Pennsylvania Impact Assessment 2021

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pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Pennsylvania 2021 Climate Impacts Assessment Approach

Initial Draft

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1 EXECUTIVE SUMMARY

2 INTRODUCTION

2.1 Purpose and objectives

- Purpose of the Impacts Assessment/Act 70
    - Act 70 of 2008 provides the mechanism for Pennsylvania to evolve its understanding of, and approach to, addressing and adapting to the causes and impacts of climate change. More specifically, the Act requires the Department of Environmental Protection (DEP) to update the Pennsylvania Impacts Assessment (IA) and CAP every three years.
    - Pennsylvania faces a range of significant impacts from climate change—flood events and warming temperatures—creating risks that vary across sectors, resources, and populations.
    - The 2021 IA is redesigned as a risk-based assessment to directly inform the CAP and help decision-makers identify meaningful and prioritized adaptation actions. The IA applies a risk-based method to a set of climate hazards by evaluating relative likelihood and consequences of impacts, across sectors. This allows for a prioritized list of risks and impacts, which will then directly inform priority adaptation strategies in the CAP. The assessment will identify relative timing and severity of impacts, along with the lead times needed for adaptation.
    - The consequence categories align with CAP focuses: environmental justice and equity, other co-benefits (e.g., social and environmental impacts)
    - Environmental justice communities are disproportionately impacted by climate change. The IA will discuss these impacts, as applicable.
    - This analysis is not a comprehensive bottom-up assessment. Clearly define boundaries, disclaimers, and limitations of both climate projections and risk analysis.
- Summary of updates relative to previous IAs
    - Transition to risk-based approach to directly inform adaptation priorities – See Appendix B for a detailed risk assessment methodology. The risk assessment includes four major steps: set context, identify potential hazards, analyze risks, and evaluate risks.
    - Explicit analysis and consideration of climate justice and equity.
        - Discussion of the importance of this issues, key definitions, context.
        - Analysis and discussion of what drives inequitable impacts or vulnerabilities and analysis of to what extent overburdened communities are disproportionately exposed to climate hazards.
    - Updated climate projects based on latest available science.
    - The updated IA will present impacts by hazard (rather than by sector). Within each hazard, there will be a breakdown by determined consequence categories. This allows for easier prioritization and comparison between different climate risks.
    - Benefits: Pennsylvania can then begin comparing relative timing and severity of expected impacts for a stronger tie-in to the Climate Action Plan (e.g., IA will identify priority adaptation needs for the CAP)

2.2 Scope

- The 2021 Impacts Assessment focuses on risks posed by climate change from the following hazards: increased average temperatures, heat waves, heavy precipitation

and inland flooding, landslides, sea level rise, and severe tropical and extra-tropical cyclones.
  - This list was derived from Table 1, which shows the climate hazards and impacts identified in the previous Impact Assessments.
  - The selected hazards represent the primary hazards expected to affect the Commonwealth. Other hazards that are noted in the previous Impact Assessments are acknowledged and their impacts summarized, but not provided detailed risk assessment analysis.
- The risk assessment focuses on the consequences of each hazards in terms of: human health; environmental justice and equity; economy (including agriculture, recreation and tourism, and "other" such as energy); forests, ecosystems, and wildlife; and built infrastructure.
- The risk assessment and ratings are focused on overall risk from each hazard at the state level, with discussion of regional variations (e.g., urban or rural, proximity to waterways), populations, industries, or other areas disproportionately affected.
- The Impacts Assessment describes potential impacts through the 21st century, and focuses on evaluating and rating risks from present-day through mid-century (2050). Climate projections are also provided for late in the 21st century (2090).

