Artificial Intelligence in Water Management

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Potential Advantages of Using AI Per WSWC's Eecutive Director, Tony Willardson

- In 2020, Tony Willardson called for "applied science to support decisionmaking, national and regional impact assessments, better, more robust forecasting models, watershed scale climate model outputs, agreed upon data standards and protocols, better understanding of climate drivers, and an internet portal for public and decisionmakers." Another municipal climate-response consultant, a California "resiliency planner," recommends "portfolio approaches," "adaptive implementation," "system vulnerability and risk assessment," and "futurecasting of vision."

- Tony Willardson, "The Challenges of Change: Resilient Water Resource Management," American Water Resources Association, Washington State Conference, October 6, 2020.

Who is thinking about AI?

- Growing body of literature on the subject, covering a wide range of topics and perspectives, that could be found via searching relevant databases such as Google Scholar, JSTOR, etc.
- In academia, researchers from various fields, such as computer science, environmental science, and engineering, are studying the potential of AI for natural resource management., and publishing their findings in journals and conference proceedings.
- Government agencies, such as the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS), also conduct research on the use of AI in natural resource management, and disseminate their findings to the public through reports, articles, and other publications.
- Companies and industries are developing and using AI-based technologies for natural resource management,
- Non-profit organizations, such as the World Wildlife Fund (WWF) and the Nature Conservancy, are conducting research and publishing information on AI and natural resource management.

Current Use of AI

- AI algorithms can be used to analyze data and provide insights that can inform conservation and land management decisions.

- Use of remote sensing technology, such as satellites and drones, to gather data on land use and land cover change, deforestation, and forest fire detection.

- Artificial intelligence programs are available now in the evaporative cooling of computerized data centers, high-occupancy hotels, convention centers, mega-resorts and office buildings, and can be used to bring better water usage efficiency in the agricultural sector.
  - Hot water, 35-40 C (95-104 F), heated by exposure to heat intensive process is plumbed through a “wet loop” to a cooling tower from which moist heat collected from the heat intensive process is discharged at a cooling tower. Then the cooler water, 24C (75 F), loop is plumbed to a condenser permitting that cooler water to be returned to the heat-generating process area to collect more heat, or otherwise for landscaping purposes. Meters, submeters and sensors in water process loops are installed throughout the system’s plumbing. Real-time data is collected and maintained in a database of historical readings. Live comparisons are made by artificial intelligence software between current data and historical data, so as to reveal plumbing system inefficiencies that can be notified to on-site operating personnel. See Apana’s Intelligent Water Management Platform, www.apana.com

- Use of AI in precision agriculture to optimize crop yields, reduce water and fertilizer use, and detect and respond to pests and diseases.

- AI also has been applied to predict and manage fish stock, predict water scarcity, and optimize water use in irrigation systems.

- Additionally, AI can be used for monitoring and management of wildlife populations, tracking animal migrations, and identifying and protecting endangered species.

The Capacity of Artificial Intelligence

- AI has the capacity to:
  - Transform conventional, nuclear and cyber weapons strategy.
  - Manage electric grids
  - Mitigate climate change
  - Revolutionize farming
  - Revolutionize medicine
  - Does AI have the capacity to transform natural systems management?

The Capacity of Artificial Intelligence

- "AI is facilitating the precise administration of pesticides, the detection of diseases, and the prediction of crop yields. In medicine, it is facilitating the discovery of new drugs, the identification of new applications of existing drugs and the detection of prediction of future maladies, e.g. breast cancer."
  - – Henry Kissinger, Eric Schmidt, Daniel Huttenlocher, *The Age of AI and the Human Future,* Back Bay Books (2021), P. 69

Potential Advantages of Using AI
Per WSWC's Executive Director, Tony Willardson

- Today's water managers refer to the challenge of establishing resource "resiliency." Challenges to resiliency include: growth and related economic and environmental needs; limited data regarding water supplies and demands; competing or poorly defined water rights; aging and often inadequate infrastructure; unpredictable climate and extreme events (inability to predict seasonal/subseasonal supply); and a constantly evolving regulatory landscape.
- Strategies to address that challenge include: "recognition of the importance of climate impacts; support for climate resiliency research; longer term forecasting (seasonal to subseasonal); continuing dynamic earth systems research; and continuing monitoring of the water cycle."

