Evaluation of Mining Permits Resulting In Acid Mine Drainage 1987-1996: A Post Mortem Study

Prepared by the

Pennsylvania Department of Environmental Protection
Office of Mineral Resources Management
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Executive Summary

Acid mine drainage (AMD) is Pennsylvania's single greatest source of water pollution, responsible for over 2,400 miles of polluted streams. Most, but not all, of this pollution is from discharges from mines abandoned before the 1964 amendment to the Clean Streams Law that required mine operators to treat mine drainage. Since that time, applicants for mining permits have been required to demonstrate that mining would not cause mine drainage pollution following reclamation of the mine. However, as is often the case, science trailed the law. It was not until the early 1980s that postmining water quality could be predicted with any degree of reliability.

A distinct drop in the number of permits resulting in postmining AMD discharges occurred beginning in 1984, when permit applicants were required to submit scientific data to be used to assess a site's potential to generate AMD. The purpose of this study was to examine all of the mining permits issued during the most recent 10 years with available data (1987-1996) to determine the frequency and severity of AMD generation and to learn how AMD can be further prevented in Pennsylvania's permitting, monitoring and compliance programs.

Of the 1,699 permits issued in this 10-year period, 50 were identified to have current or past postmining discharge problems. The remaining 1,649 sites had no known current or past postmining discharges. These 50 sites were selected for further review. On closer examination, 22 of these permits no longer

These 50 sites were selected for further review. On closer examination, 33 of these permits no longer had water quality problems or the problem had not actually resulted from the permitted mining activity. Only 17 permits, or 1 percent of the total permits issued, were found to have caused long-term postmining discharges serious enough to require treatment and prevent bond release. Analysis of these 17 sites using current knowledge of mine drainage prediction, revealed that the most common cause of error was inadequate information in the permit application. Errors in interpretation of the application data and in implementing the permit were less common. A very small percentage of all permits issued resulted in postmining discharges for no clearly identifiable reason. Trends over the 10-year study period indicated a decreasing incidence of permits resulting in postmining discharges. Further, with the exception of the first few years of data, most of the postmining discharges were of relatively mild quality and amenable to passive treatment. It was recognized that the study is best applied to bituminous surface mines. Postmining discharge problems associated with anthracite mines and underground mines are not manifested soon enough or clearly enough to have been successfully included in this study.

A science-based approach to permitting and an emphasis on preventing AMD has been very effective in minimizing the incidence and severity of new discharges. Significantly, AMD is now largely a historical problem rendered by past mining. This study provides specific findings and recommendations related to further improving the review of permits and increasing Pennsylvania's 99 percent permitting success rate.

Findings and observations relating to technical aspects of postmining water quality prediction and AMD prevention are detailed in the report. Specific findings of note include: (1) Low rates of alkaline addition appeared to have little affect on postmining water quality; (2) Alkaline sandstones or typically alkaline coal seams do not assure alkaline drainage; (3) Overburden analysis drilling must be representative of the strata to be mined; (4) Raw pit water samples are useful in early detection of postmining water quality problems; (5) Special handling alone may not prevent AMD unless alkaline strata are also present; (6) Acid-base accounting alone cannot accurately predict alkaline-manganese discharges; and (7) Some AMD problems have resulted from unmined coal barriers and leaking ponds.

Recommendations include the following: (1) Better methods should be developed for predicting postmining manganese problems; (2) Continuing education for permit reviewers has been very successful in maintaining a high level of technical ability and should be continued; (3) Pit water and untreated discharge effluents should be sampled and documented on a regular basis; (4) Special handling and alkaline addition sites warrant increased inspection frequency and should be documented in detail in inspection reports; (5) Low rates of alkaline addition cannot be relied on to make a marginal permit issueable; (6) Classification and use of receiving streams should be given consideration in permit decisions; (7) Caution must be exercised in reviewing permits with all sandstone overburden or where the only source of neutralization potential is in sandstone; (8) No environmental reason exists to leave coal outcrop barriers in place; and (9) All of the available permit review tools, not just overburden analysis, should be considered in the review of a permit application.

Evaluation of Mining Permits Resulting in Acid Mine Drainage (AMD)

1987 – 1996

I. Background

The coal measures of Pennsylvania have significant potential to generate acid drainage. A 1970s survey of active surface and underground mines showed that nearly half of the sites in northern Appalachia generated acid drainage. In other areas of the country, acid drainage was less common and less severe. Due to the nature of the geology and climate, as well as the lack of laws governing water quality for coal mining operations, mining conducted before 1966 left a legacy of over 2,400 miles of polluted streams in Pennsylvania. Because of this, many people still believe that pollution is the inevitable result of coal mining.

In 1965, Pennsylvania's Clean Streams Law was modified to regulate discharges from coal mining operations. Active mining operations were then required to treat mine drainage to meet effluent standards. Still, many mining permits were issued for operations that would continue to discharge poor quality water, long after the completion of mining. In the mid-1970s, Pennsylvania began to address this situation by requiring those applying for mining permits to demonstrate that mining would not create a long-term water quality problem. At this time, the science of postmining water quality prediction was in its infancy. Few reliable tools were available to predict whether a site would create acidic or alkaline drainage. Since then, Pennsylvania's mining program has dramatically improved its success in predicting postmining water quality and preventing acid mine drainage (AMD) formation. From 1977 through 1983, 288 of the 1,706 mining permits issued, roughly 17 percent, are known to have resulted in postmining discharges that did not meet effluent limits (Table 1). In contrast, only 37 of the 1,699, or 2.2 percent of permits issued since 1987 were identified to have resulted in postmining pollutional discharges. Subsequent evaluation has shown the actual number to be even less. The drop in the rate of permits with pollutional discharges is chiefly attributable to advances in premining prediction of postmining drainage quality, a science-based permit review program and enhanced compliance monitoring, enforcement and compliance assistance. Further, Pennsylvania's coal industry has made a conscientious effort to prevent pollution by avoiding pollution-prone sites and by incorporating pollution prevention measures into their mining plans. Pennsylvania is recognized as the leader among Appalachian coal-producing states in AMD prediction and prevention. These advances have recently culminated in the preparation of an extensive research report, "*Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania.*"

One of the keys to this improvement has been the Pennsylvania Department of Environmental Protection's (DEP) continuing program self-examination and efforts to evaluate sites that produced AMD, in spite of rigorous permit review and compliance monitoring. It is in this spirit that DEP's bureaus of District Mining Operations and Mining and Reclamation, in cooperation with the federal Office of Surface Mining, Reclamation and Enforcement, initiated a review of mining sites with applications dating from 1987 through 1996. This review became commonly known as the AMD Post Mortem study. The purpose was to study successes and failures in AMD prediction and prevention in order to adjust practices for improvement; as well as to critically evaluate our permitting and compliance monitoring program.

