybe a writeup could be made of the survey along with selected photographs bringing the debris problem to the Bureau's attention. This writeup could take different directions:

(1) Operations people would want to show the users why the concern of rocks in the basins,

(2) A gentle prod to the Bureau to review the problem, review their policy toward the problem, and see if this policy could be updated and improved upon,

(3) An emphasis for promoting users to clean abrasive debris from the stilling basins, and

(4) Promoting the underwater diving examinations.

c. The abrasive materials in stilling basin problem may be a fertile subject for formation of a team.

d. I had wondered if all the members of the different diving teams have had a joint meeting. The intent would be for the members to discuss how they make their inspections and reports, and give them the opportunity for sharing their experience. Possibly this would help them in performing their future work. (After my first rough draft, I found out that interregion meetings have been held. Thus, for the present, I suppose item d can be disregarded.)

e. How does this abrasive materials in stilling basin problem relate to the Commissioner's upgraded "Safety of Dams Program." Maybe now is the time where the Bureau would have more funds to look into this problem, and do it in an extended time range.

These are ideas which I thought the Bureau organizatiuon may want to look into. As you can see, these ideas are a much wider scope than my previous experience level with the Bureau's field stilling basins. Maybe these ideas have already been implemented and I do not know about it. Therefore I have stated them only as considerations for you. I feel you should discuss them further with me so you can make a better judgment about them and how far you wish to pursue them. I can visualize where a certain sensitivity would be needed on your part in effectively proposing many of these ideas to wider Bureau management. You would need to explore these thoughts with the other appropriate Bureau organizational units and develop a consensus upon implementing any of the ideas.

Eugene Zeigler

Enclosure
Appendices I, II, III, IV, and V

Copy to: 1530
1532 (Zeigler)

EZeigler:cdb/V5

600195

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APPENDIX Ia

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TITLE Stilling Basins, Effect of abrasive materials on

NUMBER OF CITATIONS 27

DATE SEARCH WAS PERFORMED March 1977

DATA BASES SEARCHED WRSIC (1)

LRS: NTIS (13)

COMPENDEX (8)

SDC: SSIE (5)

Jane Boan made the search for me.

Culvert Outlet Protection Design: Computer Program Documentation

Wyoming State Highway Dept., Cheyenne.*Federal Highway Administration, Washington, D.C.

Final rept.
Schilling, M. G.
C5095D1   Fld: 13B, 13C, 09B, 50*   GRAI7520
Mar 75   247p*
Contract: DOT-FH-11-7936
Monitor: FHWA-RD-75-508
Supersedes report dated Jan 74, PB-232 795.

Abstract: This computer program is capable of estimating the scour extent at culvert outlets and designing both rigid and rock riprapped stilling basins. It provides protection for the local scour problem only and not the gully scour situation. The types of erosion protection available include U.S. Army Waterways Experiment Station Estimate of Scour Extent, U.S. Army Waterways Experiment Station Rock Riprapped Basins, Colorado State University Rock Riprapped Basins, Vertical Stilling Well, St. Anthony Falls Stilling Basin, U.S. Bureau of Reclamation Type VI Basin, U.S. Bureau of Reclamation Type I Basin, U.S. Bureau of Reclamation Type II Basin, U.S. Bureau of Reclamation Type III Basin, U.S. Bureau of Reclamation Type IV Basin, and Colorado State University Smooth-Floor Flared Basin. The computer program was developed in a modular framework to facilitate the addition of new design methods that may be implemented in the future.

Descriptors: *Culverts, *Scouring, *Computer programs, Water erosion, Riprap, Check structures, Stilling basins, Hydraulic jump, Highway planning, Computer aided design, FORTRAN

Identifiers: DOT/4CZ/CG, DOT/4CZ/CA, HYDCEP computer program, NTISDOTFHA

PB-242 730/0ST   NTIS Prices: PC$7.50/MF$2.25

Spillway for Little Goose Dam, Snake River, Washington, Hydraulic Model Investigation

Army Engineer Div North Pacific Bonneville Oreg Div Hydraulic Lab*Army Engineer District, Walla Walla, Wash. (408953)

Final rept. Jan 63-Jun 65
Johnson, Richard L., Perkins, Louis Z.
C4762J1   Fld: 13B, 50B   GRAI7515
Apr 75   120p

Abstract: The spillway for Little Goose Dam, designed to pass discharges up to 850,000 cfs (2125 cfs per ft of crest), was studied in a 1:42.47-scale, 3-bay, sectional model and a 1:100-scale general model to investigate the performance of various elements of the structure and to determine flow conditions in the tailrace. Maximum velocities that fluctuated between 5 and 12 fps along the north embankment upstream from the spillway were indicated by the spillway model. Tests indicated that the stilling basin of original design was not satisfactory. An acceptable stilling basin was developed in the model, but unusual artesian flow at the site would have required a costly drainage system to protect the basin slab against uplift. Sixteen roller bucket plans were investigated in efforts to eliminate the basin slab and drainage system. A modified Angostura-type bucket, with simpler teeth and shorter apron, was adopted.

Descriptors: *Dams, *Hydraulic models, Channel flow, Waterways, Flow rate, Erosion, Baffles, Washington(State)

Identifiers: *Spillways, *Stilling basins, *Check structures, *Little Goose Dam, Snake River, NTISDODA

AD-A010 347/3ST   NTIS Prices: PC$5.75/MF$2.25

(3)

Revised Stilling Basin, Bonneville Dam, Columbia River, Oregon and Washington: Hydraulic Model Investigation

Army Engineer Div North Pacific Bonneville Oreg Div of Hydraulic Lab (408953)
C3841E4 Fld: 13B GRAI7501
Jul 58 107p
Rept No: TR-65-1
Monitor: 18

Abstract: When it was designed and constructed, the spillway for Bonneville Dam was unprecedented insofar as the magnitude of flow was concerned; the adopted plan was based on results of more than 170 experiments in a hydraulic model. As an additional measure of safety, an 80-ft-wide apron of reinforced concrete was placed downstream from the stilling basin in order to protect the structure from the effects of undercutting in the erosible foundation material. Eight baffles were reconstructed to a shape recommended after tests made in 1941-1942 in a 1:48-scale model at the Carnegie Institute of Technology, Pittsburgh, Pennsylvania. The Carnegie studies also indicated that even the original baffle piers would be relatively cavitation free if small gate openings were used and if the spillway flow were distributed among as many gates as possible.

Descriptors: *Dams, *Hydraulic models, Rivers, Water flow, Piers, Water erosion, Washington(State), Oregon

Identifiers: Bonneville Dam, Columbia River, Stilling basins, Spillways, NTISDODA

AD/A-000 321/0ST NTIS Prices: PC$5.25/MF$2.25

Culvert Outlet Protection Design: Source Program, Sample Date, and Sample Output

Wyoming State Highway Dept., Cheyenne.
Schilling, M. G.
C3203A2 Fld: 13B, 13C, 9B, 50, 62B GRAI7418
Jan 74 1 reel mag tape*
Contract: FH-11-7936
Monitor: FHWA-RD-74-501-Tape
For documentation, see PB-232 795.
Specify tape recording mode desired: 7 track, 556 and 800 BPI, odd and even parity, BCD; or 9 track, 800 BPI, odd parity, EBCDIC.

Abstract: This computer program is capable of estimating the scour extent at culvert outlets and designing both rigid and rock riprapped stilling basins. It provides protection for the implemented in the future. This is a FORTRAN 4 program written for implementation on an IBM s/370 with the Disk Operating System (D O S). The minimum core requirement is 92k bytes.

Descriptors: *Culverts, *Scouring, *Computer programs, Erosion, Riprap, Highway planning, Check structures, Stilling basins, Water erosion, Magnetic tapes, Computer aided design

Identifiers: FORTRAN 4 programming language, IBM 370 computers, NTISFHAPR

PB-232 796/3 NTIS Prices: Mag Tape $97.50;Foreign $122.50

(4)

Culvert Outlet Protection Design: Computer Program Documentation

Wyoming State Highway Dept., Cheyenne.

Final rept.
Shilling, M. G.
C3203A1 Fld: 13B, 13C, 9B, 50*, 62B GRAI7418
Jan 74 255p*
Contract: FH-11-7936
Monitor: FHWA-RD-74-501
See also Magnetic Tape PB-232 796.

Abstract: This computer program is capable of estimating the scour extent at culvert outlets and designing both rigid and rock riprapped stilling basins. It provides protection for the local scour problem only and not the gully scour situation. The types of erosion protection available include U.S. Army Waterways Experiment Station Estimate of Scour Extent, U.S. Army Waterways Experiment Station Rock Riprapped Basins, Colorado State University Rock Riprapped Basins, Vertical Stilling Well, St. Anthony Falls Stilling Basin, U.S. Bureau of Reclamation Type 6 Basin, U.S. Bureau of Reclamation Type 1 Basin, U.S. Bureau of Reclamation Type 2 Basin, U.S. Bureau of Reclamation Type 3 Basin, U.S. Bureau of Reclamation Type 4 Basin, and Colorado State University Smooth-Floor Flared Basin. The computer program was developed in a modular framework to facilitate the addition of new design methods that may be implemented in the future.

