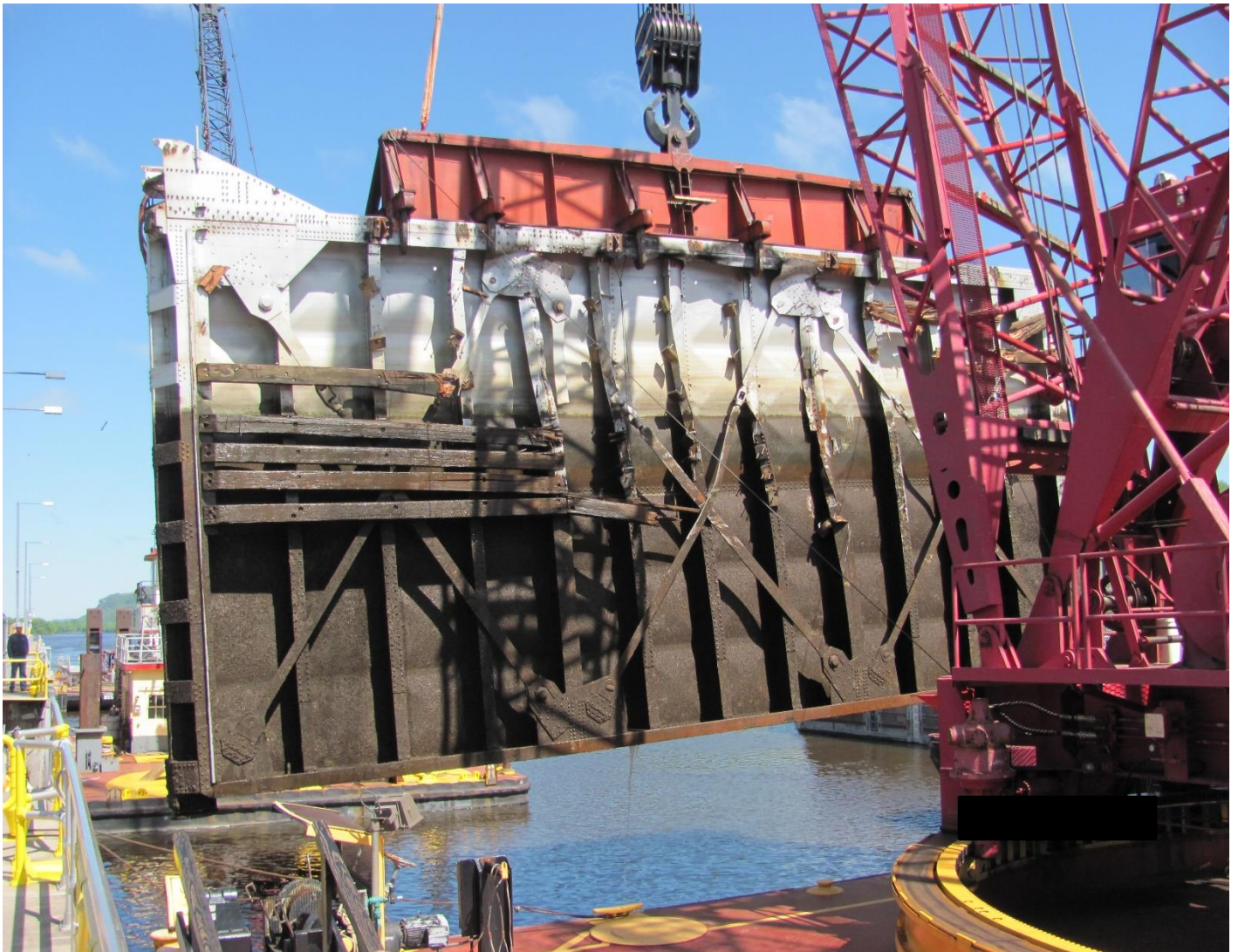




PIANC

The World Association for Waterborne
Transport Infrastructure

CRISIS MANAGEMENT OF ACCIDENTS IN NAVIGATION HYDRAULIC STRUCTURES



InCom Working Group Report N° 241 – 2024

PIANC REPORT N° 241

Inland Navigation Commission

CRISIS MANAGEMENT OF ACCIDENTS IN NAVIGATION HYDRAULIC STRUCTURES

March 2024

PIANC has Technical Commissions concerned with inland waterways and ports (InCom), coastal and ocean waterways (including ports and harbours) (MarCom), environmental aspects (EnviCom) and sport and pleasure navigation (RecCom).