Table 1: Mining Permits Issued and Postmining Non-Discharges

Year[1]	Permits Issued	Permits with a Discharge	Percent of Permits with a Discharge
1977	341	54	16%

1978	265	35	13%
1979	212	50	24%
1980	230	36	16%
1981	245	51	21%
1982	228	37	16%
1983	185	25	14%
1984	250[2]	7	3%
1985	250[2]	13	5%
1986	250[2]	2	<1%
1987	250[2]	5	2%
1988	221	7	3%
1989	181	8	4%
1990	183	5	3%
1991	167	5	3%
1992	142	4	3%
1993	148	1	<1%
1994	151	0	0%
1995	143	1	<1%
1996	113	1	<1%

[1] Year of application
[2] Estimated number of applications received for the year

II. Evaluation Criteria

Each of the cases examined presents its own unique story. Practically speaking, it is nearly impossible to develop a meaningful checklist that would accurately reflect the complexities involved in determining just what went wrong. Instead, several key questions were posed to focus, but not constrain, the evaluation. These questions served as the principal evaluation criteria.

1. On closer examination, is this a site where bond release should be held due to postmining non-complying discharges? Some sites may now be eligible for bond release, such as where a postmining discharge has subsequently improved in quality, diminished in flow or now meets the alkaline-manganese exemption.
2. Is liability due to an administrative reason rather than a pollution problem that resulted from mining on this permit? For example, is it a pre-existing on-permit discharge which did not get worse but the permittee failed to obtain Subchapter F authorization, or is it a permitted discharge

from an existing deep mining or refuse disposal operation?

3. Was the postmining water quality prediction based on inaccurate or inadequate permit application information that may have affected the outcome of the permit review? Did field conditions (if determinable) match the information in the application? These sites are referred to as having an application error.
4. Was the permit review decision flawed, given DEP’s current state of understanding about postmining water quality prediction and the information contained in the application? These permits are referred to as having an interpretation error.
5. Did the operator fail to effectively implement the mining plan in the field; i.e. was there an implementation error?
6. Did postmining AMD result despite adequate permit information and a reasonable permit review decision? In other words, is there a certain error rate in DEP's predictive ability, even when everything goes the way it is expected, i.e., a random error?
7. Did field conditions indicate an impending AMD problem that would have permitted an early remedy, possibly preventing a postmining problem?
8. How severe were the consequences of the postmining drainage, considering water chemistry, the ability to passively treat the discharge and the environmental impact of the discharge?

III. Procedure

First and foremost, this permit evaluation is intended to enhance our knowledge and understanding of predicting and preventing AMD. It is not intended to serve as a performance evaluation for individual DEP district offices or permit reviewers. A team of experienced permit reviewers consisting of the six DEP district mining office lead hydrogeologists, a DEP central office hydrogeologist, a district mining manager and two hydrologists from the OSM Pittsburgh Field Office conducted the reviews. The team members are as listed.

- David Bisko, hydrogeologist, DEP Moshannon District Mining Office
- Keith Brady, hydrogeologist, DEP Bureau of Mining and Reclamation
- Robert Evans, hydrologist, OSM Pittsburgh Regional Office
- Scott Jones, hydrogeologist, DEP Greensburg District Mining Office
- Tim Kania, hydrogeologist, DEP Ebensburg District Mining Office
- Joel Koricich, hydraulic engineer supervisor, DEP California District Office
- Jeff Kost, hydrogeologist, DEP Pottsville District Mining Office
- Eric Perry, hydrologist, OSM Pittsburgh Regional Office
- Michael Smith, mining manager, DEP Moshannon District Mining Office
- Joe Tarantino, hydrologist, DEP Knox District Mining Office

Team members averaged 17 years of experience in mine drainage issues. For consistency, the same team evaluated permits at each office, although each and every team member was not present for each office evaluation. At a minimum, four members of the team were present for each review. Except where there was no current discharge liability or only administrative liability, no team member participated in the review at his home office.

The evaluation team initially selected 37 permits to review of the 1,699 permits issued between 1987 and 1996. These 37 comprised the entire population of permits that resulted in postmining pollutional discharges for this time period. District office staff identified 13 additional permits having possible postmining discharge problems and, therefore, warranted study. In total, 50 files were reviewed. The evaluation consisted of: (1) a review of information contained in the original permit application; (2) a file review of correspondence and comments during the permit review as well as post-permit issuance inspection reports, technical reports and compliance actions; (3) personal interviews with the permit reviewer and inspector(s); and (4) a review of DEP and company water monitoring data. Two team members reviewed each file and provided a summary of their findings under the evaluation criteria listed above.

At the close of each district office visit, the review team held an exit conference with the office staff to discuss their findings. This was the only discussion of the findings relative to an individual district office. This report considers the collective findings of the review team at all of the district offices combined. In keeping with the focus of the report on the overall performance of our program, individual permits and reviewers are not identified in this report.

IV. Results

A. *Summary Statistics*

The team reviewed 50, or 2.9 percent, of the 1,699 permits issued between 1987 and 1996 (based on the year the application was made, not the actual issuance date). As described above, these 50 permits represent the entire population of permits with known postmining pollutional discharges, either temporarily or on a long-term basis. Of these sites, 21 were found to have no current treatment liability for a variety of reasons listed below. Of the remaining 29 sites, 12 had discharge liability for "administrative" reasons, i.e. the issuance of the permit and mining of the site did not cause postmining discharges. Examples of sites in this category include permits that should have been eligible for Subchapter F permits but were not permits issued to underground mines with existing discharge problems pre-dating the permit, coal prep permits with existing discharges and refuse disposal permits with permitted and existing or anticipated discharges. Sites having strictly administrative discharge liability were excluded from further study in this review. Finally, 17 sites actually had incurred long-term discharge problems and liability for treatment of discharges, resulting in a remarkably low 1 percent rate of permits resulting in postmining discharge liability.