Descriptors: *Culverts, *Scouring, *Computer programs, Erosion, Riprap, Highway planning, Check structures, Stilling basins, Water erosion, Computer aided design, FORTRAN

Identifiers: FORTRAN 4 programming language, IBM 370 computers, NTISFHAPR

PB-232 795/5 NTIS Prices: PC$6.50/MF$1.45

(5)

A Laboratory Development of Cavitation-Free Baffle Piers Bluestone Dam, New River, West Virginia

Army Engineer Waterways Experiment Station Vicksburg Miss (038100)
C0613K2 Fld: 13B GRAI7309
Mar 48 96p
Rept No: AEWES-TM-2-243
Monitor: 18

Abstract: Model studies of the stilling basin for Bluestone Dam, New River, West Virginia, were conducted at the Waterways Experiment Station in 1941-42 for the Huntington District, CE. The general purpose of the studies was to investigate the possibility and probable extent of destructive cavitation action on the Bluestone stilling-basin elements of original design, with the spillway in operation. It was also desired, if possible, to develop means of correcting any unsafe or [illegible]able conditions found to exist in the stilling basin as [illegible]

[illegible], *Hydraulic models), Model tests, Turbulence, [illegible], West Virginia

Identifiers: New River, Spillways, *Stilling basins, A

AD-757 408 NTIS Prices: PC$3.00/MF$0.95

(6)

Practical Guidance for Estimating and Controlling Erosion at Culvert Outlets

Army Engineer Waterways Experiment Station Vicksburg Miss (038100)

Final rept.
Fletcher, B. P., Grace, J. L. Jr
A4613A1 Fld: 13B, 60B GRAI7215
May 72 45p*
Rept No: AEWES-Misc Paper-H-72-5
Presented at the Mississippi Water Resources Conference held in Jackson, Miss., on 11-12 Apr 72.

Abstract: The paper summarizes the results of research conducted at the U. S. Army Engineer Waterways Experiment Station during the past nine years to develop practical guidance for estimating and controlling erosion downstream of culvert and storm-drain outlets. Initial efforts were concerned with investigation and development of means of estimating the extent of scour to be anticipated downstream of outlets. Subsequent efforts have involved investigation and evaluation of various schemes of protection for controlling erosion such as horizontal blankets of rock riprap, preformed scour holes lined with rock riprap and channel expansions lined with natural and artificial revetments. (Author)

Descriptors: (*Floods, Erosion), Mathematical ..ediction, Protection, Sanitary engineering, Inland waterways, Stability, Damage, Soils, Rock(Geology), Drainage

Identifiers: *Culverts, *Storm sewers, Riprap, Stilling basins, Soil erosion

AD-743 461 NTIS Prices: PC$3.00/MF$0.95

(7)

Hydraulic Model Studies of the Pueblo Dam Spillway and Plunge Basin

Bureau of Reclamation, Denver, Colo. Engineering and Research Center.
Isbester, T. J.
A3422J4 Fld: 13B, 60B GRAI7203
Jun 71 21p
Rept No: REC-ERC-71-18

Abstract: Studies were performed on a 1:56 scale hydraulic model of Pueblo Dam spillway and plunge basin (stilling basin) to determine if the unusual design could handle the required releases safely. The model contained the flip-type spillway, plunge basin, river outlets, and a section of downstream river channel. Channel erosion, basin impact pressures, nappe oscillations, crest rating, and flow profile studies were made on the model. Flow splitters were added to the spillway to eliminate nappe oscillations. The plunge basin initially containing 2 floor elevations was enlarged to the level of the deeper section to minimize impact pressures. A technique of data collection was used in obtaining impact pressures which provided an electronic statistical analysis. A curve was obtained to relate basin floor effective pressure head to spillway discharge for the normal river tailwater conditions. (Author)

Descriptors: (*Spillways, *Hydraulic models), (*Dams, Colorado), Rivers, Channel improvements, Channel stabilization, Impact, Statistical analysis, Model tests, Design, Stream erosion, Stilling basins

Identifiers: Pueblo Dam, Arkansas River

PB-204 882 NTIS Prices: PC$3.00/MF$0.95

8) Drop Structure for Gering Valley Project, Scottsbluff County, Nebraska; Hydraulic Model Investigation

Army Engineer Waterways Experiment Station Vicksburg Miss (038100)

Final rept.
Murphy, Thomas E.
A2034G3 Fld: 13B, 8H, 60B GRAI7111
Feb 67 44p
Rept No: AEWES-TR-2-760

Abstract: Tests were conducted on a 1:12-scale model of a rectangular drop structure designed to stabilize channel beds and minimize bank erosion in the Gering Valley drainage system. The majority of the tests were conducted on a 33-ft-wide structure with a drop height of 5 ft. Discharges up to a maximum of 6000 cfs were observed. Verification of generalized data was accomplished by tests on a structure with a 10-ft drop height. Of primary concern were development of the optimum dimensions for the various elements of the structure and determination of riprap requirements in the vicinity of the structure. (Author)

Descriptors: (*Inland waterways, *Hydraulic models), Hydrology, Erosion, Drainage, Fluid flow, Model tests, Photographs, Nebraska, Rivers

Identifiers: *Drop structures, Riprap, Gering Valley project, Erosion control, Stilling basins

AD-722 226 NTIS Prices: PC$3.00 MF$0.95

9) Spillway Modifications, Miraflores Dam, Panama Canal Zone; Hydraulic Model Investigation

Army Engineer Waterways Experiment Station Vicksburg Miss (038100)
Murphy, T. E., Cummins, R. S. Jr
A1705C1 Fld: 13B, 60B GRAI7107
Jan 65 41p
Rept No: AEWES-TR-2-667

Abstract: Miraflores Dam spillway is a gravity ogee section designed for a maxiumum head on the crest of 18 ft. The spillway is composed of eight 45-ft-wide bays with veritical-lift gates. The spillway crest is at elevation 38.67 and the downstream face of the spillway is terminated by a 38-ft radius which brings the toe tangent to a horizontal plane at elevation -15. No stilling basin is provided. Since the spillway was put in operation in 1917 a maximum flow of 25,290 cfs has been experienced. This flow is about one-fourth of the spillway design flood. Erosion of the rock downstream from the toe of the spillway has progressed until the dam is in danger of partial failure. Model investigations on a 1:36-scale general model and 1:20- and 1:50-scale section models were made to determine the suitability of various schemes for protection against further erosion and for development of design details of the selected scheme. Results indicated that adequate protection would be provided by addition of a stilling basin consisting of a 40-ft-long apron terminated by a 3-ft-high dentated end still. (Author)

Descriptors: (*Dams, *Hydraulic models), Design, Model tests, Erosion, Panama, Construction materials, Mechanical drawings, Fluid flow

Identifiers: *Spillways, *Miraflores dam, Stilling basins

AD-718 801 NTIS Prices: PC$3.00 MF$0.95

10) EROSION PROTECTION FOR THE OUTLET OF SMALL AND MEDIUM CULVERTS

South Dakota State Univ., Brookings.
Chang, Fred M., Karim, Mansour
A0144G3 Fld: 13B, 903 USGRDR7011
Feb 70 62p*
Prepared in cooperation with Bureau of Public Roads, Washington, D.C., and South Dakota Dept. of Highways.

Abstract: The study is conducted as a pilot study to investigate and evaluate the feasibility of an erosion control work for the outlet of small and medium culverts. The proposed control work consists of a recessed stilling basin armored with gravel and a transverse impact wall. The primary objectives of the investigation were to find the dimensions of the stilling basin and a proper location of the impact wall for the design flow discharge for two tail water conditions: namely low tailwater condition simulating a discharge onto an open ground and high tailwater condition simulating a discharge into a receiving channel. Two things were of main concern: (1) no further deterioration of the basin that may initiate erosion on highway grade and finally it brings total failure, and (2) minimization of scour below the impact wall. (Author)

Descriptors: (*Roads, Drainage), (*Erosion, Control systems), Feasibility studies, Gravel, Walls, Model tests, Fluid flow, Design

Identifiers: Culverts, Scour, Stilling basins

PB-190 565 CFSTI Prices: HC$6.00 MF$0.95

11

DESIGN CRITERIA FOR CONTROLLED SCOUR AND ENERGY DISSIPATION AT CULVERT OUTLETS USING ROCK AND A SILL

South Dakota School of Mines and Technology, Rapid City. (327 250)
Thorson, Donald A., Shirole, Arunprakash M.
A0144G2 Fld: 13B, 903 USGRDR7011
1969 71p*
Prepared in cooperation with Bureau of Public Roads, Washington, D.C., and the South Dakota Dept. of Highways.

Abstract: The study establishes the criteria for the effective design of rock-basin energy dissipators for flow from culverts without or with a transverse sill. Design-tables have been prepared on the basis of laboratory studies with culvert models. Models of standard end flares were used to simulate the culvert outlet conditions. Stable rock sizes and basin geometry can be determined using the design-tables developed in the study. The design-tables are applicable for angular rock as well as rounded rock. Worked examples use the tables for design of rock basins for no-scour situations and controlled depths of scour. (Author)

Descriptors: (*Roads, Drainage), (*Erosion, Control systems), Rock(Geology), Kinetic energy, Orifices, Jets, Model tests, Velocity, Design, Standards, South Dakota

Identifiers: Scouring, Culverts, Sills, Riprap, Energy dissipation, Stilling basins

PB-190 564 CFSTI Prices: HC$6.00 MF$0.95

12

RESEARCH STUDY ON STILLING BASINS, ENERGY DISIPATORS, AND ASSOCIATED APPURTENANCES--SECTION 14, MODIFICATION OF SECTION 6 (STILLING BASIN FOR PIPE OR OPEN CHANNEL OUTLETS--BASIN VI)

Bureau of Reclamation, Denver, Colo. Hydraulics Branch. (068 912)

Progress rept. no. 13
Beichley, G. L.
648461 Fld: 13B, 903 USGRDR6919
Jun 69 39p
Rept No: HYD-572
See also Progress rept. no. 7, AD-466 568.