Some AI Success Stories:

- Winning a game: AlphaZero chess victory, "Reinforcement Learning," a similator played chess against itself, each move calibrated to strategic opportunities created as a "reward" for the move. AI "trains itself."

- Killing a bacterium: MIT discovery of Halcion: "Supervised Learning" A machine learning algorithm to predict the antibacterial properties of molecules, training the algorithm with a dataset of more than two thousand molecules. An artificial "neural" network in which information nodes and numerical weights simulate neurons and synapses, i.e. like the brain. The "neural network" captured the association between the molecules and their potential to inhibit bacterial growth.
  - Henry Kissinger, Eric Schmidt, Daniel Huttenlocher, *The Age of AI and the Human Future,* Back Bay Books (2021).

AI in Language Analysis

- Utilizing language data, change the semantic relationships between words into geometric relationships.
  - Words that are near each other in meaning are near each other in geometric relationship,
  - inter-rational relationships (every concept to every other concept) within the language are encoded in the geometric shape. The computer doesn't know what anything means, it just knows how they relate.
- Compare geometric relationship of one language to another, using spatial relationships of "word clouds." Rotate one word geometric shape upon another of a different language to compare similarities.
- Build similar geometry of animal sounds, compare geometries.

  - "Talking to Animals," Karen Bakker, University of British Columbia, Aza Raskin, Center for Humane Technology, *Unexplainable*, Vox Media Podcast Network, Norm Hasenfeld, host, August 16, 2023,

AI—4^{th} generation of the Technology Era

- Technology era 1970s-2020s
  - Data collection/calculation phase
  - Menu oriented search engine phase (mature)
  - Robot phase (adolescent)
  - Artificial intelligence phase (immature)

Algorithms

- Classical algorithms consist of steps for producing precise results
- Machine learning algorithms depart from the precision and predictability of classical algorithms.
- Machine-learning algorithms consist of steps for improving imprecise results.
- “The building blocks of these ‘learning’ techniques are algorithms, sets of steps for translating inputs into repeatable outputs.”
- AI “intuits” outcomes from data analysis. It is more a matter of probability than deduction.
- AIs “learn” by consuming data, then drawing observations and conclusions based on the data. While previous systems required exact inputs and outputs, AIs with imprecise function require neither.
  – Henry Kissinger, Eric Schmidt, Daniel Huttenlocher, *The Age of AI and the Human Future,* Back Bay Books (2021)

Machine Learning Algorithms

- “The building blocks of these ‘learning’ techniques are algorithms, sets of steps for translating inputs into repeatable outputs. Machine learning algorithms are a departure from the precision and predictability of classical algorithms, including those in calculations like long division. Unlike classical algorithms, which consist of steps for producing precise results, machine-learning algorithms consist of steps for improving upon imprecise results.”
- Henry Kissinger, Eric Schmidt, Daniel Huttenlocher, *The Age of AI and the Human Future,* Back Bay Books (2021)

Forms of “Machine Learning” in Multi-Dataset Analysis

- Supervised learning: Label dataset inputs individually so as to achieve the desired output.
- Unsupervised learning: Algorithm produce gross database groupings based on some specified weight of measuring the degree of similarity.
- Reinforcement learning: AI trains itself in an artificial environment.
- Transfer learning: train one data set to identify anomalies in another data set.
- Multivariate anomaly detection: learn the patterns in multiple data sets, then identify data points that don’t fit the pattern.
  - Isolation Forest: algorithm isolates anomalies by randomly partitioning the data sets into smaller and smaller sets. Anomalies are more likely to be isolated in smaller sets.
  - Local Outlier Factor: algorithm measures the local density of each data point. Anomalies are more likely to have a lower local density than normal data points.”
  - One-Class Support Vector Machine: Algorithy learns a boundary that separates normal data from anomalies.

Relevant data sets for water resource management

- "You're in spreadsheet hell," Veselka said. "You're in silo data."
  - "Digital Dialogues: The next wave of AI in the orchard arrives," *Good Fruit Grower*, September 2023, p. 9
  - Keith Veselka, NWFM, LLC, Central Washington (Yakima) farm management company.