3 EXPECTED CLIMATE CHANGES IN PENNSYLVANIA

3.1 Overview of Changes

- Key findings related to climate change in Pennsylvania
- Notable changes from last impacts assessment

3.2 Data

- These updated projections are based on temperature and precipitation projections come from an ensemble of 32 climate models, downscaled to a 1/16th degree grid (or approximately 6 km x 6 km) using the Localized Constructed Analogs (LOCA) method.[1]
- Projected values represent the averages over three time periods: 2010-2029 (current), 2040-2059 (mid-century), and 2080-2099 (late-century).
- Values reported represent the 50th percentile of the ensemble. The report and figures below also provide the 10th and 90th percentile range across models.
- Projected values are calculated by determining the change between modeled future and modeled baseline values and adding that change to the observed baseline. Future change is presented relative to a 1971-2000 historical baseline.
- Historical data was drawn from a 6 km x 6 km gridded reanalysis[2] dataset, which uses meteorological station data across Continental United States.[3] Historical conditions represent the average over the 1971-2000 baseline.
- Current and near-century projections assume a business-as-usual greenhouse gas concentration trajectory (RCP 8.5). This conservative emissions pathway is relatively similar to the low-emissions pathway through 2050, at which point the difference between the two scenarios becomes greater. Therefore, late-century projections were developed for both a low-emissions pathway (RCP 4.5) and high-emissions pathway (RCP 8.5).
- Because each value provided in this report is generated by averaging the 10th, 50th or 90th percentile outputs from 32 models, these values are estimates of future conditions, but are not intended to be used as precise projections. Additionally, they may not reflect extreme scenarios that are plausible but projected by a minority of models.

3.3 Temperature and Precipitation Changes

- Graphs, tables, and maps summarizing projections in key sector-relevant variables (e.g., extreme heat days, heating degree-days and cooling degree-days, growing degree-days)
- Updated mid-century (2050) and end of century (2090) climate projections for Pennsylvania over a range of emissions scenarios, based on latest available climate modeling

Climate Changes Beyond 2100
[Placeholder for discussion of projected changes beyond 2100]

1 Pierce, D., Cayan, D., and Thrasher, B. 2014. "Statistical Downscaling Using Localized Constructed Analogs (LOCA)." Journal of Hydrometeorology 15 (6): 2558–85. https://doi.org/10.1175/JHM-D-14-0082.1.
2 "Reanalysis" is a term-of-art referring to the use of a model to interpolate observations in order to create spatially and temporally continuous information about past weather and climate conditions.
3 Livneh, B., Bohn, T., Pierce, D., Munoz-Arriola, F., Nijssen, B., Vose, R., Cayan, D., and Brekke, L. 2015. "A Spatially Comprehensive, Hydrometeorological Data Set for Mexico, the U.S., and Southern Canada 1950–2013." Scientific Data 2 (1): 1–12. https://doi.org/10.1038/sdata.2015.42.

- Description of uncertainty associated with projections (e.g., will provide 10th and 90th percentile of values)

3.4 Coastal Changes

- Summary of latest available science with respect to sea level rise and other coastal issues

3.5 Extreme Weather Events

- Summary of latest available science on expected changes in extreme weather events (e.g., tropical and post-tropical cyclones, ice storms, winter storms)

4 SUMMARY OF OVERALL CLIMATE RISKS

- Description of key take-away and overall impacts and risks
- Summary of highest priority risks based on relative likelihood and consequence (e.g., overall risk by hazard, hazard/sector combinations with greatest likelihood and consequences)
- Prioritized ranking of climate risks per consequence category
- Overview of potential economic impacts and economic opportunities created by potential need for greenhouse gas mitigation strategies.

5 RISK SUMMARIES BY HAZARD

5.1 Increased Average Temperatures

5.1.1 Overview

- Overview highlighting the consequences of greatest concern.
- Consequences by sector.
- Summary table of risk ratings and justification (e.g., likelihood by 2050 and consequences across categories).

Table 1. Example Statewide Hazard Risk Summary

Likelihood				
Current Rating	**Rating**	**Justification**	**Confidence**	
Current	(1-4)	1-2 sentence justification	(H/M/L rating)	
2020-2050				
Beyond 2050	(Comments on potential trends in the climate risk post-2050)			
Consequences				
Category	**Rating**	**Justification**	**Confidence**	**Differential Impacts**
Human health	(1-4)	1-2 sentence justification and description of primary impacts	(H/M/L rating)	(Description of factors that may make specific communities, locations, or populations more vulnerable)
Environmental justice and equity	(1-4)	“	(H/M/L rating)	“
Economy: Agriculture	(1-4)	“	(H/M/L rating)	“
Economy: Recreation and tourism	(1-4)	“	(H/M/L rating)	“
Economy: Other (e.g., energy)	(1-4)	“	(H/M/L rating)	“
Forests, ecosystems, and wildlife	(1-4)	“	(H/M/L rating)	“
Built Infrastructure	(1-4)	“	(H/M/L rating)	“
Potential Opportunities				
Description of potential economic opportunities				
Overall Risk	**Current**	(Total risk score and rating)	(H/M/L rating)	
	2050s	(Total risk score and rating)	(H/M/L rating)	