Abstract: Model studies on 1.6- and 2.4-ft-wide (48.76 and 73.15 cm) Type VI stilling basins were conducted to modify existing standard design procedures. Investigations were concerned with: basin entrance flow conditions including type of entrance, slope, velocity, and Froude number; basin dimensions in relation to the basin width; basin width in relation to Froude number; and riprap size and location. Performance was evaluated in terms of energy dissipation and prototype operation. An optimum tailwater, an alternate end sill design, methods of preventing clogging of the basin, and means for automatic removal of sediment from the basin were suggested. (Author)

Descriptors: (*Hydraulic accumulators, Design), Dams, Ducts, Hydraulic models, Model tests, Erosion

Identifiers: *Stilling basins, *Riprap

PB-185 115 CFSTI Prices: HC$6.00 MF$0.95

13 ID NO.- EI721001638 279637
ANALYSIS OF RIGID OUTFALL BASINS WITH HIGH TAILWATER.
Watts, Frederick J.; Simons, Daryl B.; Stevens, Michael A.
Univ of Idaho, Moscow
DESCRIPTORS- *STILLING BASINS, (HYDRAULIC STRUCTURES, Energy Dissipators), (FLOW OF WATER, Jets), CULVERTS,
IDENTIFIERS- TAILWATER
CARD ALERT- 406, 441, 631, 632
CODEN- HIRRAX SOURCE- Highw Res Rec n 373, 1971 p 11-23
Diffusion characteristics of jets from circular pipes discharging into basins lined with stones were measured under conditions of tailwater either slightly above or slightly below the crown of the pipes. These data together with data from a previous study on culvert outlet protection and with data from orifice jet diffusion studies are incorporated into a method for designing stable energy-dissipating basins at culvert outlets where high tailwater exists. 7 refs.

14 ID NO.- EI71X039904 139904
Flood- control facilities for unique flood problems
WONG RF; ROBLES JR A
DESCRIPTORS- *FLOOD CONTROL, LEVEES, RIVERS, (FLOW OF WATER, Open Channels), (BRIDGE PIERS, Scour), STILLING BASINS,
CARD ALERT- 401, 407, 441, 442, 444, 631
SOURCE- ASCE J Waterways H9gbors Div v 97 n WW1 fFeb 1971 paper 7894 p 185-203
The unusual climatic, hydrologic, topographic and physiographic conditions in southern California are discussed. The unusual conditions include extreme concentration of seasonal rainfall and runoff, short- duration and high- peak storms, steep topographic gradients, and combination of physiographic and cultural characteristics. Facilities include debris basins, concrete- paved channels, leveed earth channels with and without grade- control structures, and continuous single levees.

15)

ID NO.- EI76637344 637344
DAM FIGHTS EROSION WITH PLASTIC COAT OF ARMOR.
Anon
DESCRIPTORS- (*DAMS, GRAVITY, *Slope Protection), (SOILS, Erosion), (CONCRETE CONSTRUCTION, Plastics Applications), STILLING BASINS,
CARD ALERT- 405, 441, 483, 817
CODEN- ENREAU SOURCE- Eng News Rec v 196 n 11 Mar 11 1976 p 18-19
It is reported how polymer-impregnated concrete lines an outlet tunnel and part of the stilling basin floor at Dworshak dam in Idaho, providing protection against erosion and cavitation experienced during the first few years of operating the 717-ft-high gravity structure. Its voids plugged with plastic, the concrete has a compressive strength four to five times that of untreated concrete.

16)

ID NO.- EI740638313 438313
BETRACHTUNGEN ZUR KOLKSICHERUNG VON WEHRANLAGEN. $left bracket$ Considerations on Protection of Weirs Against Scouring $right bracket$.
Juniewicz, Stanislaw
Tech Hochsch, Wroclaw, Pol
DESCRIPTORS- (*WEIRS, *Erosion), (STILLING BASINS, Erosion), (HYDRAULIC STRUCTURES, Erosion),
CARD ALERT- 441, 632, 641
CODEN- WZTDAU SOURCE- Wiss Z Tech Univ Dresden v 22 n 5 1973 p 907-911
In a natural river bed there always exists an equilibrium between the constantly changing capacity of the river and the resistance forces of the river bed. Construction of weirs disturbs this equilibrium, resulting in scouring after the structures. Despite many contributions on this subject, the problem is still not entirely clear. In this paper, the problem is considered from a new point of view. Starting from an analysis of the behavior of an interacting falling stream, and following experimental investigations, a stilling basin end sill is proposed which deviates from the usual shape. Further, in order to minimize erosion under the stilling basin, it is recommended to provide the stilling basin end sill with tear-shaped concrete blocks. In German.

17)

ID NO.- EI730628248 328248
VOPROSY ISSLEDOVANIYA KAVITATSIONNOI EROZII GASITELEI ENERGII I RASSHCHEPITELEI POTOKA. $left bracket$ Problems Associated with the Investigation of Cavitational Erosion of Energy Dissipators and Flow Separators $right bracket$.
Rozanov, N. P.; Kaveshnikov, A. T.
DESCRIPTORS- (*DAMS, *Energy Dissipators), STILLING BASINS, (HYDRAULIC STRUCTURES, Cavitation), CAVITATION, EROSION,
CARD ALERT- 441, 632, 641
CODEN- GTSTA8 SOURCE- Gidrotekh Stroit n 1 Jan 1973 p 29-32
10 refs. In Russian.

(18)

ID NO.- EI721212824 290823
PRACTICAL GUIDANCE FOR ESTIMATING AND CONTROLLING EROSION AT CULVERT OUTLETS.
Fletcher, B. P.; Grace, J. L. Jr.
U S Army Engineer Waterways Experiment Station, Vicksburg, Miss
DESCRIPTORS- *CULVERTS, EROSION, STILLING BASINS,
IDENTIFIERS- SCOUR
CARD ALERT- 406, 641
SOURCE- U S Army Eng Waterw Exp Stn, Misc Pap H-72-5 May 1972, 43 p
Efforts were concerned with investigation and development of means of estimating the extent of scour to be anticipated downstream of outlets. Investigation and evaluation of various schemes of protection for controlling erosion such as horizontal blankets of rock riprap, preformed scour holes lined with rock riprap and channel expansions lined with natural and artificial revetments. 6 refs.

(19)

ID NO.- EI72X033810 233810
Cavitation in high- head conduit control dissipators
RIPKEN JF; HAYAKAWA N
Univ of Minnesota, Minneapolis
DESCRIPTORS- (*HYDRAULIC MACHINERY, *Cavitation), (DAMS, Energy Dissipators), HYDRAULICS, STILLING BASINS,
CARD ALERT- 441, 631, 632
CODEN- JYCEA SOURCE- ASCE J Hydraul Div v 98 n HY1 Jan 1972 paper 8678 p 239-56
Hydraulic design criteria for a valve- orifice- chamber type of control dissipator are reviewed with regard to the influence that cavitation has on flow capacity, vibration, noise, and erosion. Orifices modified with peripheral devices to break up the continuity of the troublesome vortex rings showed substantial performance benefits when tested. 14 refs.

ID NO.- EI70X148356 048356
Sill- controlled flow transitions and extent of erosion
RAND W
City Univ of New York, NY
DESCRIPTORS- (*FLOW OF WATER, *Open Channels), (SOILS, Erosion), (RIVERS, Sedimentation), HYDRAULICS, HYDRAULIC JUMP,
CARD ALERT- 407, 483, 631, 632
SOURCE- ASCE J Hydraul Div v 96 n HY4 Apr 1970 paper 7212 p 927-39
The distance is determined over which scour will develop downstream of a sill- controlled flow transition in an erodible open channel, in which the sediment motion is impending. Determination is based on the concept of dynamic similarity that makes it possible to relate the erosion length in an erodible channel to the total length of flow transition in a fixed- bed channel. Prediction of the limiting extend of erosion becomes possible for a wide variety of sill- controlled flow transitions, including the cases present in the hydraulic jump stilling basins, and the natural hydraulic jump.

[illegible]

21 (W71-08507) OUTLET WORKS, COCHITI DAM
RIO GRANDE, NEW MEXICO.HYDRAULIC MODEL
INVESTIGATION!

MURPHY,THOMAS E.!BUCCI,DON R.!

ARMY ENGINEER WATERWAYS EXPERIMENT STATION,VICKSBURG,MISS.!

AVAILABLE FROM THE NATIONAL TECHNICAL INFORMATION SERVICE AS AD-719 681,$3.00 IN PAPER COPY, $0. 95 IN MICROFICHE. TECHNICAL REPORT NO 2-705,NOV 1965.73 P, 49 FIG,2 TAB.!

DAMS ! DESIGN ! HYDRAULIC MODELS!FLUID FLOW ! PIERS!OPERATION!SAND!SILT!COCHITI DAM !RIO GRANDE!NEW MEXICO!OUTLET WORKS! WEIRS!STILLING BASINS!

08B!

THE COMBINATION ENERGY DISSIPATOR-IRRIGATION DIVERSION STRUCTURE WAS STUDIED IN A 1:20-SCALE HYDRAULIC MODEL TO VERIFY AND POSSIBLY

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DIS 51/6/000001-000002//1 PAGE 2

REFINE THE DESIGN OF THE PRIMARY AND SECONDARY STILLING BASINS,DETERMINE THE DISCHARGE CHARACTERISTICS OF THE WEIR BETWEEN THE TWO BASINS AND EACH OF THE TWO DIVERSION SLUICES, AND INVESTIGATE QUALITATIVELY THE PERFORMANCE OF THE SILT SLUICES. THE PERFORMANCE OF THE ENERGY DISSIPATOR WAS IMPROVED BY RAISING THE APRON OF THE SECONDARY BASIN 5 FT AND MODIFYING THE POSITION OF THE BAFFLE PIERS IN THE PRIMARY BASIN AND THE SIZE AND POSITION OF THE BAFFLE PIERS AND END SILL IN THE SECONDARY BASIN. THE CAPACITY OF THE IRRIGATION DIVERSION SLUICES WAS FOUND TO BE ADEQUATE. THE HYDRAULIC PERFORMANCE OF THE SILT SLUICES WAS AS ANTICIPATED,BUT AT LOW DISCHARGES,FINE SAND WAS REMOVED FROM THE MODEL ONLY IN THE IMMEDIATE VICINITY OF THE SLUICE INTAKES.!