Appendix A summarizes the results of each of the 50 permit reviews and is the principal basis of this report. The 17 sites with discharge liability are highlighted. Of these 17 sites, 11 had inadequate information in the permit application on which to make a sound judgement ("application error"); in 9 of the 17 cases, the reviewer erred in judgement when recommending issuance if viewed in the context of what we know today ("interpretation error"); 5 sites had documented problems implementing the mining plan as required ("implementation error"); 6 sites unexpectedly resulted in postmining AMD, even given the current state of our knowledge in predicting postmining water quality ("random error"). Some sites were determined to be subject to more than one category of error; therefore, some overlap in classifications exists.

Table 2: AMD Post Mortem Summary Statistics	
Total Permits Issued	1699
Sites Reviewed	50

Sites with Current AMD Liability	17
Sites with Administrative Liability	12
Sites with No Current Liability	21

CHART 1

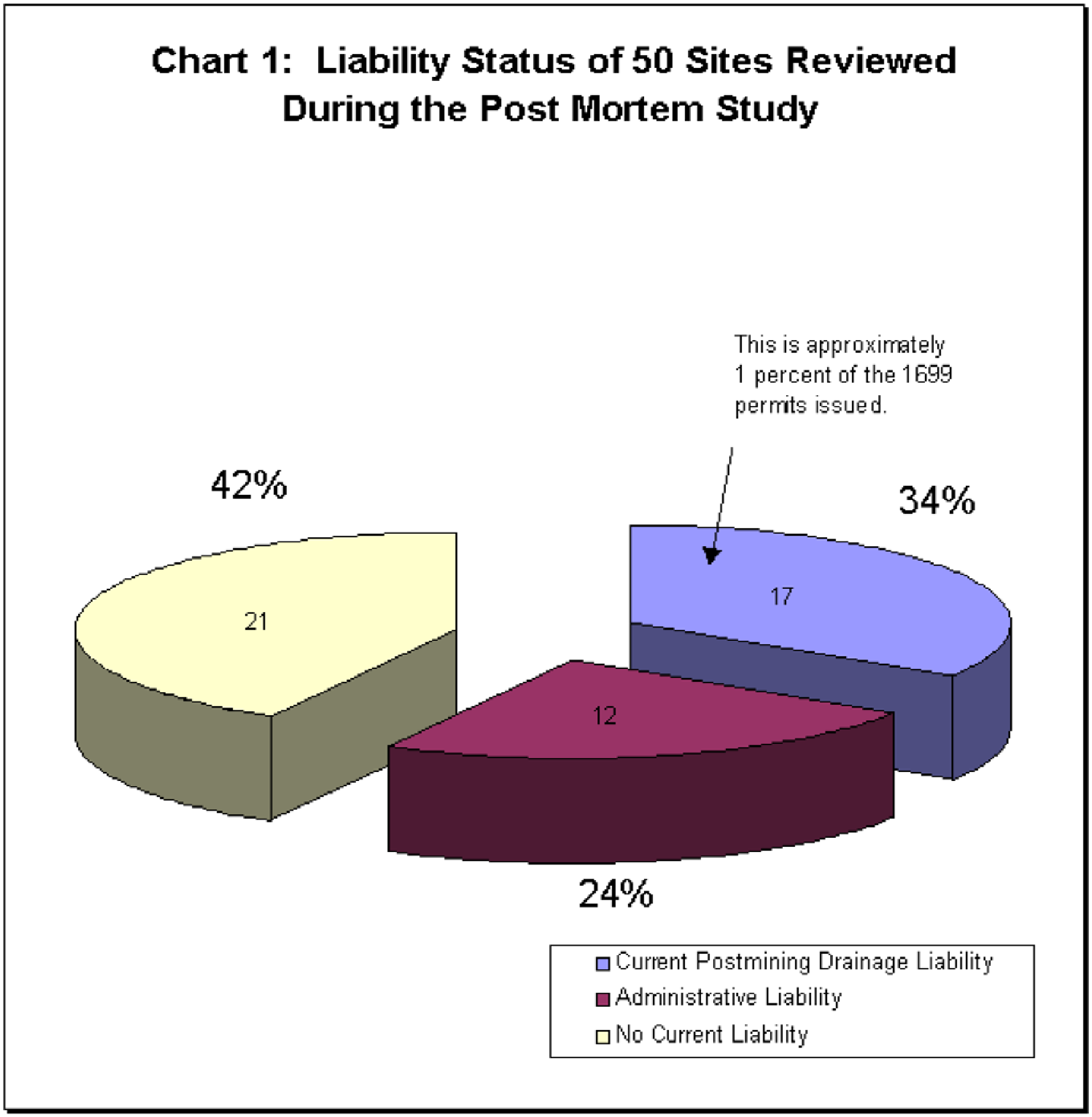


Table 3: Summary of Sites with Current AMD Liability	
Application Error	11

Interpretation Error	9 [1]
Implementation Error	5 [2]
Random Error	6 [3]
Preventable in Field	3

[1] 5 sites overlapped with application error
[2] 4 sites had insufficient documentation to determine
[3] 2 sites overlapped with application error

Table 4: Postmining Discharge Severity		
Mild AMD	8	1987, 87, 87, 88, 89, 91, 92, 96
Moderate AMD	6	1987, 88, 88, 88, 88, 94
Severe AMD	3	1987, 87, 89
Acidic Discharges	13	1987, 87, 87, 87, 88, 88, 88, 88, 89, 89, 91, 92, 94,
Alkaline Discharges	4	1987, 87, 88, 96