5.1.2 Likelihood

- Overall state of science and expected timing of changes
- Process for arriving at 2050 likelihood rating (on a scale of 1-5, Unlikely to Almost Certain)

5.1.3 Consequences

- Summary and justification for ratings (overall, and for the following sectors) (on a scale of 1-5, from Minimal to Catastrophic):
- Human health
- Environmental justice and equity
- Economy
- Agriculture
- Recreation and tourism
- Other economic activity (e.g., energy sector)
- Built infrastructure
- Forest, ecosystems, and wildlife
- Identification of specific geographies, populations, industries, or other areas disproportionately affected
- Cost of inaction on a rough order of magnitude (high, medium, low)

5.2 Heat Waves

See section 5.1 as an example.

5.3 Heavy Precipitation and Inland Flooding

See section 5.1 as an example.

5.4 Landslides

See section 5.1 as an example.

5.5 Sea Level Rise

See section 5.1 as an example.

5.6 Severe Tropical and Extra-Tropical Cyclones

See section 5.1 as an example.

6 CONCLUSIONS AND RECOMMENDATIONS

- Recap of overall findings
- Recommended adaptation priorities
- Identification of research gaps, if any, or recommendations for subsequent IA update

7 APPENDIX A – KEY TERMS

- Risk
- Vulnerability
- Impact
- Hazard
- Likelihood
- Consequence
- Emission scenario

8 APPENDIX B – RISK ASSESSMENT METHODOLOGY

8.1.1 Introduction

- The risk assessment methodology is consistent with the International Organization for Standardization (ISO) 31000 Risk Management standard.
- This is a risk-based approach to assessing and prioritizing climate impacts.
- The risk assessment evaluates the likelihood that a climate hazard will occur and the magnitude of its consequences.
- The risk assessment process includes four major steps:

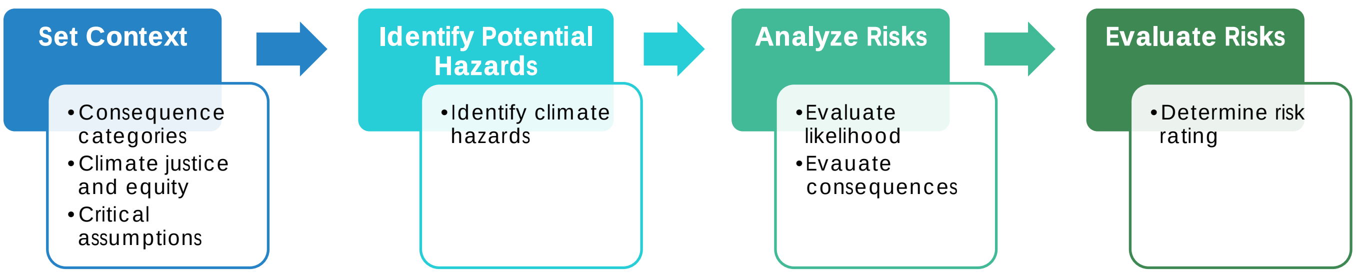

Figure 1. Risk Assessment Process

8.1.2 Step 1 – Set Context

The first step of a risk assessment is to establish the critical context and focus areas for the assessment.

Consequence Categories

The risk assessment will focus on consequences in the following categories. These categories cover all sectors specified in Act 70, with additional attention to impacts to built infrastructure and environmental justice and equity, which are emerging as key potential cross-cutting consequence areas related to the other sectors.