This report has been produced by an international Working Group convened by the Inland Navigation Commission (InCom). Members of the Working Group represent several countries and are acknowledged experts in their profession.

The objective of this report is to provide information and recommendations on good practice. Conformity is not obligatory and engineering judgement should be used in its application, especially in special circumstances. PIANC disclaims all responsibility in the event that this report should be presented as an official standard.

PIANC HQ
Boulevard du Roi Albert II 20 B. 3
1000 Brussels | Belgium

<http://www.pianc.org>

VAT BE 408-287-945

ISBN 978-2-87223-039-6

© All rights reserved

TABLE OF CONTENTS

LIST OF FIGURES.....	6
LIST OF TABLES.....	8
1 Introduction.....	9
1.1 Objectives.....	9
1.2 Methodology.....	10
1.3 Research Field.....	11
1.4 General Framework of Report.....	12
1.5 Terms of Reference.....	13
1.6 Abbreviations.....	16
1.7 Related PIANC Reports.....	17
1.8 Members of the Working Group.....	18
1.9 Meetings.....	19
1.10 Acknowledgements.....	19
2 Context and classification of accidents.....	20
2.1 Introduction.....	20
2.2 Definitions.....	20
2.2.1 Navigation Hydraulic Structure.....	20
2.2.2 Failure.....	20
2.2.3 Accident.....	21
2.2.4 Calamity.....	22
2.2.5 Failure vs Accident vs Calamity.....	22
2.2.6 Regular Demand or Regular Procedures.....	23
2.2.7 Loss of Service.....	23
2.3 Calamity Versus Regular Demand.....	24
Table 2-1: Regular demand vs calamity, overview.....	24
2.4 Accident Perspective.....	24
2.4.1 Collision of Humbeek Bridge, Belgium (Case Study 14).....	26
2.4.2 Barge Accident at Lock 5A on Mississippi River, USA, 2013.....	26
2.5 Crisis Management.....	27
2.5.1 Crisis Management System.....	27
2.5.2 Crisis Management Team.....	28
2.6 Classification System.....	28
2.6.1 Initial Classification.....	29
2.6.2 Example of Emergency Legislation in Belgium.....	29
2.6.3 Example Emergency Legislation in the Netherlands.....	30
2.6.4 Example RIS in European Union & DVW, Belgium.....	31
2.6.5 USACE Example.....	31
2.6.6 SLSMC Example.....	32
2.6.7 Belgium.....	32
2.6.8 Panama Canal.....	33
2.7 Investigative Classification.....	33
2.7.1 USACE.....	33
Table 2-3: Classification of accidents and their investigations, source: USACE 385-1-99 regulation [1] updated in 2019.....	34
2.7.2 Example from the Netherlands.....	34
2.7.3 Internal Classification.....	35
2.7.4 USACE Lock Performance Monitoring System.....	36
2.7.5 ARIA: French Database of Accidents.....	37
Table 2-7: Parameters of the economic aspect, C in Millions of € [ARIA].....	38
2.8 Summary.....	38
3 Summary of case studies.....	39
3.1 Introduction.....	39
Table 3-1: Related WG 241 case studies of accidents and calamities (cf. appendix A2).....	39
3.2 Case 01 – Damage and Reconstruction of the Lith Weir Gate on the Meuse River.....	40
3.3 Case 02 – Ship Collision to the Grave Weir Gate Structures on the Meuse River.....	40
3.4 Case 03 – Markland Lock Gate Failure on the Ohio River, Warsaw, KY.....	41