CHART 2

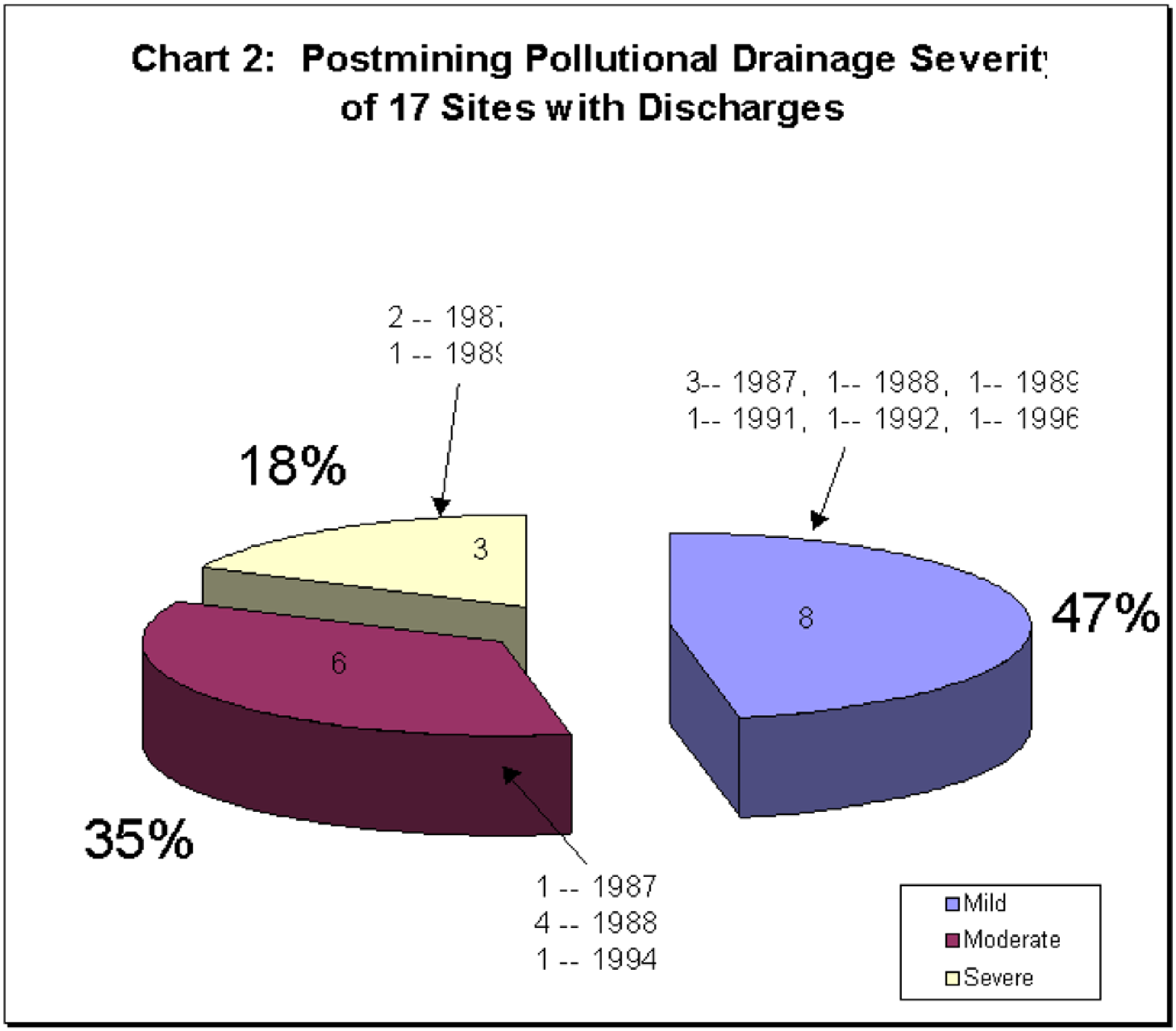


Table 5: Summary of Sites Determined to Have No Current AMD Liability		
Alkaline-Manganese Sites	8	ID nos. 8, 11, 14, 16, 29, 33, 35, 36
Discharge Improved Later	2	ID nos. 4, 12
No Current Discharge Problem	10	ID nos. 6, 7, 19, 20, 22, 31, 34, 37, 44, 49
Discharge Disappeared/Dried Up	1	ID no. 15