- Human health
- Environmental justice and equity
- Economy
  - Agriculture
  - Recreation and Tourism
  - Other economic activity (e.g., energy sector)
- Forests, ecosystems, and wildlife
- Built infrastructure

Approach to Climate Justice and Equity

The 2021 Impacts Assessment focuses on improving understanding of the equity impacts of climate change in the Commonwealth. The assessment seeks to answer two key questions:

- Identifying vulnerable communities – Which communities will be disproportionately bear the impacts of climate changes?
- Identifying overburdened communities – To what extent are climate changes affecting overburdened communities that are already disproportionately burned with environmental, economic, health, or other concerns?

Identifying Vulnerable Communities

- The Impacts Assessment describes and highlights describing expected the consequences of each hazard, the risk assessment describes and highlights (using call-out boxes, summary tables, or other visual cues as appropriate) the factors that would exacerbate vulnerability to each type of consequence for each hazard.
- For example, factors such as demographics (e.g., race, gender), socio-economic status, and life- or livelihood-sustaining needs (e.g., dependence on electricity for critical medical care) may affect populations' risk factors. For instance, people who do not speak English may face barriers related to accessing social or health services, making those groups more vulnerable to climate hazards such as increased frequency of extreme heat conditions. Poverty may reduce a person's capacity to handle significant changes (e.g., temporary loss of work or damage to housing) that may be associated with climate risks.

Identifying Overburdened Communities

- In addition, the impacts assessment applied a rating for each hazard to describe the degree to which impacts are projected to fall to already disadvantaged communities.
- The impacts assessment uses Pennsylvania's defined "Environmental Justice (EJ) areas" to represent these communities. An EJ area is any census tract where 20 percent or more individuals live in poverty, and/or 30 percent or more of the population is minority.[4]
- These areas are commonly used by DEP and other state agencies for similar purposes. This approach is also consistent with the approach used in the North Carolina 2020 Climate Risk Assessment and Resilience Plan and commonly in similar analysis to capture potentially underserved populations.[5]
- EJ areas serve as an indicator of locations that are overburdened by environmental hazards and other structural disadvantages. While they cannot capture all characteristics of disadvantaged, vulnerable, or historically overburdened or underserved communities (e.g., these areas draw defined lines of EJ locations, are based on percentiles, and are based on thresholds from two indicator variables), they provide an approach to identify which climate change impacts could be falling disproportionately to overburdened communities.
- The environmental justice and equity consequence analyses in this assessment will dive deeper into the nuances of what drives vulnerabilities to each hazard, identifying specific communities or groups that may be vulnerable to particular climate changes, and noting where additional factors critical to equity analysis come into play.
- Table 1 provides an example of how the risk assessment information (likelihood, consequences, equity considerations, etc.) could be summarized for a given hazard to present the overall impacts, relative risks, key target areas, and overall equity implications of the impacts.

Other Critical Assumptions

- To be developed (e.g., assumptions about population, demographics, distribution, economic growth, etc.)

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[4] https://www.dep.pa.gov/PublicParticipation/OfficeofEnvironmentalJustice/Pages/PA-Environmental-Justice-Areas.aspx
[5] https://files.nc.gov/ncdeq/climate-change/resilience-plan/2020-Climate-Risk-Assessment-and-Resilience-Plan.pdf

8.1.3 Step 2 – Identify Potential Hazards

- The second step is to identify and select potential hazards for detailed risk evaluation.
- Table 2 summarizes expected impacts of climate change by sector in Pennsylvania, as described in previous iterations of the Impacts Assessment.
- The six focus hazards identified (increased average temperatures, heat waves, heavy precipitation and inland flooding, landslides, sea level rise, and severe tropical and extra-tropical cyclones) represent the primary hazards expected to affect the Commonwealth drawn from previous Impact Assessments—see Table 2. These hazards cover nearly all of the impacts represented in Table 2 below.
    - o The risk assessment will prioritize impacts reasonably likely to occur within mid-century timeframe, likely to result in potentially major or catastrophic consequences, and with have adequate information to evaluate risk.
- The 2021 Impacts Assessment focuses on updates to the expected impacts from the selected hazards based on the latest science, with **priority placed on providing additional information with respect to impacts on equity and human health.**

Table 2. Summary of Climate Impacts and Associated Hazards from Previous Pennsylvania Climate Impact Assessments