3.5	Case 04 – Sablons Lock Gate Failure on the Rhône River.....	41
3.6	Case 05 – John Day Lock Vertical Lift Gate Failure on the Columbia River	42
3.7	Case 06 – Valleyfield Bridge Counterweight Sheave Failure on the Beauharnois Canal.....	42
3.8	Case 07 – Lock 7 Chamber Wall Collapse on the Welland Canal	43
3.9	Case 08 – St. Louis Bridge Over Speed Descent on the Beauharnois Canal.....	43
3.10	Case 09 – Gate Failure at the Eefde Lock in the Twente Canal	44
3.11	Case 10 – Vessels Collision in the Gamboa Reach, Panama Canal	44
3.12	Case 11 – Canal Partly Blocked: Vessel Damage and Crude Oil Spill, Panama Canal	45
3.13	Case 12 – Lock Gate Fatigue Failures in Germany in the 1980's and 1990's.....	45
3.14	Case 13 – Ship Collision to Lock Gate in the Kiel Canal.....	46
3.15	Case 14 – Vessel Impact on Humbeek Bridge, Belgium.....	46
3.16	Case 15 – Collision of Vessel 'Else' with Gate of Lock Kiel-Holtenau	47
3.17	Case 16 – Contact of Bulk Carrier Huron with the Soo Locks West Centre Pier	47
3.18	Concluding Remarks.....	48
4	Identifying and reducing the risk.....	49
4.1	Identifying Risks	49
4.1.1	Common Failure Modes	49
4.2	Risk Considerations.....	50
4.2.1	Hazard Categories	51
4.2.2	Risk Assessment	51
4.2.3	Risk Reduction.....	52
4.2.4	Maeslantkering Barrier.....	52
4.2.5	Panama Canal Regulations	53
4.2.6	Maintenance and Design Considerations to Reduce Risk.....	53
4.3	Interlock Failures	54
4.3.1	Markland Lock	54
4.3.2	Melvin Price Lock Interlock Failure	56
4.3.3	Risk Reduction with Interlock Systems.....	59
4.4	Gate Anchorage Failures and Fatigue Cracking on Mitre Gates.....	60
4.4.1	Markland Lock Fatigue Cracking.....	60
4.4.2	Mitre Gate Anchorage Failures.....	61
4.5	Ship Impacts	63
4.5.1	Soo Locks 1909 Accident Canadian Side	65
4.5.2	Soo Locks Accident 1909 American Side.....	68
4.5.3	Soo Locks Poe Lock 2020 Accident	69
4.5.4	Ship Arrestors	69
4.6	United States Demopolis Lock Failure	70
4.7	Safety Considerations for Risk Reduction.....	72
4.7.1	European Union Directive	72
4.7.2	Machinery Directive	72
4.8	Chapter Summary	73
5	Investigations of accidents	74
5.1	Importance and Objectives	74
5.2	Framework for Investigations.....	75
5.2.1	USACE: Regulation No. 385-1-99 USACE Accident Investigation and Reporting	76
5.2.2	United States Coast Guard and National Transportation Safety Board	77
5.2.3	International Maritime Organisation.....	78
5.3	Accident Boards.....	78
5.3.1	USACE: Board of Investigation.....	78
5.3.2	Canadian Safety Board	79
5.3.3	The Netherlands.....	79
5.3.4	Panama Canal Authority.....	80
5.3.5	Belgium	81
5.4	Other Investigation Issues	82
5.4.1	Conflicting Interests	82
5.4.2	Influence of Other Investigations	82
5.4.3	Warning Signs.....	83
5.5	Conclusions.....	83

6	Handling life safety risks	84
6.1	Introduction	84
6.2	Safety Regulations – Life Safety as an Absolute Priority.....	85
6.2.1	Canada.....	86
6.2.2	Panama.....	86
6.2.3	United States	87
6.2.4	France.....	87
6.2.5	The Netherlands.....	87
6.3	Potential Hazards Arising from Navigational Hydraulic Structures	87
6.3.1	Dangerous and Fast Currents.....	89
6.3.2	Risk of Collapse	89
6.3.3	Risk of Entrapment or Confined Spaces.....	90
6.3.4	Risk of Falling from Heights	91
6.3.5	Other Hazards	92
6.4	Emergency Response Planning	92
6.5	Safety of Life at Design Phase.....	93
6.6	Summary and Conclusions.....	94
7	Recovering from the damage	95
7.1	Introduction	95
7.2	Recovery Process in a Fish-Diagram.....	95
7.3	Replacement or Repair	97
7.4	National Practices Examples.....	99
7.4.1	United States	99
7.4.2	The Netherlands.....	100
7.4.3	Belgium.....	101
7.4.4	Panama.....	102
7.4.5	France.....	103
7.4.6	Germany	104
7.4.7	Canada.....	105
7.4.8	China	106
7.4.9	Cambodia and Vietnam.....	107
8	Conclusions and Recommendations.....	109
8.1	Conclusions.....	109
8.2	Recommendations	111
9	References.....	112
9.1	Report references.....	112
9.2	PIANC References.....	114
9.3	Literature References and Bibliography	114
10	Appendices.....	116