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22 70R0007912 WRA-W3-19 02.J0

(W70-07912) VELOCITIES OF CULVERT JETS FOR INCIPIENT EROSION!

SEABURN,GERALD E.!LAUSHEY,LOUIS M.!

GEOLOGICAL SURVEY, MINEOLA, N. Y.!AND CINCINNATI UNIV. , OHIO. DEPT. OF CIVIL ENGINEERING.!

FRENCH SUMMARY INCLUDED. PROCEEDINGS 12TH CONGRESS OF THE INTERNATIONAL ASSOCIATION FOR HYDRAULIC RESEARCH,SEPT 11-14, 1967, COLORADO STATE UNIV, FORT COLLINS, VOL 3 (EROSION AND LOCAL SCOUR DOWNSTREAM FROM HYDRAULIC STRUCTURES), PAPER C1,P 1-8,1967.8 P,4 FIG.!

ASSOCIATION FOR HYDRAULIC RESEARCH,SEPT 11-14, 1967, COLORADO STATE UNIV, FORT COLLINS, VOL 3 (EROSION AND LOCAL SCOUR DOWNSTREAM FROM HYDRAULIC STRUCTURES), PAPER C1,P 1-8,1967.8 P,4 FIG.|

VELOCITIES OF CULVERT JETS|STREAMBED EROSION|

02J|08B|

HIGH CAPACITY CULVERTS TOO OFTEN CAUSE STREAMBED EROSION AT THE OUTLET. THE CONSTRUCTION OF STILLING BASINS DESIGNED TO REDUCE EROSION IS TOO EXPENSIVE AND

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DIS 51/6/000002-000002//2 PAGE 2

IS SELDOM JUSTIFIED FOR SMALL CULVERTS. THEORETICAL AND EXPERIMENTAL STUDIES WERE UNDERTAKEN USING LOOSE STONES TO PREVENT EROSION AT THE OUTLET OF SMALL CULVERTS.THE CRITICAL VELOCITY THAT WILL INITIATE EROSION WAS FOUND BY TRIALS UNDER FULL-PIPE AND PARTIALLY-FULL PIPE FLOWS.IN THE FULL-PIPE FLOW,THE CRITICAL MOMENTUM WAS PROPORTIONAL TO THE CUBE OF THE STONE SIZE.FURTHER,A LARGER VELOCITY WAS REQUIRED TO SCOUR THE SPHERES THAN THE STONES, BECAUSE THE SPHERES HAVE A SMALLER DRAG COEFFICIENT AND A BETTER HYDRODYNAMIC SHAPE.THE PIPE DIAMETER IS NOT A USEFUL PARAMETER IN PARTIALLY-FULL PIPE FLOW. THE CRITICAL VELOCITY OF THE OUTLET OF CULVERTS REQUIRED TO INITIATE THE SCOURING OF A NONCOHESIVE BED IS (1) DEPENDENT ON THE SIZE OF STONES AND THE DIAMETER OF THE CULVERT IF THE CULVERT FLOWS FULL|AND (2)DEPENDENT ON THE STONE

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DIS 51/6/000002-000002//2 PAGE 3

SIZE BUT INDEPENDENT OF THE DIAMETER OF THE CULVERT IF THIS FLOWS ONLY PARTLY FULL. THE TAILWATER PROVIDED NO PROTECTION AGAINST BED EROSION WHEN THE DEPTH OF PIPE WAS LESS THAN ONE-HALF OF THE PIPE DIAMETER.(CARSTEA-USGS)|

SCOUR | CULVERTS | JETS | ENGINEERING STRUCTURES | EROSION|STREAMBEDS|STILLING BASINS | STONES | PIPE FLOW | MOMENTUM EQUATION|SHEAR DRAG|TAILWATER|

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52 1875 IT=EROSION

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53 1875 IT=EROSION

ENTER:#su=erosion

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54 102 SU=EROSION

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(23)

ACCESSION NUMBER ZUF 677
TITLE [redacted]
INVESTIGATORS ZEIGLER ER
ORGANIZATIONAL SOURCE U.S. DEPT. OF THE INTERIOR, BUREAU OF RECLAMATION, HYDRAULICS BRANCH, DENVER FEDERAL CTR., BLDG. 67, DENVER, COLORADO, 80225
PERIOD OF PERFORMANCE 10/76 TO 9/77
FISCAL YEAR 77
SPONSORING ORG. U.S. DEPT. OF THE INTERIOR, BUREAU OF RECLAMATION
FUNDING $12,000
SPONS. ORG. CONTROL NO. DR-406
TECHNICAL SUMMARY (AB)

Some stilling basins have required expensive repairs because of abrasive materials circulating with the water. These materials entered the basins in different ways: upstream rock movement by circulating action of the water, rock and debris thrown in by spectators, and/or debris left by the contractor. Hydraulic model studies may show design changes that will provide better flushing and lessen the tendency for material to move from downstream into the basin. However, information is needed to define the problem before starting laboratory studies.

Phase I - An interdisciplinary team will determine what structures have the abrasion problem, whether the material entered by man or flowing water, and if by flowing water from what source, the location and extent of damage, and operating conditions causing the damage.

Phase II - Hydraulic models of stilling basins will be constructed and modifications tested if team search shows need.

ACCESSION NUMBER ZUF 663
TITLE LOW FROUDE NUMBER STILLING BASIN
INVESTIGATORS RHONE TJ
ORGANIZATIONAL SOURCE U.S. DEPT. OF THE INTERIOR, BUREAU OF RECLAMATION, HYDRAULICS BRANCH, DENVER FEDERAL CTR., BLDG. 67, DENVER, COLORADO, 80225
PERIOD OF PERFORMANCE 7/74 TO 6/75
FISCAL YEAR 75
SPONSORING ORG. U.S. DEPT. OF THE INTERIOR, BUREAU OF RECLAMATION
FUNDING $5,000
SPONS. ORG. CONTROL NO. DR-384
TECHNICAL SUMMARY (AB)

The objective of this project is to develop a stilling basin or energy dissipator for spillway flows having a Froude number of less than 4.5.

12

The initial phase of the study will be to design two or more basins based on the principles developed for USBR stilling basins Types II, III, or IV. These basins will be modified as necessary to provide good energy dissipation, minimum downstream channel bed erosion and very small surface waves.

First tests will concentrate on a hydraulic jump basin that can be used on projects that are presently planned for near future construction.

ACCESSION NUMBER	ZTK 355
TITLE	MODEL STUDIES OF CLINTON AND FORT SCOTT OUTLET WORKS, WAKARUSA AND MARMATON RIVERS, KANSAS
INVESTIGATORS	MELSHEIMER ES
ORGANIZATIONAL SOURCE	U.S. ARMY, WATERWAYS EXPERIMENT STATION, STRUCTURES BRANCH, P.O. BOX 631, VICKSBURG, MISSISSIPPI, 39180
PERIOD OF PERFORMANCE	7/73 TO 6/74
FISCAL YEAR	74
SPONSORING ORG.	U.S. DEPT. OF DEFENSE, ARMY, CORPS OF ENGINEERS

TECHNICAL SUMMARY (AB)

Purpose of study/investigation: To observe the hydraulic flow conditions in the outlet works conduits and verify the adequacy of the stilling basins and riprap requirements. Of particular concern was development of design criteria for outlet works stilling basins where the outlet invert is submerged by tailwater, or where there is little drop from invert to tailwater. These conditions result in separation of flow at the sidewalls for small or intermediate discharges with resulting eddies and abrasive damage to the stilling basin.

Approach or plan: Tests were conducted on a 1:16-scale model which reproduced a schematic intake structure, the conduit, the outlet works stilling basin, and 800 ft. of the exit channel. Tests were also conducted with a 1:5-scale model to ensure satisfactory flow conditions in a single low-flow conduit in the Fort Scott outlet works that will be used for selective withdrawal.

Progress to date: Model tests indicated that separation of flow along the sidewalls and eddy action in the stilling basin could be eliminated or greatly reduced by limiting the sidewall flare to a maximum of 1V on 8H. However, some eddy action in the basin is likely when the outlet invert is set at an elevation that allows tailwater to force the jump to the vicinity of the outlet at low and intermediate flows. Sloping the upstream face of the end sill in the stilling basin facilitates the removal of any material entering the basin. Tests on the low-flow outlet for Fort Scott revealed satisfactory flow conditions for all discharges with the control gate located within and perpendicular to the conduit. Unsatisfactory conditions were observed with the control

ACCESSION NUMBER	ZTK 118 1
TITLE	MODEL STUDY OF SOUTH ELLENVILLE FLOOD CONTROL PROJECT, NEW YORK
INVESTIGATORS	MELSHEIMER ES
ORGANIZATIONAL SOURCE	U.S. ARMY, WATERWAYS EXPERIMENT STATION, STRUCTURES BRANCH, P.O. BOX 631, VICKSBURG, MISSISSIPPI, 39180
PERIOD OF PERFORMANCE	7/73 TO 6/74
FISCAL YEAR	74
SPONSORING ORG.	U.S. DEPT. OF DEFENSE, ARMY, CORPS OF ENGINEERS

TECHNICAL SUMMARY (AB)

Purpose of study/investigation: To determine the hydraulic and structural adequacy of the design and to refine the design of various elements of the project as necessary. To investigate flow conditions in the high-velocity chute and stilling basin of the project. Of particular interest will be the disturbance effect of large boulders in the chute, the effects of increased disturbances due to the proximity of the bends to each other, and the effect of bends on free-board requirements. Erosion characteristics below the stilling basin are also to be determined.