Sector	Impact	Hazard
Human Health	Decreased mortality from cold-related stress	Higher average temperatures / decreased frequency of extreme low temps
Human Health	Negative health impacts to agricultural workers; in most agricultural fields, workers will be exposed to more extreme heat.	Higher average temperatures / increased frequency and temperature of extreme high temps
Human Health	Increased mortality from heat-related stress (e.g., excessive heat event days). Greatest risk for elderly and those with cardiovascular disease. Air conditioning is key adaptation option. Equity may be an issue here due to costs of air conditioning and impacts felt most by those required to be outside for long periods of time.	Greater frequency of extreme heat/heat waves
Human Health	Increased air pollutants and associated increased respiratory and cardiac illness (e.g., increased emergency room visits for childhood asthma) if increased ozone, etc. creation not balanced by emissions reduction	Higher temperatures à increased ground-level ozone Potential change in concentration of small airborne particulates Increase in pollen and mold concentrations (e.g., more pollen with faster plant growth; more thunderstorms = trigger for pollen-induced asthma)
Human Health	Reduced water quality and associated impacts on health through drinking water and contact during outdoor recreation	Higher average temperatures, increase in heavy rain events, surface runoff à more growth and potential greater concentration of water-borne pathogens in wastewater and surface water
Human Health	Increased pathogen loads from increased surface runoff from livestock farms, sewer	Increase in heavy rain events, surface runoff

	overflows (esp. in older cities, which may also have more equity and EJ concerns)	
Human Health	Increased risk of harmful algal blooms in eutrophied lakes and reservoirs (e.g., impacts already experienced on Lake Erie)	Increase in heavy rain events, surface runoff
Human Health	Possible injury and death, especially associated with flooding from severe storms (e.g., from driving through floodwaters or structural damage to buildings from high winds).	Increase in extreme weather events
Human Health	Change in distribution and prevalence of vector-borne diseases (e.g., Lyme disease, West Nile Virus). Greatest effects may be to those with limited healthcare coverage (e.g., low income and rural populations).	Higher average temperatures
Agriculture	Change in heating/cooling costs for mushroom production	Higher average temperatures
Agriculture	Change in price of agricultural commodities	Indirect
Agriculture	Mixed effects on field crop and livestock production, including: - movement of livestock industries northward -indoor livestock production (e.g., poultry) - invasive species (e.g., spotted lanternfly) may be able to survive in more northerly climates	Higher average temperatures Higher average precip More intense precip events (e.g., 95th, 99th percentile) Higher CO_2 concentrations
Agriculture	Negative impacts to dairy production, including loss in milk yield, lower levels of forage quality	Higher average temperatures Increased periods of sustained high temperatures
Outdoor Recreation	Longer warm season, increase in outdoor recreation (opportunity)	Higher average temperatures (warmer spring and fall temperatures)
Outdoor Recreation	Severe, negative impact on snow-based recreation (e.g., skiing)	Higher average temperatures (loss of snow cover)
Outdoor Recreation	Change in types of recreational fishing. Certain species such as trout may experience a decline in suitable habitat. However, total precipitation in recreational fishing may increase due to the longer season	Higher average temperatures (air and stream temperatures)
Outdoor Recreation	Negative impact to sport fish populations	Reduced summer stream flows
Outdoor Recreation	Increased demand for water-based recreation (likely small)	Higher average temperatures
Outdoor Recreation	Shift in types of general outdoor leisure activity and a generally lengthened outdoor recreation season	Higher average temperatures and high-threshold temperatures (days with Tmax between 75 and 100)
Outdoor Recreation	Increase need for shaded parks and cooling centers	Higher average temperatures (and urban island effect)
Energy	Increased demand for energy (esp. electricity sector) in summer and fall, and at peak times. Pennsylvania's Alternative Energy Portfolio Standard (AEPS) work may help mediate impacts, and additionally energy efficiency, demand side management, and more backup power sources could help adapt.	- Higher average temperatures (monthly avg temps; heating degree days [HDD]/cooling degree days [CDD]) - Higher peak temperatures during the summer (95th or 99th percentile temperatures by month or season)
Energy	Impacts on energy transportation (e.g., decreased air travel in polar vortex; warmer	Extreme weather events Higher average temperatures Occurrence of freeze-thaw cycles