LIST OF FIGURES

Figure 1.1:	'Fish diagram' for process stages in handling accidents.....	15
Figure 2.1:	Failures vs. accidents vs. Calamities (by WG)	22
Figure 2.2:	Damaged lock gate (left) and spare gate (right) for Lock 5A on Mississippi River (Photos by James Ulrick USACE St. Paul District).....	27
Figure 2.3:	'Fish diagram' for accident and calamity handling: points of classification (R. Daniel)	29
Figure 3.1:	Lith weir gate failure, photo by Rijkswaterstaat	40
Figure 3.2:	Grave weir after ship collision, photo by Rijkswaterstaat	40
Figure 3.3:	Markland Lock gate failure (Photos by USACE)	41
Figure 3.4:	Sablons Lock gate failure (Photo by CNR)	41
Figure 3.5:	John Day vertical gate (Photos by USACE)	42
Figure 3.6:	Valleyfield Bridge Sheave Failure (Photo by SLSMC)	42

Figure 3.7:	Lock 7 chamber wall collapse (left) and repair (right) (Photos provided by SLSMC)	43
Figure 3.8:	St. Louis Bridge over Speed Descent on the Beauharnois Canal (Photo provided by SLSMC)	43
Figure 3.9:	Gate of the Eefde Lock in the Twente Canal after failure (Photo provided by Rijkswaterstaat)	44
Figure 3.10:	Damage to both vessels after collision in the Gamboa Reach (Photos provided by ACP)	44
Figure 3.11:	Crude oil spill collection and tanker blocking the lock chamber (Photo provided by ACP)	45
Figure 3.12:	Geesthacht Lock gate after (left) and before (right) repair of fatigue damage (Photos provided by BAW)	45
Figure 3.13:	Ship collision to Kiel-Holtenau Lock gate (Photo provided by WSA Nord-Ostsee-Kanal)	46
Figure 3.14:	Humbeek Bridge over the Brussels–Scheldt Canal (Photo provided by De Vlaamse Waterweg)	46
Figure 3.15:	Collision of vessel 'Else' to the gate of Kiel-Holtenau Lock (Photo provided by WSA Nord-Ostsee-Kanal)	47
Figure 4.1:	Markland Lock mitre gate leaf being lifted out after the failure (Photo by USACE Louisville)	55
Figure 4.2:	Markland Lock gate damage details: a) landward gate leaf ripped from anchorage; b) damage to the other mitre gate leaf (Photos by USACE)	56
Figure 4.3:	Mel Price auxiliary lock downstream gates after failure (Photo by USACE)	57
Figure 4.4:	Mel Price gate failure, details: a) damage to gudgeon anchors b) damage to the pintle (Photos by USACE)	58
Figure 4.5:	Interlock logic diagram for closing downstream mitre gate (USACE)	59
Figure 4.6:	Holt Lock anchorage failure (Photo by USACE)	62
Figure 4.7:	Initiation of fatigue cracks in fractured gate components: a) anchor bar of Mel Price Lock gate (Photo by USACE); b) chain connection pin of Lith Weir gate (Photo by Rijkswaterstaat)	62
Figure 4.8:	John Day Lock barge accident: a) gate lifted out of guides; b) damage to wire rope sheave (Photos by USACE)	64
Figure 4.9:	Mississippi River Lock 2 damage from barge impact (Photo by USACE)	64
Figure 4.10:	Smithland Lock United States damage to barge after collision with lock wall (Photo by USACE)	65
Figure 4.11:	Canadian Side Soo Locks accident showing water rushing out of lock (Photo and copyright by Parks Canada)	66
Figure 4.12:	Soo Locks lower gate damage (Photo and copyright by Parks Canada)	67
Figure 4.13:	Emergency dam and wickets (Photo and copyright by Parks Canada)	68
Figure 4.14:	Soo Locks ship arrestors: a) MacArthur Lock, general view; b) Poe Lock, top view of ship arrestor (Photos by USACE)	70
Figure 4.15:	Demopolis mitre gate sill failure (Photo by USACE)	71
Figure 4.16:	Demopolis Lock with barge helping to close lower mitre gates (Photo by USACE)	71
Figure 6.1:	Accident at Ohio River Montgomery Dam subsequent stages drawing by R. Daniel	84
Figure 6.2:	Accident at Ohio River Montgomery Dam sunken towboat (Photo by United States Coast Guard LTG Jesse Garrant)	85
Figure 6.3:	Prohibition signs for swimmers and boaters on small river weirs (Photos by R. Daniel)	85
Figure 6.4:	A hierarchy of controls taken from most effective to least effective measures (from United States National Institute for Occupational Health and Safety and Centers for Disease Control)	88
Figure 6.5:	Uncontrolled flow through the Lith weir gate on the Meuse River (Photo by R. Daniel)	89