Approach or plan: Tests were conducted in a 1:20-scale model that reproduces about 200 ft of the approach to the high-velocity chute, the entire chute, the stilling basin, and approximately 600 ft of Sandburg Creek at the channel junction.

Progress to date: Tests indicated that the original design of the entrance to the high-velocity chute, which was based on a flow equal to two-thirds of the Standard Project Flood, was inadequate to handle the Standard Project Flood, which had become the revised design flow. The approach channel was revised to include a low weir and a higher debris barrier for greater capacity. Chute performance was satisfactory. The stilling basin approach floor was raised to reduce low-flow eddy currents. Tests indicated that stone with an average weight of 360 lbs was sufficient to furnish riprap protection at the junction of North Gully and Sandburg Creek. Additional tests to determine the effects on flow conditions of debris accumulations in excess of project design volumes revealed that such accumulation resulted in the stilling basin being choked with debris and the basin walls being overtopped some 8 to 10 ft. All tests on the project have been completed, and the preparation of a final report on the result of these tests is in progress.

ACCESSION NUMBER AW 578
TITLE SPINNEY MOUNTAIN PROJECT SPILLWAY MODEL STUDIES
INVESTIGATORS BABB AF
ORGANIZATIONAL SOURCE WASHINGTON STATE UNIVERSITY, SCHOOL OF ENGINEERING, HYDRAULICS, PULLMAN, WASHINGTON, 99163
PERIOD OF PERFORMANCE 7/74 TO 1/75
FISCAL YEAR 75
SPONSORING ORG. R. W. BECK & ASSOCIATES
TECHNICAL SUMMARY (AB)

The purpose of this study is to conduct hydraulic model investigations that will assist in designing the service spillway of the Spinney Mountain project in Colorado. Studies will include investigations of approach flow conditions, spillway entrance, discharge coefficients, crest pressures, stilling basin pressures, flow characteristics in the combination stilling basin-flip bucket, and erosion of the discharge channel.

* * * * * * * * * E N D O F O F F - L I N E P R I N T * * * * * * * * *

APPENDIX I6 - Some Bureau Library Reports

DESCRIPTOR — USAGE DENSITY
NT DOCUMENT # — SHORT TITLE

SCOUR (CONTINUED) — 176

•	101349	HYDRAULIC MODEL INVESTIGATION OF GABION
•	113657 70A	HYDRAULIC MODEL STUDY* JACKSON LAKE DAM BAFFLE BLOCKS
	113579 70A	HYDRAULICS OF BRIDGE WATERWAYS, 2ND EDITION
	M500331X67A	HYDRAULICS OF MEANDERING RIVERS WITH FLOOD PLAINS
	R200335	INLET + OUTLET TRANSITIONS FOR CANALS + C
	M503953 70A	IRRIGATION CHANNEL STRUCTURES, VICTORIA, AUSTRALIA
•	108108	JOHN MARTIN DAM, COLO - SPILLWAY & BASIN
•	108502	KEYSTONE DAM, OKLA - SPILLWAY, STILLG BSN
•	105552	LAKE CAWNDILLA OUT. REGULATOR DISSIPATOR
	118149 74A	LINED CHANNEL EXPANSNS DSGN AT CULVERT OUTLETS MODL ST
•	M503135X68A	LOCAL CHANNEL SCOUR DOWNSTREAM OF HYDRAULIC STRUCTURES
•	R203799 68A	LOCALIZED SCOUR IN ERODIBLE-BED CHANNELS
	109873 67A	LOWER JET SECTION ON DROPS & SPILLWAYS
-	103595	LOWER TWO MEDICINE DAM - HYDRAULIC MODEL
•	R200744	MAINTENANCE OF CURVE SECTIONS OF EARTH CA
	R201276	MANGLA SPILLWAY DESIGN FEATURES
	101082	MEANDERING IN STRAIGHT ALLUVIAL CHANNELS
	R203455X68A	MEANDERING IN STRAIGHT ALLUVIAL CHANNELS
	106528	MODEL & PROTOTYPE MORPHOLOGY OF RIVERS
	R203931X68A	MODEL STUDIES OF AN ARMORED ROCKFILL OVERFLOW DAM
	106948	MODIFIED OUTLET WORKS NAVAJO DAM - STUDY
	108265	MORGANZA FLOODWAY CONTROL STRUC MISS RIV
	106067	MUNMORAH PWRPLT, AUSTRALIA - HYDRAULICS
•	108503	OAHE DAM, SO DAKOTA - OUTLET WORKS
	105923	ON THE EQUILIBRIUM BED PROFILES OF RIVERS
	119969 75A	OWENS RIV NEAR BISHOP, CA* EROSION & SEDIMENT TRANSPRT
	R204521X69A	PORTAGE MOUNTAIN DEVELOPMENT SPILLWAY
	118408 73A	REMOTELY SENSED DATA FOR WTR RESOURCE MDLS* FEASBILTY
•	R205668 71A	RIPRAPPED BASINS FOR CULVERT OUTFALLS
	M505055 72A	RIVER BED DEGRADATION AFTER CLOSURE OF DAM
	104162	RIVER BED VARIATIONS DURING FLOODS
•	106547	RIVER-BED SCOUR
•	R202403	RIVERBED DEGRADATION BELOW DAMS
•	R204849X70A	RIVERBED DEGRADATION PREDICTION
•	R205771 72A	RIVERBED DEGRADATION AFTER CLOSURE OF DAMS
•	R200564	RIVERBED VARIATION MEASUREMENT DURING FLC
	R200953	RUEDI DAM SPILLWAY AND OUTLET WORKS MODEL
	113354 70A	SCALE EFFECTS* HYDRAUL MODEL TESTS OF ROCK STRUCTURES
	116308 72A	SCOUR & FILL IN MISSOURI RIV AS RELTD TO WTR RESOURCE
•	R204279X69A	SCOUR AROUND BRIDGE PIERS
•	R201683	SCOUR BELOW SPILLWAYS OF HIGH-HEAD DAMS
•	105288	SCOUR CAUSED BY NAPPE FROM ARCH DAM
•	117815 72A	SCOUR HOLE BELOW KARIBA DAM
•	R204370X69A	SCOUR IN SAND AND GRAVEL BEDS BELOW APRONS
•	R202452	SCOUR IN TAILWATER OF SHAFT SPILLWAYS
•	R200486	SCOUR PROBLEMS AT BRIDGE CROSSINGS
	109961 68A	SCOUR RESISTANCE OF DAM SPILLWAYS WITH GRASS DORMANT
•	117706 73A	SCOURING ACTION OF FREE JETS DOWNSTREAM OF HYD STRUCS
•	R202451	SCOURING CAPACITY OF AIR-WATER JETS

I didn't find pertinent information for a solution to stilling basin abrasion. Most stilling basin referenc relate to scour downstream from the basin.

Zeigl

DESCRIPTOR WT	DOCUMENT #	USAGE DENSITY SHORT TITLE
OUR (CONTINUED)		176
	109328	SEDIMENT PROBLEM
•	103182	SEDIMENT SCOUR AT STRUCTURES
	102540	SEDIMENT TRANSPORT AND SCOUR
	R205395 71A	SEEPAGE FORCE ON INTERFACIAL BED PARTICLES
	106940	SEEPAGE WTR EFFECT ON EARTH EMBANKMENTS
•	101978	SHIHMEN SADDLE CHUTE SPILLWAY
•	110748 58A	SIMILARITY OF SCOUR IN MODEL TESTS - CZECH TEXT
•	110749 58A	SIMILARITY OF SCOUR IN MODEL TESTS
	M501603X67A	SIMPLIFIED DESIGN FOR FLUME INLETS
•	R205767X72A	SOIL--AN EARTH RESOURCE
	111228 33A	SOLIDS TRANSPT BY FLOWG WATER IN OPEN CHANNELS* BIBL
	108243	SPILLWAY & SLUICES FOR CONEMAUGH DAM, PA
→	R202506	SPILLWAY AND OUTLET DAMAGES Arther and Jabara's paper
•	108151	SPILLWAY DSGN FOR WHITNEY DAM, BRAZOS RIV
•	108123	SPILLWAY FOR DETROIT DAM, OREG - MODEL
•	108250	SPILLWAY FOR PHILPOTT DAM, VIRGINIA
•	108694	SPILLWAYS AND OUTLET STRUCTURES
	118336 74A	SPRING SNOWMELT RUNOFF EFFECT ON AQUATIC POPLUATIONS
	R201971	SPUR DIKES FOR RIVER REGULATION
•	R204284X69A	STABILITY OF BLOCKS SUBJECTED TO PLUNGING WATER JETS
	R205051 69A	STABLE CANAL BEDS IN WEAK, FINE-GRAINED GROUND
	102462	STABLE CHANNEL DESIGN IN ALLUVIAL MATERIA
	119957 56A	STEEL JETTIES FOR BANK PROTECTN & CHANNELZTN IN RIVERS
	R204523X69A	STILLING BASINS WITH WEDGE-SHAPED BAFFLE BLOCKS
	R203645 68A	STREAMFLOW FLUCTUATION, ROUGHNESS, AND BEDLOAD
•	100508	STUDIES OF TRACTIVE FORCES OF COHESIVE SO
	105030	STUDIES ON SEDIMENTS IN IRRIG CHANNELS
	R203164	SUBMARINE PIPELINES
•	108491	TABLE ROCK DAM, MO - SPILLWAY & CONDUITS
	R202757	TEHAMA-COLUSA FISH BARRIER
	R200710	TESTS OF SLOTTED FLUME OUTLET
•	R205413 71A	THEORIES OF CLOSURE OF ROCKFILL DAMS
	R200422	THIN CONCRETE SLABS FOR CANAL LINING
	R205500 71A	TRACER STUDIES OF SEDIMENT TRANSPORT PROCESSES
	116114 69A	TURBULENT FLOW IN WATER CONTROL STRUCTURES
	R202509	TURBULENT FLOW IN SUDDEN ENLARGEMENTS
•	108302	TUTTLE CREEK DAM, KANS - OUTLET STRUCTURE
•	107846	ULTRASONIC SCOUR METER - DSGN & DVLPMT
•	108110	WAPPAPELLO DAM, MO - OUTLET STRUC MODEL
	S100618	WATER RESEARCH LAB., U. OF NEW SOUTH WALE
•	R203201	WAVE PROPAGATION IN ERODIBLE-BED CHANNELS
OUR METERS		1
•	107846	ULTRASONIC SCOUR METER - DSGN & DVLPMT
REENING		11
•	115145 61A	AGGREGATE SEPARATION PLANT, GLEN CANYON DAM
	104190	AGGREGATE VARIATION REDUCTION BY SAMPLING
	R200300	CONSTRUCTION OF ICOS CUTOFF WALL--QUEBEC