CHART 3

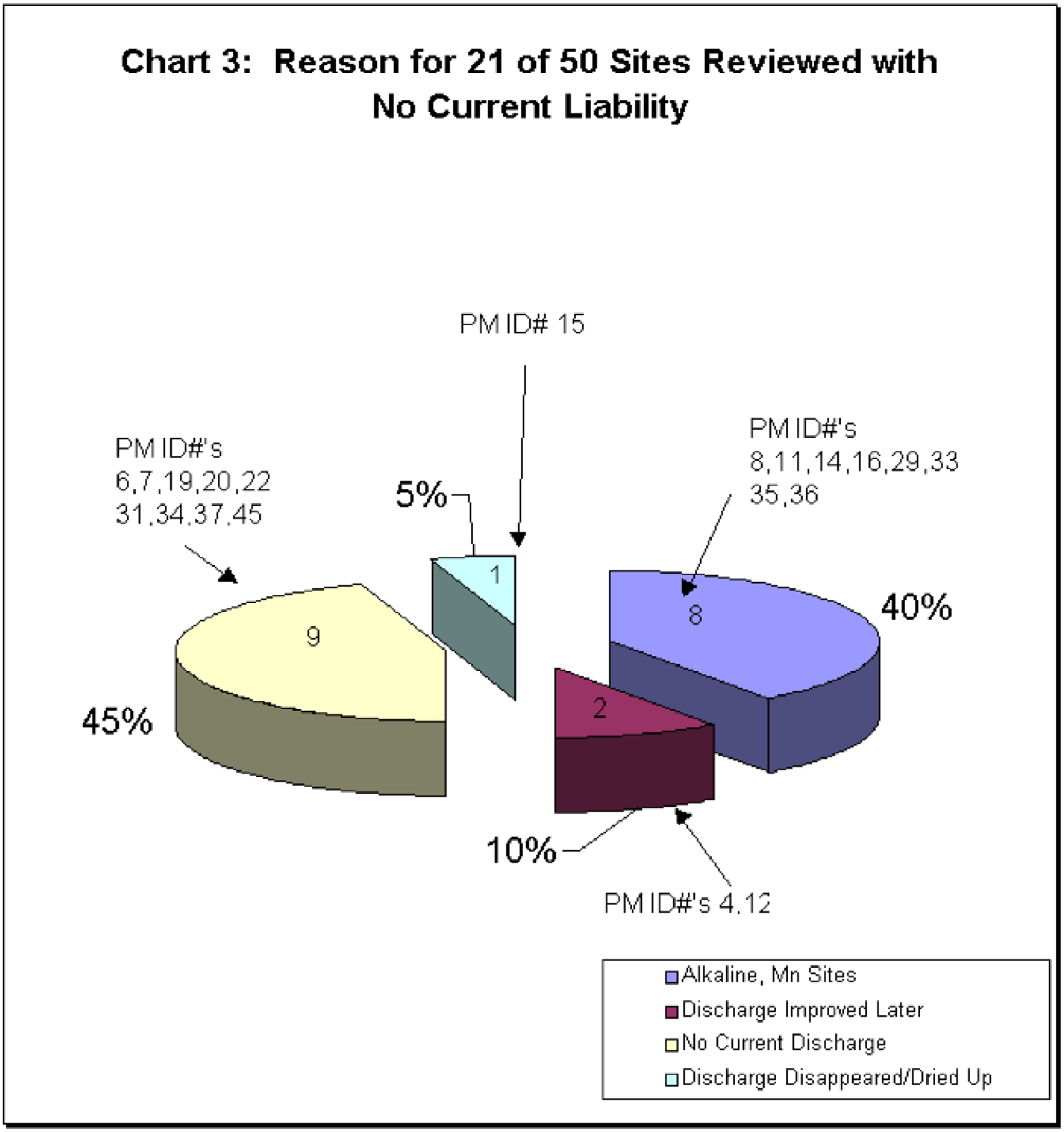
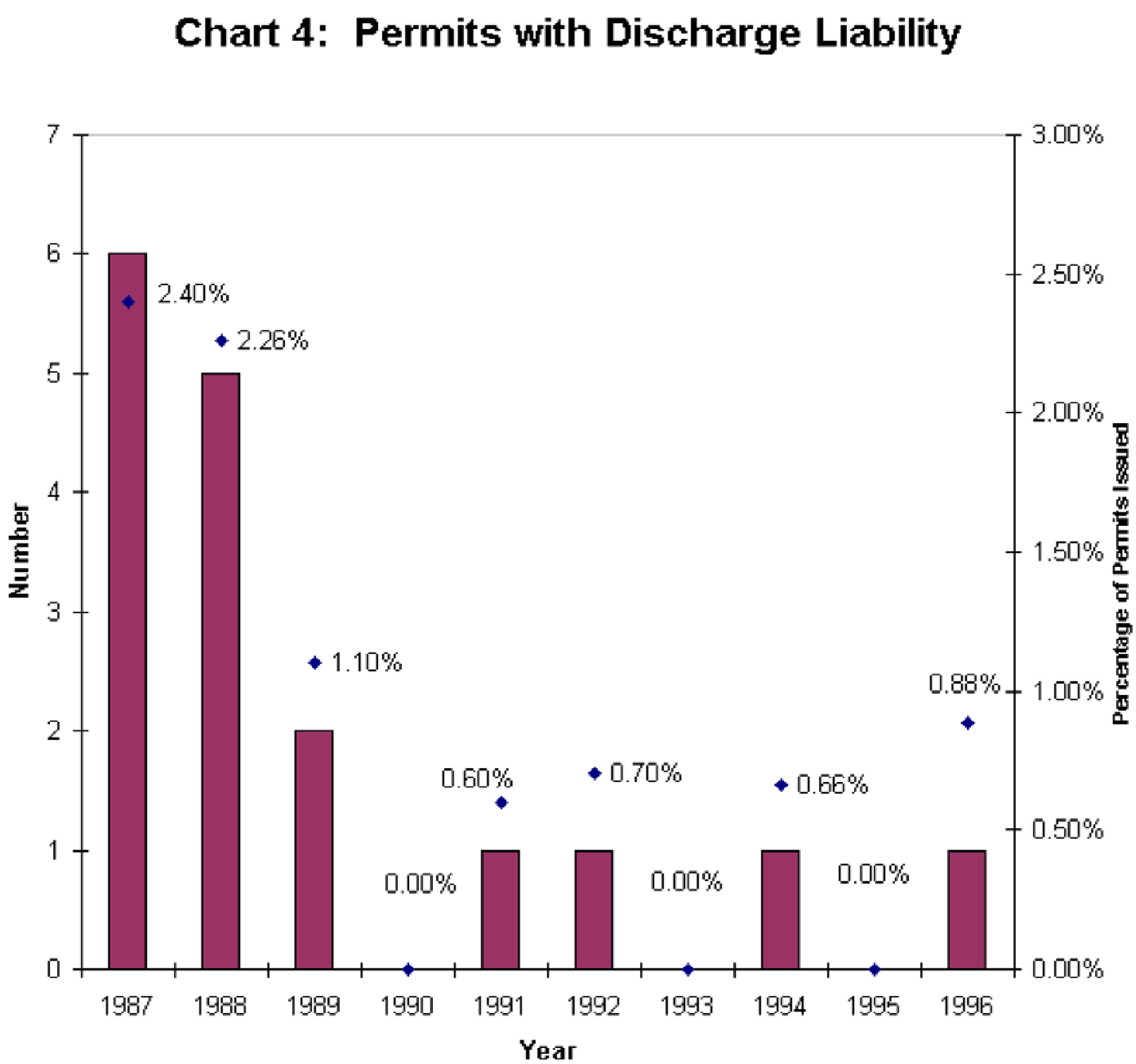