	climate could lower infrastructure maintenance costs)	
Energy	Impacts to energy delivery reliability: extreme weather events can damage infrastructure, and increased cooling demand places higher demand on infrastructure at times when it's likely to be stressed already; large impacts may be mediated by a more distributed generation system.	Extreme weather events Higher average temperatures
Energy	Potential improved reliability of energy availability in winter months	Decreased occurrence of extreme cold-weather events
Energy	Declines in energy commodity prices, particularly for electricity and nat gas, may present challenges to some technology options that could contribute to mitigation, as well as "stranded gas" issues.	Policy/regulatory transition
Forests	Shift in suitable habitat for tree species and wildlife species to higher latitudes and elevations	Higher average temperatures
Forests	Increased stress for some species inhabiting decreasingly suitable habitat	Higher average temperatures
Forests	Increased overall forest growth due to longer growing seasons, warmer temperatures, higher rainfall, nitrogen deposition, and increased atmospheric CO_2, but the increased growth rates for some species may be offset by increased mortality for others	Higher temperatures (longer growing seasons) Higher rainfall Increased atmospheric CO_2 Nitrogen deposition
Forests	Associated shift in forest products industry	Higher average temperatures
Forests	Exacerbated impacts/stress from non-climate threats to forest health and diversity (e.g., insect pests, diseases, invasive plants and animals, overabundant deer populations, unsustainable harvest practices, and atmospheric deposition)	Higher average temperatures
Forests	Increase insect metabolic and reproductive rates. Increase in insect range northward and to higher elevations	Higher average temperatures
Forests	Shift in timing of key biological events (e.g., broods hatcher later or earlier than timing of peak food supply)	Higher average temperatures, change in seasonal temperature and precipitation patterns
Forests	Increased mortality from heat-related stress and increased evapotranspiration rates (e.g., drier soil moisture conditions, high temperatures).	Higher average temperatures / increased frequency of extreme high temps
Water	Increased flood risks (and associated impacts across sectors) in both urban and rural areas River/stream bank erosion Higher sediment output	Higher precipitation, increased extreme precipitation, storm surge
Water	Low summer flows (magnitude and severity will vary by location/ watershed). The impacts of droughts are likely to be short-term, but risks include wetlands degradation and competition for water resources in low-flow, high-temperature periods between different sectors, and water availability issues for vulnerable communities may exist due to multidimensional inequalities.	Short-term drought

Water	Decreased water supplied for urban areas and irrigation	Short-term drought
Water	Reduced quality of raw water and increased drinking water risks	Higher average temperatures Extreme precipitation and flooding (increased sediment, nutrient, and pollutant loadings; disruption of treatment facilities) Drought (increased concentration of pollutants)
Water	Water pollution from increased stormwater runoff and pollution	Extreme precipitation and flooding
Water	Fish impacts	Higher average temperatures (stream temperatures), including hottest-day temperatures, esp. in summer, and sediment from runoff
Water	Increased potential for eutrophication causing lower dissolved oxygen levels and an increase in the prevalence of harmful algal blooms in Lake Erie or other water bodies	Higher average temperatures (summer) Drought (reduced stream flows)
Wetlands and Aquatic Ecosystems	Drying of wetland acreage in Ridge and Valley ecoregion and loss of associated ecosystem services (e.g., water quality)	Higher average temperatures
Wetlands and Aquatic Ecosystems	Changes in stream flow quantity and quality lead to loss of biodiversity and habitat fragmentation from hydrologic modification and stream-bank erosion	Higher average temperatures Heavy precipitation and flooding Drought
Wetlands and Aquatic Ecosystems	Negative physiological and behavioral changes to macroinvertebrate and fish species	Higher average temperatures (Increase in stream temperatures)
Wetlands and Aquatic Ecosystems	Decreased survival and reproductive success for fish and macroinvertebrates due to higher rates of sedimentation and increased scouring of stream banks and floodplains	Heavy precipitation and flooding (increased stream flows)
Wetlands and Aquatic Ecosystems	Impacts to species that have adapted their life cycles to coincide with times of high water (e.g., mismatched timing of life cycle stages, insufficient duration of inundation, lack of sufficient habitat refugia)	Heavy precipitation and flooding (change to seasonal flood patterns and reeducated groundwater recharge)
Coastal resources	Reduced water quality (and associated threats to fauna) in tidal freshwater portion of Delaware estuary and along Lake Erie	Increased water temperature (decreased dissolved oxygen concentration) Saltwater intrusion / sea level rise
Coastal resources	Potential drowning of wetlands	Sea level rise
Built Infrastructure	"Large portions of multiple energy and transport infrastructures in Pennsylvania are potentially susceptible to direct damage from flooding. Particularly in the Southwestern portion of Pennsylvania, infrastructures face additional risk exposure from landslide potential associated with heavy precipitation events"	Heavy precipitation and flooding Landslides
Built Infrastructure	Flooding and associated infrastructure damage	Coastal storm surge