APPENDIX II - Desired Survey Information

Research Project - Abrasive Materials in Stilling Basins

Some stilling basins have required expensive repairs because of materials circulating with the water. Hydraulic model studies may show design changes that will provide better flushing and lessen the tendency for material to move from downstream into the basin. However, information is needed to determine whether or not model studies should be made. Is this problem only of a very limited nature, or of wide enough scope to support hydraulic model studies, and if so what conditions should be examined? Information from the following survey will be useful in making this determination.

1. What stilling basins have abrasion problems?

2. Location and extent of damage - depth of erosion, and where on walls, floor, or blocks of structure?

3. Type of material in basin - steel rebars, metal scrap, rocks, or other.

4. How material entered basin - by man, left by contractor, debris thrown in by spectators, or by circulating water.

5. If by circulation, location downstream from structure where material came from.

6. Circulation pattern of water bringing material in, and also causing damage.

7. Operating conditions for which damage occurred:

    a. Structures operating - outlets, spillway, powerplant

    b. Discharges and tailwater elevations

    c. Time estimate for damage to occur - hours, days, weeks, years

8. What repairs made.

9. Cost of repairs.

10. Photographs showing damage or flow conditions causing damage.

11. Drawings showing structure location and dimensions pertinent to hydraulic flow.

APPENDIX III - Information Received From Vern Yocom of Water O&M

Mason Dam, Baker Project - completed 1968

1. 1969 - Cavitation damage to OW chute floor downstream of regulating gates. One and three-fourths inches deep. Repair method outlined in December 24, 1969 letter.

2. 1975 - Underwater examination - OW basin - exposed aggregate and reinforcing steel. In one location 20-24 inches of concrete gone exposing second layer of reinforcing steel. Cobbles 10 to 12 inches (very rounded). Theorized that rock is thrown in basin. Repairs made in 1976.

3. 1975 - Underwater examination - spillway basin - spillway has never spilled; consequently, concrete in excellent condition. Large quantity of rock in basin, 1 to 3 feet in cross section. Assume the rock was thrown or rolled in from the side slope. Dive team spent 1-1/2 days removing rock.

Causey Dam, Weber Basin Project - completed 1966

1. 1975 - Underwater examination, sketches and photographs OW Basin - concrete eroded through reinforcement steel 35-foot-long area across entire outlet basin. Walls also eroded 3-5 inches in depth. Scattered rounded rock up to 1 foot in diameter in basin. Twisted 2-inch pipe also in basin. Basin repaired in 1976. Spillway basin - concrete in excellent condition. Scattered gravel and cobbles on floor up to 3-6 feet in depth extending across the entire channel. Rocks were up to 2-3 feet in diameter. Other debris present such as tires and waterlogged wood.

Navajo Dam, Colorado River Storage Project

1. 1963 - Cavitation damage downstream of regulating gate in auxiliary outlet works. Repaired in 1964.

2. 1965-68 - Cavitation damage to 72-inch hollow-jet valves in main OW.

3. Underwater examination of main OW basin in 1968: 15 to 20 gallons of rock ranging up to 8 inches in diameter. Minor amount of concrete damage up to three-eighths inch deep. Downstream channel improved to prevent swirling flows carrying material back into basin.

4. 1970 - Cavitation damage to 72-inch hollow-jet valves in main OW and also downstream of gates in auxiliary OW.

5. Main OW stilling basin tests - 1970.

6. Auxiliary OW model studied in 1970 - aeration slot recommended to correct cavitation problem.

7. 1970 underwater examination of main OW basin, minor damage, very few rocks in basin.

(Underwater divers found extensive abrasion damage in the hollow-jet valve stilling basin during April 1965, and temporary repairs were made in May. Hydraulic model studies were made investigating the abrasion problem, and then modifications made to the prototype stilling basin. The converging entrance flow wedges and center dividing wall were removed, and a 42-m (137-ft) distance downstream from the basin was paved with a 0.46-m (18-inch) thick concrete pad. Zeigler)

8. Nitrogen gas supersaturation - auxiliary outlet works and 30-inch bypass.

Echo Dam, Weber River Project - completed 1931

1. OW and spillway combined stilling basin. Unwatered and inspected 1968. Erosion to the entire floor. Depth of approximately 4 feet below concrete floor. Side walls eroded in places almost through thickness of wall. Est: $260,000. Repaired in fall of 1968.

2. 1969 basin examined - gravel and rocks sloughed from road construction into basin - some erosion damage and short section of rebar exposed.

3. 1975 examination - up to 2 feet of debris in basin - rock, wire, pipe, rope, reinforcing bars. Concrete eroded up to 6 inches in depth exposing rebars through entire length of basin. Repaired in 1976.

Tiber Dam, Pick-Sloan Missouri Basin Program, Marias Division

Spillway basin, $8,000,000 plus (later in looking at the O&M file I concluded this was for reconstruction of the spillway which suffered damage because of foundation settlement problems. Presently there is a cofferdam at the spillway entrance blocking waterflow. Zeigler)

Yellowtail Dam, Pick-Sloan Missouri Basin Program, Lower Bighorn Division

Minor erosion - no repair required. Spillway tunnel and basin - cavitation in tunnel; air slot modification - large quantity of rock in basin, no damage to concrete.

APPENDIX IV - Tabulation of the rock and abrasion survey made of the USBR stilling basins

S - spillway stilling basin OW - outlets works stilling basin

Name	Rocks	Abrasion	Exposed rebars	Repaired
Mason Dam S	x			
OW	x	x	x	x
Anderson Ranch Dam Combined S&OW	x	x	x	x
Unity Dam Combined S&OW	x	x		
Crescent Lake Dam OW	x			
Arther R. Bowman Dam Combined S&OW	x	x	x	
Haystack Dam OW	x	x	x	
Wickiup Dam OW	x	x	x	x
Mann Creek Dam S	x			
OW		x		
Agate Dam Combined S&OW	x			
Emigrant Dam OW	x	x	x	
Howard Prairie Dam S	x			
OW	x			
Keene Creek Dam S	x			
Agency Valley Dam Combined S&OW	x			
Bully Creek Dam S	x			
OW	?			
Canal OW	x	x		
Cle Elum Dam Combined s&ow	x	x		

APPENDIX IV - Tabulation of the rock and abrasion survey made of the USBR stilling basins - (Continued)

S - spillway stilling basin   OW - outlets works stilling basin

Name	Rocks	Abrasion	Exposed rebars	Repaired
Folsom Dam S Needs repair	x	x	x	
Shasta Dam S	x	x		
Lewiston Dam S *Repaired dentate, no floor damage		x	x	*x
Spring Creek Debris Dam S	x			
OW	x			
Trinity Dam OW	x	x	x	x
Rye Patch Dam Combined S&OW	x	x		
Link River Dam S		x		
Lahontan Dam Combined S&OW	x	x		
Twitchell Dam OW	9-m silt deposit			
Boca Dam S	x			
Casitas Dam S	x			
Prosser Creek Dam S	x			
OW	x			
Steinaker Dam Combined S&OW	x			
Vega Dam S	Earth material			
Navajo Dam S	x			
OW	x	x	x	x

APPENDIX IV - Tabulation of the rock and abrasion survey made of the USBR stilling basins - (Continued)

S - spillway stilling basin OW - outlets works stilling basin

Name	Rocks	Abrasion	Exposed rebars	Repaired
Morrow Point Dam S&OW plunge basin	x	x	x	
Joes Valley Dam OW	x	x		
Lemon Dam Combined S&OW	x	x		
Fruitgrowers Dam S	x			
Jackson Gulch Dam OW	x	x		
Moon Lake Dam S	x			
Pineview Dam Combined S&OW	x	x	x	x
Vallecito Dam OW	x			
Scofield Dam S	x			
Fontenelle Dam OW	x	x	x	x
Crawford Dam S	x			
Taylor Park Dam S	x			
Causey Dam S	x			
OW	x	x	x	*
*Needs repairing				
Lost Creek Dam S	x			
OW	x			
Wanship Dam S	x			
OW	x	x	x	x
Echo Dam Combined S&OW	x	x	x	x

APPENDIX IV - Tabulation of the rock and abrasion survey made of the USBR stilling baains - (Continued)

S - spillway stilling basin OW - outlets works stilling basin

Name	Rocks	Abrasion	Exposed rebars	Repaired
Sanford Dam S	x			
OW	x			
Flood control	x			
Summer Dam Combined S&OW	x			x
Minor repair				
Caballo Dam S	x			
OW	x	x		*x
*Minor repair				
Twin Butes Dam S	x			
OW	x			
Foss Dam S	x			
OW	x			
Altus Dam S	x			
Fresno Dam Combined S&OW	x	x		
Boysen Dam S	x			
Keyhole Dam OW	x			
Pactola Dam OW	x	x		
Jamestown Dam S	x			
OW	x			
Shadehill Dam Combined S&OW	x	x	x	
Heart Butte Dam Combined S&OW	x			
Canyon Ferry Dam Combined S&OW	x	x	x	