Table 6: Number of Permits with Discharge Liability by Year

1987	6		1992	1
1988	5		1993	0
1989	2		1994	1
1990	0		1995	0

1991	1		1996	1

CHART 4

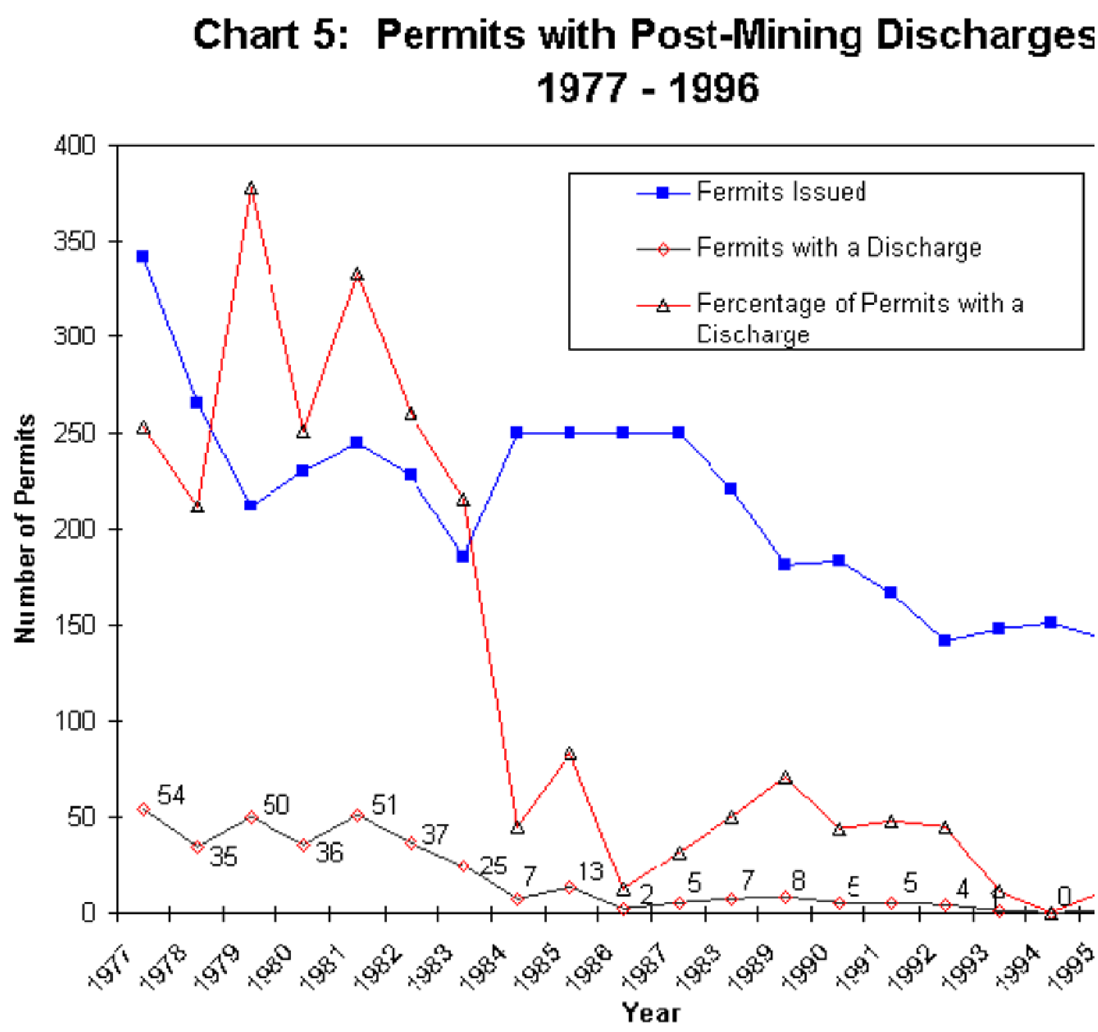


B. *Discussion*

In interpreting the statistics, caution must be taken in a few areas. First, the most recently issued permits in the group studied may have not yet been reclaimed long enough for a postmining discharge to develop. On reclaimed surface mines, at least one or two spring recharge seasons are usually required before mine spoils saturate enough to discharge groundwater. The life of underground mining permits is particularly long and several additional years may be required after closure until the mines flood with water. Therefore, this study is a much better indicator of the results of surface mining permits rather than underground mining permits. Anthracite mines, because they usually are located above large mine pools or represent only a small fraction of a large mine complex, tend to not have on-permit or nearby postmining discharges and accordingly, are not represented in this report. Likewise, the remaining 1,649 sites resulted in no visible or known postmining discharge. This does not mean that the site is not producing mine drainage or affecting water quality, only that it does not occur at the surface in proximity to the mine site.

The graph below shows the marked decline in the number of permits with postmining discharges. This decline appears to have started in 1982 or 1983 or about the time Pennsylvania adopted primary jurisdiction for enforcement of the federal Surface Mining Conservation and Reclamation Act. By 1990, very few permits resulting in postmining discharges were issued.

CHART 5



Another indicator of our success in preventing or reducing AMD is the severity of postmining AMD when it does occur. Only 3 of the 17 discharge sites produced severe AMD. Half of the sites produced mild AMD or drainage that is readily amenable to passive treatment and results in little impact to streams or water supplies. Moderate AMD is considered to either have impediments to passive treatment (such as elevated metals) or adversely impacted a stream or water supply. Severe AMD could not be passively treated and/or resulted in significant environmental impacts. Of the 9 sites with moderate or severe water quality impacts, only 1 was a permit issued after 1989. It can be concluded; therefore, that even in relatively rare cases where current permits result in postmining discharges, they are likely to be of very minor impact and amenable to passive treatment.

very minor impact and amenable to passive treatment.

The impact of special handling plan implementation on postmining water quality is often difficult to determine. Of the 17 sites with postmining discharges, 5 had documented problems in implementing special handling or alkaline addition plans, but on an additional 4 sites, it was impossible to determine, through a file review, whether or not the handling plan had been implemented as required. Conversely, some inspectors did a very thorough job documenting whether the special handling plan was being implemented. Documentation of special handling tended to be either exceptionally detailed and thorough or largely absent.

Only 3 of the 17 sites reviewed by the team were thought to have been preventable by paying heed to early indications of AMD. Oftentimes there is no early indicator of a problem, especially where the postmining AMD tends to be relatively mild. In some cases, early warnings of a problem existed but the only solution was to cease additional mining. While this did not prevent AMD, it certainly prevented causing a more severe AMD problem.

C. *Findings and Observations*

While the summary statistics are mostly self-explanatory, several interesting observations come out of their review. Some are obvious and some are more speculative. However, they do provide insight as to where permit reviewers need to be more cautious during permit reviews and where new research in postmining water quality prediction needs to be focused. The following observations are listed in no particular order of importance or certainty.