Figure 6.6:	(a) Lift gate shown out of position following being struck by a vessel (left) (Photo by USACE) – (b) Repair of lock wall in the Welland Canal: notice the unstable position and potential for further movement (right) (Photo by SLSMC)	90
Figure 6.7:	Damage on the deck of the Maria Valentine following collision with the Grave Weir on the Meuse River (Photo by Rijkswaterstaat)	91
Figure 6.8:	(a) View of Bridge 9 superstructure in the St. Lawrence Seaway (Photo provided by SLSMC) (b) view of Humbeek bridge on the Brussels-Scheldt Sea canal in Belgium (Photo provided by De Vlaamse Waterweg).....	92
Figure 7.1:	Stages and engagement of resources when handling accidents.....	95
Figure 7.2:	Melvin Price Lock gate repair after failure in 2004: a) cutting the anchors, b) gate in turning feet on barge, c) heat straightening, d) gate return on maintenance barge (Photos provided by USACE)	96
Figure 7.3:	Armour rock dam laid after a ship collision to the Meuse River weir gate in Linne, May 2020 (Photo M. Hensen, Rijkswaterstaat).....	97
Figure 7.4:	Lith Weir flap gate replacement in 2008: a) damaged gate temporarily supported, b) old gate removed, c) fabrication of new flap, d) new gears for gate chain hoists, (Photos by R. Daniel and Hollandia b.v.).....	98
Figure 7.5:	Example repair event tree for Upper Ohio navigation structures [37], [24]	100
Figure 7.6:	Maintenance of Asper Weir gate with disassembly of top flap section [2] (Photos by MOW Vlaanderen).....	102
Figure 7.7:	Crack in the Geesthacht Lock vertical lift gate in the Elbe: a) cracked box girder, b) crack in flange, c) crack in web plate (Photos provided by W. Meinhold, BAW)	105
Figure 7.8:	A crack in the gate pintle (a) at the Seaway's lower Beauharnois lock required the removal of a lock gate during the navigation season for off-site repair (b) (Photos provided by SLSMC).....	106
Figure 7.9:	Resilience in transportation systems, redrawn from in Xinpin Yan presentation [35].....	107
Figure 7.10:	Cai Lon tidal gates in the Mekong delta, Vietnam (Photo provided by ICMB10 (Vietnam)).....	108

LIST OF TABLES

Table 1-1:	Related PIANC reports.....	17
Table 2-1:	Regular demand vs calamity, overview	24
Table 2-2:	Yearly Incidents Incurring Property Damage from Vessels Related Accidents while Transiting the St. Lawrence Seaway (Source: SLSMC).....	32
Table 2-3:	Classification of accidents and their investigations (Source: USACE 385-1-99 regulation [1] updated in 2019)	34
Table 2-4:	Classification of accidents in the risk matrices followed by Rijkswaterstaat, translated from Dutch [2, 20].....	35
Table 2-5:	Related Emergency closures longer than 24 hours on USACE waterways from 1999 to 2005 [8]	37
Table 2-6:	Graphic representation of the four aspects of industrial accidents [ARIA]	38
Table 2-7:	Parameters of the economic aspect, C in Millions of € [ARIA].....	38
Table 3-1:	Related WG 241 case studies of accidents and calamities (Cf. appendix A2)	39
Table 4-1:	Markland Main Lock Chamber – Closure Consequences for Mitre Gate Repairs, in 2016 dollars.....	61
Table 4-2:	Safety Integrity Level.....	73
Table 4-3:	ISO 13849 Performance Levels.....	73