APPENDIX IV - Tabulation of the rock and abrasion survey made of the USBR stilling bains - (Continued)

S - spillway stilling basin OW - outlets works stilling basin

Name	Rocks	Abrasion	Exposed rebars	Repaired
Yellowtail Dam S	x			
OW	x			
Tiber Dam OW	x	x	x	x
Auxiliary OW	x	x		
Clark Canyon S	x			
OW	x	x	x	
Olympus Dam S	x			
Shadow Mountain Dam S	x	x		
Ruedi Dam S	x			
OW	x	x		x
Minor repair				
Sugar Loaf Dam OW	x	x		
Alcova Dam S	x			
Seminoe Dam OW	x			
Box Butte Dam Combined S&OW	x			
Lovewell Dam S	x			
Enders Dam S	x			
OW	?	x	x	
Trenton Dam S	x			
Red Willow Dam S	x			
OW	x	x		
Medicine Creek Dam S	x			
Norton Dam S	x			

APPENDIX IV - Tabulation of the rock and abrasion survey made of the USBR stilling basins - (Continued)

S - spillway stilling basin OW - outlets works stilling basin

Name	Rocks	Abrasion	Exposed rebars	Repaired
Shereman Dam S	x			
OW	x			
Glendo Dam S	x			
Merritt Dam S	x			
OW	x	x	x	x
Cedar Bluff Dam S	x			
Glen Elder Dam S	x			
Webster Dam S	x			
Pilot Butte Dam S	x	x		
Palisades S	x			
OW	x	x		
Wasco Dam OW	x			
Kachess Dam S	x	x	x	
Bradbury (Cachuma) Dam Combined S&OW	x			

APPENDIX IV - Tabulation of the rock and abrasion survey made of the USBR stilling basins - (Continued)

S - spillway stilling basin OW - outlets works stilling basin

Name		Rocks	Abrasion	Exposed rebars	Repaired
Friant Dam	S	x			
	OW	x	x	x	
Friant-Kern Canal	OW		x		
Keswick Dam	S	x	x		
Arbuckle Dam	S	x			
	OW	x			
Cheney Dam	S	x			
	OW	x			
Dickinson Dam	S	x			
Hyrum Dam	S	x			
Norman Dam	S	x			
	OW	x			
Starvation Dam	S	x			
	OW	x			
Stampede Dam	S	x			
	OW	x	x		

APPENDIX V - Information brief of the rock and abrasion survey made of USBR stilling basins

NOTE: S = Spillway stilling basin
OW = Outlet works stilling basin

Mason Dam

S - 12 m^3 removed 1975.

OW - rebars exposed, maximum erosion in left bay 0.5 m deep, repaired 1976.

Anderson Ranch Dam

Combined S & OW - 456 m^3 removed 1959, 115 m^3 in place 1965, maximum erosion 0.1 m deep, rebars exposed, repaired 1962.

Unity Dam

Combined S & OW - 225 m^3 removed 1966, 150 m^3 removed 1977, some abrasion.

Crescent Lake Dam

OW - 0.5-m-depth rock deposit reported 1969, could not find record of removal, but 1 m^3 of rocks reported 1975.

Arthur R. Bowman Dam

Combined S & OW - rock in basin, abrasion, and small area of exposed rebars.

Haystack Dam

OW - rock in basin, erosion 0.15 m deep, exposed rebars.

Wickiup Dam

OW - exposed rebars was repaired 1954, 1975 found some gravel, pipe, cable, and rock - maximum erosion 0.1 m deep.

Agate Dam

Combined S & OW - 1-m depth of rocks, no damage reported.

Emigrant Dam

OW - rock and sand, erosion 0.15 m deep, exposed rebars.

Howard Prairie Dam

S - scattered to 0.3-m depth of rocks.

OW - some rocks.

Keene Creek Dam

S - varied depth deposit rock and silt, maximum depth 0.8 m.

Cle Elum Dam

Combined S & OW - rock with maximum 0.08-m erosion.

Folsom Dam

S - rock with maximum 0.45-m erosion, rebars exposed, broken and bent.

Shasta Dam

S - rock and 0.05-m-depth erosion.

Lewiston Dam

S - downstream surface of the leftmost dentate, exposed rebars.

Spring Creek Debris Dam

S - rock in basin.

OW - rock, gravel, sand, and silt removed 1971.

Trinity Dam

OW - rock, gravel, and damaging erosion, maximum erosion depth 0.6 m, rebars broken, damage repaired and some lighter-type erosion has occurred. Presently very careful to have divers remove rock before operation. Prototype tests have documented that rock has been hydraulically drawn into the basin.

Rye Patch Dam

Combined S & OW - 210 m^3 rock removed 1970, 95 m^3 found by divers 1971, some erosion of the basin floor and eroded hole in riprap downstream from basin.

Link River Dam

S - slight erosion on floor upstream of floor blocks, probably caused by bedload passing through structure.

Lahontan Dam

Combined S & OW - rock and some erosion.

Twitchell Dam

OW - 9-m-deep silt deposit in basin and some rocks, silt entered through intake, 115 m^3 silt removed 1973 and 252 m^3/s discharge to flush additional material from basin. Afterwards approximately 900 kg of loose steel rebars removed from basin.

Boca Dam

S - 45 m^3 rock in basin.

Casitas Dam

S - flood rains in 1969 washed large rocks into basin, 1973 estimated 700 m^3 rock in basin.

Lemon Dam

Combined S & OW - angular rocks in basin similar to riprap.

Prosser Creek Dam

S - 60 m^3 rock, located near toe of chute.

OW - 8 m^3 rock removed 1969, chain link fence installed, 1 m^3 rock 1971.

Steinaker Dam

Combined S & OW - rock.

Vega Dam

S - slide of earth material entered chute and then the basin.

Navajo Dam

S - some rock.

OW - rock, exposed rebars, erosion 0.05 to 0.13 m on the walls, and 1.2-m-deep cavity at the toe of the left bay.

Morrow Point Dam

S & OW plunge basin - removed 33 m^3 rock, erosion 0.15 to 0.20 m below rebars.

Joes Valley Dam

OW - rock in basin, 0.03-m-depth erosion downstream chute blocks, lesser erosion on side walls.

Fruitgrowers Dam

S - cleaned in 1966, rock and mud deposit presently at toe of chute.

Jackson Gulch Dam

OW - few scattered rocks downstream from chute blocks and rock deposit downstream from floor blocks; concrete erosion on chute.

Moon Lake Dam

S - rocks.

Pineview Dam

Combined S & OW - basin repaired 1957, presently rocks in basin, some erosion on chute, maximum depth 0.10 m, portion of four rebars exposed.

Vallecito Dam

OW - some rocks removed from basin.

Scofield Dam

S - rocks.

Fontenelle Dam

OW - some rocks in basin, basin was repaired 1967.

Crawford Dam

S - rocks.

Taylor Park Dam

S - rocks, but flip bucket basin and and larger discharge will flush rocks out.

Causey Dam

S - rocks.

OW - rocks, extensive damage, some rebars completely ground away, others exposed, floor eroded to 0.3-m depth.

Lost Creek Dam

S - rocks.

OW - rocks.

Wanship Dam

S - rocks 0.6-m-deep deposit at right side immediately downstream from spillway chute.

OW - 1975 two 0.05-m-deep sand and gravel deposits, with some scattered cobbles. Some slight surface erosion. 1969 - the basin was repaired after considerable erosion, maximum 0.45 m deep, rebars exposed and some ripped away, most extensive damage was between the floor blocks and chute blocks. Besides rocks there were cables, pipes, and angle iron which were believed to have been left after construction.

Echo Dam

Combined S & OW - 1975, 0.6-m-deep deposit at downstream end of basin which also contains rebars, cable, and wire; 0.15-m-deep erosion with exposed rebars and some rebars bent 90° to a vertical position. 1969 - basin dewatered, gravel and rocks removed by highway contractor (road had been built upslope from basin and during construction rocks rolled into basin). In photographs it appeared there were some steel rebars in the debris. 1968 - extensive repairs made, 18-m length of concrete floor eroded away and a 1.2-m depth eroded below the floor from a tightly cemented conglomerate material.

Sanford Dam

Three basins - (1) flood control, (2) spillway with a morning-glory inlet, (3) and river outlets. Rock removed from all the basins in 1972. A chain link fence was built around the morning-glory intake to stop people from dropping rocks into the structure.

Summer Dam

S - 150 m^3 silt and rock removed, and some displacement of riprap repaired downstream by dozer. One dentate repaired and eight chute blocks patched on the side.

Caballo Dam

S - some debris.

OW - unwatered each year; in previous years minor floor erosion repaired with epoxy.

Twin Buttes Dam

S - rocks.

OW - rocks.

Foss Dam

S - 2.7-m depth silt with scattered rocks.

OW - silt and rocks.

Altus Dam

Uncontrolled spillway - One-third covered with rock and debris but not over 0.15 m deep.

Controlled spillway - cleaned by releases (spillway basins are a concrete slab sloping downward from the downstream face of the dam).

Fresno Dam

Combined S & OW - 1973 inspection by boat revealed some erosion and pile of tumbled gravel. 1967 report stated broken concrete slabs and rebars in basin which was waste from earlier spillway repairs. (No reports found saying this material has been cleaned from basin - but must have been.)

Boysen Dam

S - 1974, some scattered rock in basin. In 1969, 4.6 m^3 rock removed from basin, and 150 to 230 m^3 removed from apron downstream from the basin.