1. Relatively low rates of alkaline addition, 20 to 100 tons per acre for example, appear to have little or no lasting effect on postmining water quality and should not be relied upon to ensure alkaline drainage from a site with marginal overburden quality. Further, small amounts of lime on the pit floor may delay recognition of the long-term impacts by producing anomalously alkaline pit water that does not persist after reclamation. However, this should not be construed to discourage small rates of alkaline addition as a best management practice on permits that would be otherwise issueable (sites 1, 3, 5, 10, 17, 28a, 28b).
2. Alkaline sandstones can be misleading, particularly where high neutralization potential (NP) only appears in one or two test holes. The alkaline zone does not necessarily persist along with the sandstone. Coal seams that typically produce alkaline water (Upper and Lower Freeport, for example) may still produce AMD where all sandstone overburden and no source of NP exist. It is not always prudent to waive the requirement to conduct overburden analysis (OBA) on these sites (sites 2, 5, 11, 15, 25).
3. Overburden analysis data in the permit application may not be representative of the mining operation where the OBA is done at maximum cover, but much of the mining will take place at low cover. High NP zones evident in a high-cover OBA hole were often not present at the shallow cover that was actually mined (sites 1, 3, 15, 24, 25, 26).
4. Raw pit water samples are extremely useful in early detection of postmining water quality problems, except where lime is being applied to the pit. Also, good documentation of where the pit water is coming from is crucial for interpretation (i.e. Is the water coming from the highwall, the backfill, a limed pit floor, etc.?). Similarly, water samples of the raw discharge water, not just the treated effluent, are very helpful for early assessments of postmining water quality problems (sites 1, 4, 8, 10, 25, 27, 29, 32, 36).
5. Special handling alone is not sufficient to ensure postmining drainage meets standards unless some source of NP exists (sites 5, 17, 18, 24, 28a, 28b).
6. Alkaline manganese discharges cannot be predicted solely through acid-base accounting. The most reliable predictor at this time appears to be postmining water quality from adjacent sites. Manganese problems were noted to occur most typically with the Freeport sandstones and where a marine shale accompanies the Lower and Middle Kittanning coals (sites 2, 4, 8, 10, 11, 14, 16, 29).
7. Some relatively minor AMD problems appear to have been caused by unmined barriers of coal or

7. Some relatively minor AMD problems appear to have been caused by unmined barriers of coal or leaking treatment and sedimentation ponds (sites 8, 9, 10).
8. Sometimes, although very infrequently, despite a good application and experienced permit reviewers making reasonable judgements, poor postmining water quality results. Reassuringly, this was the case on only 6 of the 17 permits reviewed or on only 0.35 percent of the 1,699 permits that were the basis of this study (sites 3, 13, 23, 27, 30, 32).
9. It frequently takes a year or longer after backfilling for poor water quality to become evident. Pollution prevention, not after-the-fact abatement needs to be stressed in permit review (sites 2, 10, 17, 24, 25, 28a, 28b, 32).
10. Special handling plans were difficult to document if they were followed in the field. There are some notable exceptions where special handling was very well documented (sites 3, 8, 9, 10, 14, 15, 17, 24, 25, 26, 27, 29).
11. A disproportionately large number of postmining discharges occurred on sensitive or special protection watersheds. These are the watersheds where permitting decisions should be the most conservative. On the other hand, given the low rate of postmining discharges and the fact that most of them are amenable to passive treatment, it may be appropriate to be more flexible in permitting decisions on severely AMD-impacted watersheds. This is especially the case on remining sites where considerable reclamation or a reasonable chance of water quality improvement will result (sites 10, 12, 17, 18, 32).
12. Inadequate information in the application was the most frequently cited problem with the permits that produced postmining discharges (sites 1, 2, 5, 13, 17, 24, 25, 26, 27, 28a, 28b).
13. The retention of trained staff, knowledgeable about postmining water quality prediction, permit review and DEP policies and procedures appear to be important elements in our ability to predict and prevent postmining discharges.

V. Summary and Recommendations

The summary statistics clearly show the high degree of success achieved in predicting the occurrence of and preventing additional acid mine drainage. Only 1 percent of the permits issued in the past 10 years resulted in postmining water quality problems severe enough to warrant holding reclamation bonds. This contrasts markedly with our performance during the prior 10 years -- 1977 through 1986, which resulted in a much higher incidence of postmining AMD (Table 1).

The high level of success in preventing AMD is mostly due to advances in the science of AMD prevention and prediction. But it also speaks very well of the quality of DEP's permit review and compliance monitoring staff. Good science can only come from good scientists who are adequately trained and current. Most errors in interpretation occurred during the earliest years of the study period, suggesting that inexperience might be a large part of the problem that has since been remedied by the high staff retention currently experienced by the DEP district mining offices. Further, no particular pattern was noted indicating that any single district office had a particularly good or poor record. It is reasonable to expect that experienced permit reviewers are more likely to be familiar with standards for review and less likely to issue flawed permits.

During the 10-year period examined in this study, three program changes were implemented which undoubtedly improved performance including: (1) A district office lead hydrogeologist was designated, who is responsible for mentoring and reviewing the work of less experienced hydrogeologists; (2) The bureaus of Mining and Reclamation and District Mining Operations initiated a technical training program emphasizing AMD prediction and prevention; and (3) Post-permit issuance conferences with the lead permit reviewer, the inspector and the mine operator became a standard operating practice whenever a new permit was issued, ensuring that the field staff and operator were fully briefed on technical aspects of the permit.

Of the 17 sites with postmining discharges, the most common error noted was inadequate or inaccurate permit information (11 sites). Using current review standards, different permit review decisions would have been made on 9 sites. On 5 sites, special handling or alkaline addition was not properly implemented in the field. Only 6 sites produced postmining discharges for no clear reason. This equates to 0.35 percent of the permits issued during the period.

Most postmining discharges, especially those from permits issued during the past five years, are relatively mild in quality and amenable to passive treatment. At least on surface mining operations, the days where permits were issued resulting in severe AMD requiring chemical treatment are largely over. Based on the results obtained from this study, several recommendations are in order.

1. Better methods should be developed for predicting postmining manganese problems.
2. Continued education for permit reviewers has been very successful in maintaining a high level of technical ability and should be continued.
3. Pit water and untreated discharge effluents should be sampled and documented on a regular basis.
4. Special handling and alkaline addition sites warrant increased inspection frequency and should be documented in detail in inspection reports.
5. Low rates of alkaline addition have their place, but should not be counted on to make a marginal permit issuable.
6. Classification and use of receiving streams should be given consideration in permitting decisions. Permit reviewers should be conservative on special protection or sensitive watersheds, but open to new ideas and reclamation opportunities on badly degraded streams.
7. Caution should be exercised in reviewing permits with all sandstone overburden or where the only source of NP is in sandstone.
8. There is generally no environmental reason to leave coal outcrop barriers in place.
9. Use all available permit review tools, not just overburden analysis.