Relevant data sets for water resource management:

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ᴳGeo-specific

- Surface water
- Precipitation*G
- Snowpack*
- Climate*
- Bathymetric data (2 and 3 dimensional) G
- Hydrographic data*G
- Stream gage (water surface elevation] data* G
- Flow volumes*
- Flow speed (velocity)*
- Surface water hydrograph, generated from other listed data
- Surface water chemistry data*
- Surface water temperature data*
- Water storage data*
- Hydropower volume and production dataG
- Geomapping data G

Relevant data sets for water resource management:

*Calendar formatted

[G]Geo-specific

- <u>Ground water</u>
- Aquifer elevations [G]
- 3-dimentional definition [G]
- gradients, topography and bathymetry [G]
- Hydrogeologic formation [G]
- Permeability [G]
- Hydraulic conductivity attributes [G]
- Water supply volume [G]
- Recharge data [G]
- Points of diversion [G]
- Historic use ("drawdown") [G]

Relevant data sets for water resource management:

*Calendar formatted

[G]Geo-specific

- Environmental
- Fishery data
- Other aquatic species data
- Aves data
- List of ESA (or other) listed species[G]
- Human recreation data
- Related ecosystem data

Relevant data sets for water resource management:

*Calendar formatted

[G]Geo-specific

- Water Demand
- Diversion rights data [G]
- Seniority Date
- Permit or license number
- Maximum annual diversion
- Maximum daily or seasonal diversion
- Consumptive/nonconsumptive use volumes
- Categorical Use (municipal, industrial, agricultural, etc.)
- Return Flows (including hydropower plant once-through returns)
- Points of diversion data [G]
- Water delivery volume data*
- Distribution of use type data*[G]

Relevant data sets for water resource management:

*Calendar formatted

[G]Geo-specific

- <u>Economic</u>
- Economic return-on-use data per use category, e.g., hydropower, agricultural, municipal*
- Water rights transaction data*
- Agricultural Market value data*[G]
- Agricultural crop mix data*[G]
- Agricultural gross product value data*
- Agricultural specific product value data*
- Human population density and other demographic data*[G]
    - Per capita use data
    - Urban gross production value data*
- Economic: annual inches of irrigation & area (agricultural use)*

How Can AI Data Analysis Be Used?

- A generator network creates potential outputs.
- A Generator Discriminator Network prevents poor outputs from being generated.
- A Generator Adversarial Network refines its outputs from its learning refinements based on rejected outputs.
  – Henry Kissinger, Eric Schmidt, Daniel Huttenlocher, *The Age of AI and the Human Future,* Back Bay Books (2021), P. 75

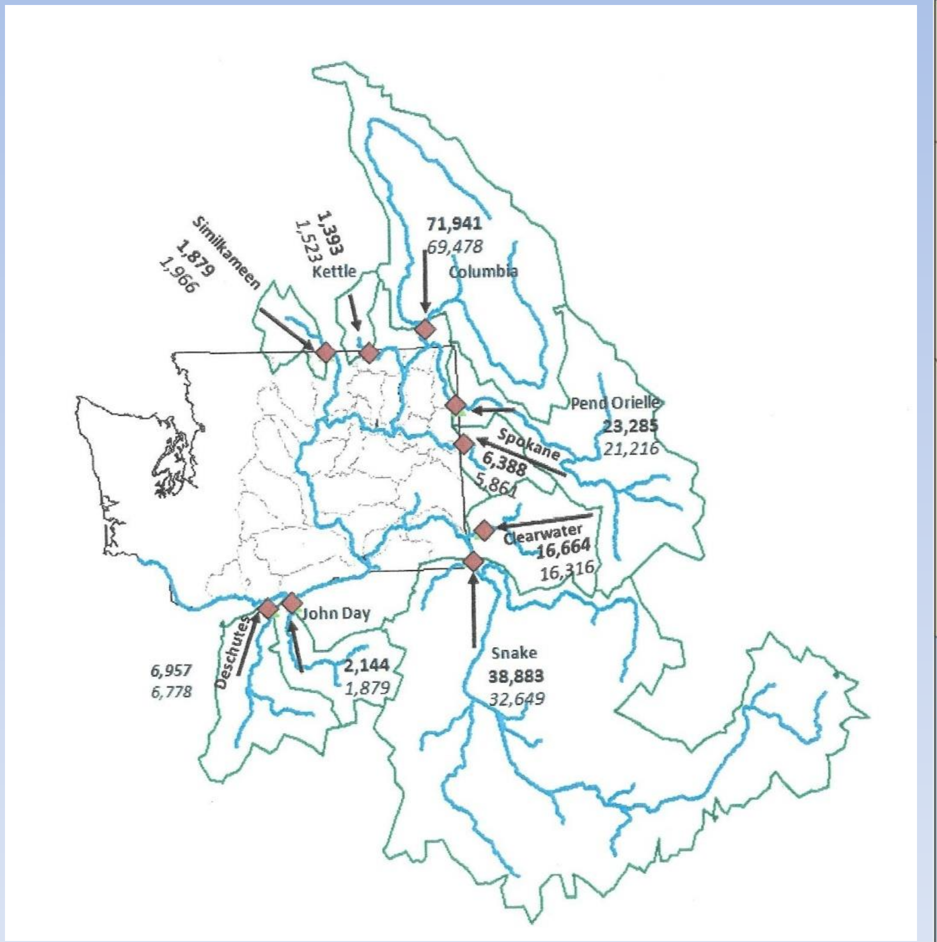
How Can AI Data Analysis Be Used?