Keyhole Dam

OW - 1971, 39 m^3 rock removed from basin. Rock located mostly by end sill, with small amount upstream of floor blocks.

Pactola Dam

OW - 1971, 39 m^3 rock removed from basin, located near end of basin and a 1.2-m-high deposit 1.2 m downstream from the chute blocks, slight abrasion of concrete downstream from chute blocks.

Jamestown Dam

S - dewatered and cleaned 1973, 0.9- to 1.2-m deposit of mud and rock.

OW - dewatered and cleaned 1973 (from photographs would judge less than 3 m^3), rocks located downstream from chute blocks and near end of basin.

Shadehill Dam

Combined S & OW - rocks, erosion has occurred at three locations exposing rebars, also some floor blocks are damaged. Damage was first found in 1968 when dewatered. The last dewatered examination was made in 1976 and reported "slightly more degradation has occurred since last examination in 1973."

Heart Butte Dam

Combined S & OW - dewatered in 1973, less than a wheelbarrow of rocks found.

Canyon Ferry Dam

Combined S & OW - April 1972, 13,350 m^3 rock removed, by contract, $165,441. However, in July 1972, 380 m^3 more rocks found and removed, $26,000. Hydraulic model study currently underway.

Yellowtail Dam

S - 1974, 3 m^3 rock cleaned from basin.

OW - 1974, several rocks 460 to 610 mm in diameter were on the floor of the hollow-jet valve basin.

Tiber Dam

OW - basin repaired 1975 after severe erosion. Chute floor eroded 0.02 to 0.05 m at toe, upstream basin floor eroded 0.07 m, and downstream basin general erosion below top level of rebars, with exception of two holes completely through the floor, the left hole at least 1.2 m deep, the right hole 0.4 m deep. Chute block eroded 0.05 m at back side, floor blocks 0.10-m erosion, and dentates more than 0.10-m erosion and one dentate completely ripped out and left 9 m downstream.

Auxiliary OW - some rocks.

Clark Canyon

S - 1976, 4 m^3 rock removed from lower end of basin; 1970, rocks removed.

OW - 1976, no rock but several joints of pipe (4 in, origin unknown) removed. A small area of erosion, 0.08 m deep with slightly exposed rebars, was found in middle of the basin. 1970, rocks removed.

Olympus Dam

S - sloping concrete apron downstream from dam, rock, gravel, and sand removed 1970, concrete reported in good condition with no erosion.

Shadow Mountain Dam

S - 1976, scattered rocks from 0.10 to 0.46 m in diameter, dentated end sill almost covered with rocks, slight concrete surface erosion in center of basin.

Ruedi Dam

S - 2 m^3 rock removed 1974.

OW - 1969, removed 20 (5-gal) buckets of rocks, 0.03-m erosion floor of right bay, epoxy resin repair.

Sugar Loaf Dam

OW - 1976 left bay, 0.02-m erosion for 7.5 m on floor downstream from chute and in left bay the erosion depth was from 0.03 to 0.05 m deep. Found old metal pieces on floor (pieces of chain, bumper jack base, part of a chain hoist, hooks, rods, and other items). It was suspected these were items dropped by contractor when building the gantry crane above the basin walls.

S - no reports (I bet it has rocks in it).

Alcova Dam

S - 1974, considerable rock and debris and miscellaneous pieces of rebars in basin, some rocks 0.7 m in diameter.

Seminoe Dam

OW - 1974, small amount of rocks and debris in basin.

Box Butte Dam

Combined S & OW - 1976, gravel and sand deposit in center upstream part of basin 1.2 m deep, and dentates of end sill covered with sand and gravel.

Lovewell Dam

S - 1975, few 0.36- to 0.46-m square sandstone rocks and sand deposit in middle of basin, 6 to 9 m wide, extending to a narrow point at the spillway chute.

Enders Dam

S - 1976, 0.6 to 1.0-m layer of silt on bottom of basin. At the upstream corners on both the left and right there are rock deposits below the side drain inlets. It is believed these rocks were placed there during construction to break the fall of side drainage.

OW - 1976, erosion of concrete and exposed rebars.

Trenton Dam

S - 1976, silt deposit 0.6 to 1.0 m deep with a few rocks.

Red Willow Dam

S - 1976, 1.2 - to 1.5-m-depth silt deposit with some rocks. Some sand entered basin from a slide overtopping the right wall of the spillway chute.

OW - 1976, rocks generally located at the upper and lower ends of the basin, and slight floor erosion exposing aggregate.

Medicine Creek Dam

S - 1976, silt deposits over 0.6 m deep, center portion and sides of basin bare of silt, some rocks which are mostly located along the left wall (probably thrown in).

OW - no divers' report, but O&M reports of 1954 and 1956 mention erosion of the bottom chute and upstream basin floor.

Norton Dam

S - 1975, rock deposit along the toe of the chute, some rock 0.6 m across and 0.2 m thick.

Sherman Dam

S - 1976, 1.5-m-depth silt deposit with few rocks, most rocks upstream end of basin.

OW - 1976, few small rocks.

Glendo Dam

S - floor covered with 0.15 to 0.25 m fine sediment, numerous small rocks found on chute from waterline to 2-m depth.

Merritt Dam

S - 1976, large sand deposit with varying depth, 3.7 m deep in middle, right side of the end sill completely covered, left side partially exposed, and chute blocks completely covered.

OW - 1976, rocks just upstream from the end sill, more than a dozen 380 to 460 mm in diameter, 0.05 to 0.08 m erosion downstream from chute blocks along a 2-m length, rebars exposed, repaired. 1977 - more rocks, repaired patch gone.

Cedar Bluff Dam

S - 1975, floor covered with 0.05 to 0.20 m fine sediment with scattered rocks, from softball size to 460-mm boulders.

Glen Elder Dam

S - 1975, 0.2-m sediment deposit, with some rocks at each upstream corner of the basin.

Webster Dam

S - 1975, 0.6-m-deep sediment deposit with some scattered rocks.

Mann Creek Dam

S - 1974, scattered rocks on floor, and chute blocks partially covered with silt, sand, and rocks.

OW - 1974, some deposits of sand and fine gavel, 10-mm erosion on sidewalls upstream of dentates bay No. 1 and minor scour on downstream area of the floor bay No. 2.

Agency Valley Dam

Combined S & OW - 1965, basin dewatered and rock cleaned out. 1971, some scattered rock.

Bully Creek Dam

S - 1965, basin dewatered, debris cleaned out, no repair required. 1971, considerable rock, more on the left side, chute blocks covered and dentates partially covered.

OW - not examined.

Canal OW - rocks with maximum 0.08-m erosion.

Pilot Butte Dam

Wyoming Canal Wasteway S - floor eroded, caused by riprap brought in by water action from the basin end at the right bank. The spillway exit flow channel had been changed from a straight course to curve which made bad flow conditions at the end of the stilling basin.

Palisades Dam

S - some rocks.

OW - cavitation and abrasion damage.

Wasco Dam

OW - 1972, rocks in bottom of basin, no reported damage. Rocks had evidently been thrown in because district had reported cleaning basin previously.

Kachess Dam

S - 1973, erosion on the upstream face of the dentates with some exposed rebars.

Bradbury (Cachuma) Dam

Combined S & OW - 1970, most of the basin covered with a 0.3-m silt deposit. Rock deposit 4 to 8 m^3 located left side of basin immediately downstream from chute blocks, also a 3.0- to 3.7-m-length steel object located at edge of rock deposit. The 1969 flood flows flushed some rocks from the basin which were known to be there previously.

Friant Dam

S - 1974, 25 percent of the basin visible and concrete in good condition, silty sand to gravelly sand deposits, up to 0.82 m deep.

OW - 1974, erosion more extensive in left bay, 6.5-m^2 area of exposed rebars with some missing; right bay erosion, but no exposed rebars. Both bays 0.057 m^3 small rocks which were mostly located in the depressions of the construction joints, more erosion occurred at the construction joints. Consensus of the divers was very small amount of erosion since 1966.

Friant-Kern Canal OW - 1975, 7- to 18-mm-deep erosion in middle third of basin, no report of rocks.

Kenswick Dam

S - 1975, general scour of basin floor 0.05 m, spills had flushed 0.2 m^3 rocks from basin which were reported there in a previous divers' examination.

Arbuckle Dam

S - 1976, soft silt deposit 0.15 to 0.40 m deep with scattered rock, most rock located near toe of the spillway chute.

OW - 1976, eight buckets of rock, 20 to 200 mm in diameter, removed, most rock located at toe of the chute. Concrete in good condition.

Cheney Dam

S - 1976, silt deposit left downstream end of basin extending over to the right wall, 6.2-m-deep left wall and 1.4-m-deep right wall. Silt entered basin from surface runoff and also from sediment-laden water released from the outlet works. Scattered rocks from pebble size to 0.2 m in diameter were on and in the silt.

OW - 1976, about 0.3 m^3 scattered rocks in basin, no concrete damage.

Dickinson Dam

S - basin unwatered in 1967 and 1973, and debris cleaned out (photographs of 1973 indicated very small amount of debris and some rocks).

Hyrum Dam

S - 1975, rock and mud at upstream and downstream ends of the basin. There did not appear to be any appreciable "ball mill" action of the rocks.

Norman Dam

S - 1976, floor covered with 1.8-m-depth soft silt sediment deposit. Few rocks, most prevalant at toe of the chute.

OW - 1976, 2-m soft silt deposit, with scattered wood debris and rocks up to 250 mm in diameter.

Starvation Dam

S - 1975, deposit 0.3 m thick of gravel and cobbles on spillway chute about 1.5 m upstream from the toe, 8 to 9 m^3.

OW - 1975, 0.3-m-depth deposit of sand and small gravel extending 2.4 m downstream from the toe of the chute.