Built Infrastructure	Extreme heat in particular has been associated with public health challenges, and represents an adaptation need for Pennsylvania's infrastructure	Higher average temperatures / increased frequency of extreme high temps

8.1.4 Step 3 – Analyze Risks

Risk is a function of the likelihood and consequences of a hazard. The approach to evaluating each of these for the selected hazards is described below.

Likelihood

To assess likelihood, the analysis draws on exposure information available in previous IAs and the latest available projections. Then, the probability of each hazard event occurring in a given year is evaluated using the scale below.

Likelihood is evaluated for a baseline and mid-century (e.g., 2040-2059) time frame. Projected changes beyond mid-century and beyond the end-of-the-century are described qualitatively.

The Pennsylvania All-Hazard Mitigation Planning Standard Operating Guide describes the likelihood of hazard events occurring in terms of their frequency. "Probability of occurrence" estimates can then be used by community officials to inform and assess future development and risks. Table 3 builds on this Guide, and describes climate hazards' likelihood in terms of their probability of occurring in a given year. Discrete hazards are those related to individual extreme events (e.g., a heat wave) that occur over a relatively short period of time (e.g., days or weeks). Ongoing risks are those related to gradual changes in climate occurring over many years (e.g., higher average temperatures or sea level rise); they may include critical thresholds which, if reached or surpassed, engender particular risks (e.g., X feet of sea level rise).

Table 3. Likelihood Rating Scale

Likelihood	Rating	Criteria for Discrete Hazards	Criteria for Ongoing Hazards
Highly Likely	4	Greater than 50% annual probability	Risk is extremely likely to cross critical threshold by the 2050s.
Likely	3	Between 10% and 50% annual probability	Risk is likely to cross critical threshold by the 2050s. It would be surprising if this did not happen.
Possible	2	Between 2% and 10% annual probability	Risk is just as likely as not to cross critical threshold by the 2050s.
Unlikely	1	Below 2% annual probability	Risk is not anticipated to cross critical threshold by 2050s.

The rating scale for discrete hazards (i.e., individual events like heat waves or storms) is consistent with the Pennsylvania All-Hazard Mitigation Planning Standard Operating Guide.[6] To expand the rating scale to accommodate the more gradual or ongoing nature of some hazards (e.g., higher average temperatures, sea level rise), DEP and ICF expended the rating scale as shown above in the rightmost column, consistent with how the Intergovernmental Panel on Climate Change defines likelihood of climate changes. The 'critical thresholds' for

[6] https://www.pema.pa.gov/Mitigation/Planning/Documents/All-Hazard-Mitigation-Planning-Standard-Operating-Guide.pdf

ongoing hazards (e.g., increased average temperatures) are based on likely projections for mid-century.

Consequences

DEP and ICF applied a consequence rating scale to assess the severity of impacts for key consequence categories, and indicated the rationale behind different ratings.

After updating relevant climate science projections, DEP and ICF sought input from PSU experts and key stakeholders as needed to complement information on the consequences of each climate risk as described in the 2015 and 2018 Impacts Assessments, and then to rate the consequences using the scale.

The proposed consequence rating scale is in Table 4. This scale was developed through review of the Pennsylvania All-Hazard Mitigation Planning Standard Operating Guide (striving for consistency where possible, such as in the overall 1-4 rating scale and the criteria for several types of impacts), and expanding upon this guidance as needed to fit additional consequence categories for the climate impact assessment. The metrics to define each category are intended to ensure consistency and comparability across risk scenarios.