- Determine quality of data sets:
  - Uniformity of data collection
  - Consistency of data collection
  - Integrity of data collection
- Use machine learning techniques to:
  - Determine correlation between data bases
  - Discover anomalies between data bases

How Can AI Data Analysis Be Used?

- Develop simulation models, (“digital twins”) of natural systems.
  - Models capable of natural system operation outcomes premised on variable hypotheses.
- Amend existing simulation models to accommodate consideration of greater number of data variables.

Simulation Models exist for Columbia and Colorado River Systems (and likely many others)



How Can AI Data Analysis Be Used?

- Populate Simulation Models ("Digital Twins") with access to AI-recommended, relevant data bases.
- Use AI-discovered data relationships to construct cause-effect infrastructure (algorithms) of Model.
- Use AI to suggest hypotheses for digital twin analysis.
- Hypothecate alternative data inputs to discover implications to Simulation Model outputs.
- Evaluate hypothecated data input variation against desired resource system performance data.

How Can AI Data Analysis Be Used?

- Consider modifications to natural system management in line with simulation model-suggested results.
- “Using machine learning to create and adjust models based on real world feedback, modern AI can approximate outcomes and analyze ambiguities that would have stymied classical algorithms.”
  - Henry Kissinger, Eric Schmidt, Daniel Huttenlocher, *The Age of AI and the Human Future,* Back Bay Books (2021), p. 62.

Shortcomings of AI

- Depends upon quality, uniform data sets.
- Limited understanding of human emotions and social interactions.
- Lack of common sense and ability to reason.
- Difficulty in handling tasks that require creativity and originality
- Limited ability to learn from unstructured data.
- Lack of transparency and explainability in decision-making processes.
- Potential for bias in data and algorithms.
- Limited ability to generalize from specific examples to new situations.
- Current AI systems are not perfectly robust and can be deceived by cleverly crafted inputs.

AI is not sentient

- AI has no self awareness.
- AI does not know what it doesn’t know.
- AI cannot reflect on the accuracy or significance of what it discovers.
- AI cannot “feel” moral or philosophical compunction.
- AI does not have or use intuition.
- AI does not hope or pray.

The “Audit” Function

- Managing the risks that increasingly prevalent AI will pose is a task that must be pursued concurrently with the advancement of the field.
- Technology should be used in conjunction with other data sources and expertise.
- Ethical and environmental considerations should be taken into account.
- AI design, process and outcome all need be audited by human evaluation.
- AI can misidentify poorly presented data.
- The Age of AI has yet to define its organizing principles, its moral concepts, or its sense of aspirations or limitations.
- Leaders will have to confront the implications of the technology, for whose application they bear significant responsibility.