Footnotes

[1]Bituminous Coal Research, Inc., 1977, Assessment of Research and Development Needs and Priorities for Acid Mine Drainage Abatement. BCR Report L-822, U.S. Bureau of Mines Contract J0265044.
[2]Pennsylvania's regulations require an affirmative demonstration that mining will not cause pollution. While AMD can readily be treated with current technology, long-term drainage, which persists after mining has ceased, may persist for decades or even centuries.
[3]EPA's effluent guidelines for coal mining operations and DEP regulations exempt manganese for alkaline discharges where untreated iron is less than 10 mg/l and in-stream water quality criteria are not exceeded.
[4]Special handling is a practice where potentially acid-forming strata in the overburden or coal reject material is segregated from the remaining overburden and placed in a manner that minimizes AMD formation.
[5]Alkaline addition is the practice of importing alkaline material from off-site into the mine spoil in order to compensate for overburden which is naturally deficient in alkaline ($CaCO_3$-rich) strata which tend to generate neutral or alkaline, rather than acidic, mine drainage.
[6]In some situations, like when typically very low sulfur overburden with limited natural neutralization potential exists, alkaline addition is used at relatively low rates (less than 200 tons per acre) as an added safety factor to ensure alkaline drainage. Alkaline addition would not necessarily be required to prevent AMD.
[7] Overburden analysis (OBA) is the geochemical analysis of the strata that will be affected by mining used to assist in predicting postmining water quality. Acid-base accounting, which compares sulfur contents (potential acidity) to the availability of potential neutralizing agents is the most common form of OBA.
[8]Special protection watersheds are listed in 25 PA Code Chapter 93 as high-quality or exceptional value streams. Sensitive watersheds, while not formally designated, are those that would be easily impacted by mine drainage, such as naturally-reproducing trout streams.

Appendice: AMD Post Mortem Review Data

Site ID					Hold Bonds?	Admin. Liability	App. Error	Interp. Error	Field Imple.	Rand. Error	Prevent-able?	How Sever
No.	year	type	Reviewer 1	Reviewer 2	1	2	3	4	5	6	7	8
1	87	surface	Tarantino	Jones	yes	no	yes	yes	no	no	no	low
2	88	surface	Bisko	Brady	yes	no	yes	yes	d.k.	no	yes	mod
3	89	surface	Brady	Jones	yes	no	no	no	d.k.	yes	no	low
4	89	surface	Tarantino	Brady	no	no	no	no	no	yes	no	low
5	89	surface	Bisko	Brady	yes	no	yes	yes	no	no	no	severe
6	89	surface	Jones	Tarantino	no	no	na	na	na	na	na	na
7	90	reprocess	Brady	Bisko	no	no	na	na	na	na	na	na
8	91	surface	Jones	Perry	no	no	yes	no	no	no	no	low
9	92	surface	Bisko	Perry	no	yes	no	no	d.k.	yes	no	low
10	92	surface	Tarantino	Perry	yes	no	no	yes	no	no	d.k.	low
11	87	surface	Kania	Koricich	no	no	yes	no	no	no	no	low
12	87	surface	Tarantino	Koricich	no	no	no	no	no	no	no	na
13	88	surface	Kania	Koricich	yes	no	yes	no	no	yes	no	low
14	88	surface	Tarantino	Perry	no	no	no	no	d.k.	no	no	low
15	89	surface	Brady	Perry	no	no	no	no	d.k.	yes	no	low
16	95	surface	Brady	Kania	no	no	no	no	no	no	no	low
17	94	surface	Brady	Tarantino	yes	no	yes	yes	d.k.	no	no	mod

17	94	surface	Brady	Tarantino	yes	no	yes	yes	d.k.	no	no	mod
18	96	surface	Kania	Perry	yes	no	no	yes	no	no	no	low
19	87	surface	Jones	Smith	no	no	na	na	na	na	na	na
20	96	surface	Jones	Smith	no	no	na	na	na	na	na	na
21	89	surface	Jones	Smith	yes	yes	na	na	na	na	na	low
22	92	reprocess	Jones	Smith	no	no	na	na	na	na	na	na
23	87	surface	Jones	Kost	yes	no	no	no	no	yes	no	low
24	87	surface	Kania	Kost	yes	no	yes	yes	yes	no	no	mod
25	88	surface	Kania	Perry	yes	no	yes	no	yes	no	yes	mod
26	88	surface	Kania	Perry	yes	no	yes	no	yes	no	no	mod
27	91	surface	Kost	Jones	yes	no	yes	no	d.k.	yes	no	low
28a	87	surface	Perry	Jones	yes	no	yes	yes	yes	no	no	severe
28b	87	surface	Perry	Jones	yes	no	yes	yes	yes	no	no	severe
29	87	surface	Brady		no	no	no	no	no	na	no	low
30	87	surface	Bisko	Kania	yes	no	no	no	no	yes	yes	low
31	88	surface	Tarantino	Smith	no	no	na	na	na	na	na	na
32	88	surface	Perry	Brady	yes	no	no	no	no	yes	no	mod
33	89	surface	Kania		no	no	no	no	no	yes	no	low
34	90	surface	Tarantino	Smith	no	no	na	na	na	na	na	na
35	90	surface	Tarantino	Smith	no	no	na	na	na	na	na	na

35	90	surface	Tarantino	Smith	no	no	na	na	na	na	na	na
36	91	surface	Bisko	Perry	no	no	no	no	no	yes	yes	low
37	88	undergnd	Koricich	Smith	no	no	na	na	na	na	na	na
38	88	ind.waste	Koricich	Smith	yes	yes	na	na	na	na	na	na
39	91	ind.waste	Koricich	Smith	yes	yes	na	na	na	na	na	na
40	91	undergnd	Koricich	Smith	yes	yes	na	na	na	na	na	na
41	90	refuse	Koricich	Smith	yes	yes	na	na	na	na	na	na
42	90	refuse	Koricich	Smith	yes	yes	na	na	na	na	na	na
43	91	prep.plant	Koricich	Smith	yes	yes	na	na	na	na	na	na
44	91	undergnd	Koricich	Smith	no	no	na	na	na	na	na	na
45	92	prep.plant	Koricich	Smith	yes	yes	na	na	na	na	na	na
46	93	prep.plant	Koricich	Smith	yes	yes	na	na	na	na	na	na
47	95	refuse	Koricich	Smith	yes	yes	na	na	na	na	na	na
48	95	refuse	Koricich	Smith	na	yes	na	na	na	na	na	na
49	96	undergnd	Koricich	Smith	no	no	na	na	na	na	na	na