The scale was applied to expected consequences from the climate hazards at the state scale by mid-century. It evaluates consequences from individual discrete hazard events, and the cumulative impacts of ongoing hazards.

The overall consequence score is an average of the five consequence category ratings. However, the overall risk assessment results also emphasize the disaggregated nine consequence ratings.

Finally, while the climate change risk assessment is focused on evaluating negative consequences of the hazards (in order to inform adaptation priorities), the assessment includes information on positive impacts or opportunities that may arise – see Table 1.

Table 4. Consequence Rating Scale

	Human Health	Environmental justice & equity	Economy			Forests, Ecosystems, and Wildlife	Built Infrastructure
			Agriculture	Recreation and Tourism	Other (e.g., Energy)		
4 – Catastrophic	1000+ people potentially affected; high number of deaths or injuries possible; long duration of impact	Percent of population in EJ areas that is exposed is > 2x the average percent of population exposed statewide	Severe, disruption to multiple industries and employment lasting months to years Over $1 billion in potential annual losses	Severe disruption to multiple seasons or employment Over $1 billion in potential annual losses	Severe, disruption to multiple industries and employment lasting months to years Over $1 billion in potential annual losses	Irreversible damage to a significant natural asset	Over 50% of infrastructure in affected area damaged, destroyed or completely shut down; long duration impact for critical facilities (30+ days), or potential for at least impact across >50% of the state
3 – Critical	100-1000 people affected; multiple deaths, sicknesses, or injuries possible; moderate to long duration of impact	Percent of population in EJ areas that is exposed is 1.5-2x the average percent of population exposed statewide	Moderate, disruption to multiple industries and employment; or severe impacts to one industry lasting months to years $100 million to $1 billion in potential annual losses	Severe disruption to one season or employment $100 million to $1 billion in potential annual losses	Moderate, disruption to multiple industries and employment; or severe impacts to one industry lasting months to years $100 million to $1 billion in potential annual losses	Widespread damage to a natural asset Recovery would take years to decades	More than 25% of infrastructure in affected area damaged or destroyed. Complete shutdown of critical facilities for more than one week., or potential for at least moderate impact across > 25% of the state
2 – Limited	10-100 people affected; minor injuries only; brief to moderate duration of impact	Percent of population in EJ areas that is exposed is 1-1.5x the average percent of population exposed statewide	Moderate, weeks- to months-long disruption to multiple industries and employment; or severe short-term impacts to one industry $10 million to $100 million in potential annual losses	Moderate disruption to multiple seasons or employment; or severe weeks-long disruption to one season $10 million to $100 million in potential annual losses	Moderate, weeks- to months-long disruption to multiple industries and employment; or severe short-term impacts to one industry $10 million to $100 million in potential annual losses	Localized, significant damage to a natural asset Recovery would take years to decades	More than 10% of infrastructure in affected area damaged or destroyed. Complete shutdown of critical facilities for more than one day.
1 – Minor	Very low potential for health impacts; very few injuries, if any; brief duration of impact	Percent of population in EJ areas that is exposed is equal to or less than the average percent of population exposed statewide	Moderate-to-minor disruption to industries and employment Or < $10 million in potential annual losses	Moderate disruption to one season or employment Less than $10 million in potential annual losses	Moderate-to-minor disruption to industries and employment Or < $10 million in potential annual losses	Localized, moderate damage to a natural asset Recovery would take months to years	Only minor property damage. Temporary shutdown of critical facilities.

8.1.5 Step 4 – Evaluate Risks

- To compute a total risk score and corresponding risk rating for each climate hazard, the likelihood score and overall consequence score are multiplied together
- A risk matrix and scoring rubric are used to determine total risk

Table 5. Risk Rating Matrix

Likelihood	Consequence			
	Minor	Limited	Critical	Catastrophic
Highly Likely	4	8	12	16
Likely	3	6	9	12
Possible	2	4	6	8
Unlikely	1	2	3	4

Table 6. Risk Rating Rubric

Risk Score (low end inclusive)	Rating
1 – 2	Low
3 – 9	Medium
6 – 9	High
12+	Extreme