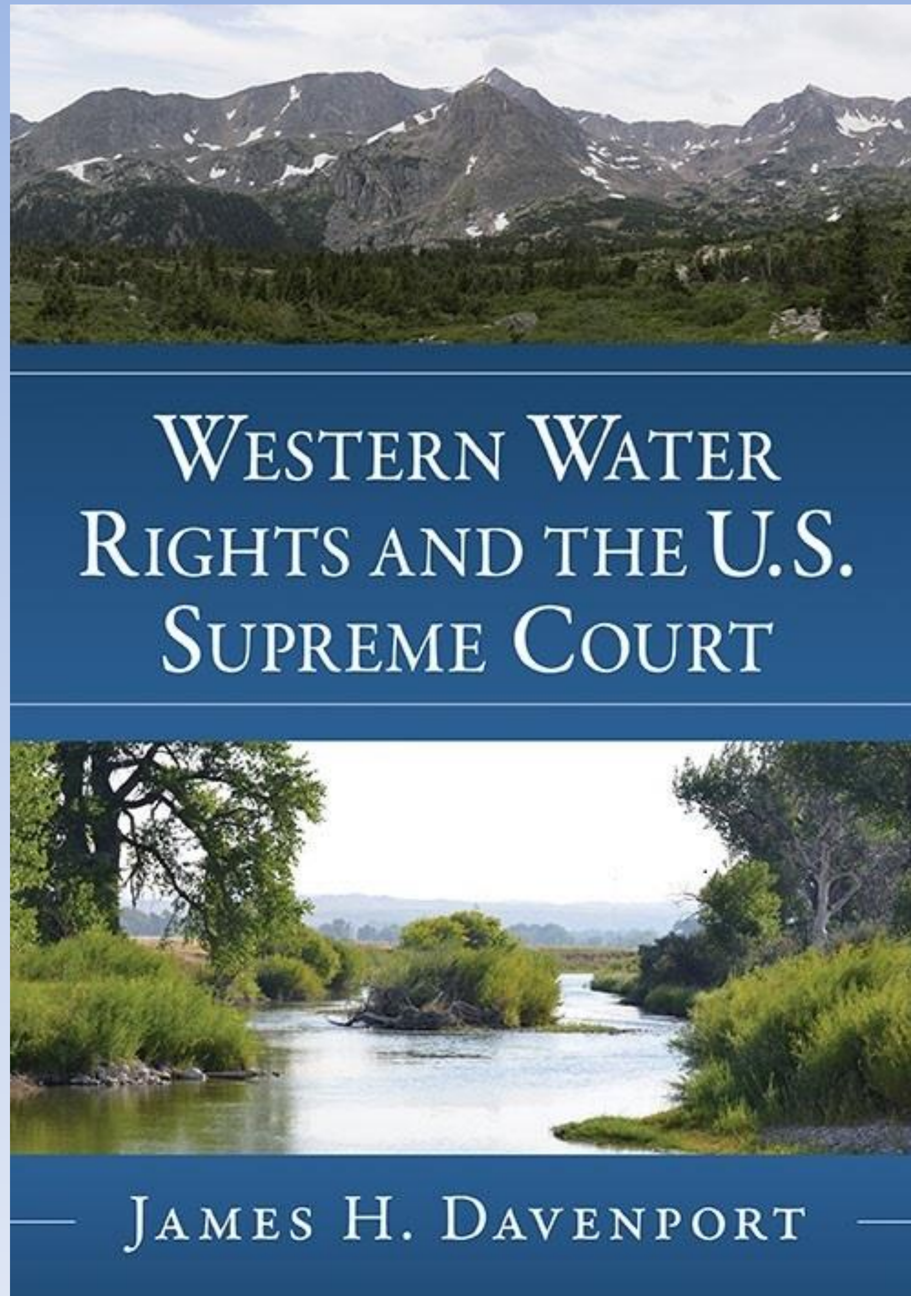
Costs

- Neural network training is resource-intensive. The process requires substantial computing power and complex algorithms to analyze and adjust to large amounts of data.

What needs doing?

- Data inventory—identify whereabouts and accessibility of existing data sets.
- Research AI design knowledge base.
- Describe relational attributes of data sets
  - Cause and effect
  - Influence
  - Statistical similarity
  - Congruence/incongruence
  - Timing
- Create a task-particular AI application

- *https://en.wikipedia.org/wiki/Algorithm*
- *https://en.wikipedia.org/wiki/Artificial_intelligence*
- *The Age of AI and the Human Future,* Henry Kissinger, Eric Schmidt, Daniel Huttenlocher, Back Bay Books (2021).
- “Talking to Animals,” Karen Bakker, University of British Columbia, Aza Raskin, Center for Humane Technology, *Unexplainable*, Vox Media Podcast Network, Norm Hasenfeld, host, August 16, 2023.
- Kaustuv M. Das, “Blockchains and Streaming and AI, Oh My!" 73/7 *NW Lawyer* 39, Sept. 2019
- Colin Rigley, “Clinical Diagnosis—Old Law in New Tech, And How Lawyers Can Guide Smarter Policy” 73/7 *NW Lawyer* 26, Sept. 2019.


WESTERN WATER
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Columbia River from Source to Mouth