Kramer et al. (2012)
Wetland Banking Assessment Tools

Kramer et al. (2012) identifies suitable locations throughout the landscape for siting wetland and stream creation, restoration, and protection projects using several ArcGIS-based raster calculator models. These models generate spatial metrics representing various wetland functions and values (e.g., water quality and quantity) considered by stakeholders to be important for implementing the watershed approach to compensatory mitigation. Kramer et al. (2012) combines these spatial metrics to generate two different outputs: 1) a Potential Wetland Banking Site Index (PWBSI), which identifies priorities for wetland bank creation, and 2) a Wetland Condition Index (WCI), which identifies priorities for wetland restoration and preservation. In addition, the Kramer et al. (2012) Human Development Index (HDI) combines landscape metrics related to development pressure (e.g., percent impervious surfaces) to forecast past, present and future human impacts on aquatic resources across HUC-12 units. These tools are highly transferable to other wetland programs seeking to apply a watershed approach to the identification of suitable wetland and stream restoration and protection projects because they are easy to use and modify.

OVERVIEW

Lead Developers: Dr. Elizabeth Kramer and Stephen Carpendo, University of Georgia; Georgia Environmental Protection Division (GAEPD).[1]

Date Developed: 2011.[1]

Geographic area: The state of Georgia.[1]

Resource types: Wetlands.[1]

Restoration/conservation: The PWBSI targets creation and restoration (reestablishment). The WCI targets rehabilitation, enhancement, preservation/protection, and acquisition without preservation protection.[2]

Stakeholders: Stakeholders include government, non-profits, and industry groups with an interest in wetland mitigation and regulation.[1]

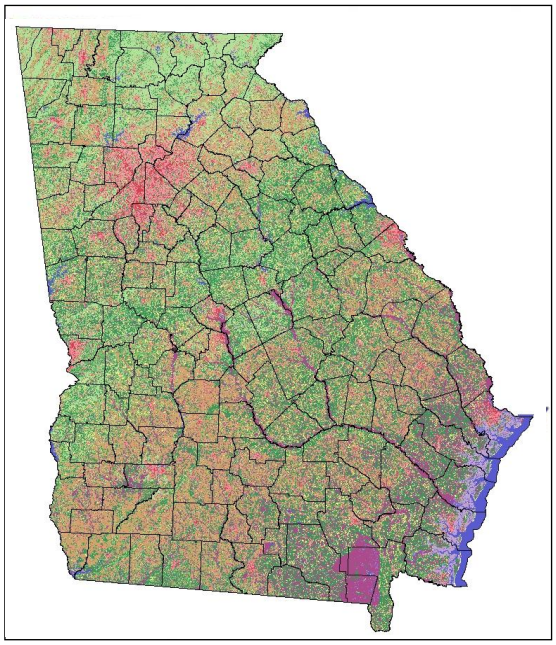

Figure 1. The PWBSI and WCI tools evaluated priority areas within the state of Georgia. Used with permission from University of Georgia.

Current status: So far, PWBSI and WCI model results have only been used as a basis for allocating points for the NRCS Wetland Reserve Program. However, GAEPD is in the process of determining other ways to apply it. Current discussions are underway to determine how the results will be incorporated into the U.S. Army Corps of Engineers Standard Operating Procedures for the establishment of mitigation banks in Georgia.[3]

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PRIORITIZATION ANALYSIS

Determination of prioritization objectives: A technical steering committee led by GAEPD and including representatives from state and federal agencies, non-governmental organizations, and forest product industry groups identified prioritization objectives to be targeted for compensatory wetland mitigation based on regulatory, planning, and management considerations. These objectives included:[1]

- Water quality and quantity
- Flood control and flow regulation
- Biodiversity conservation
- Connectivity
- Ease of restoration
- Education
- Recreation
- Scenic value
- Wildlife habitat

Landscape prioritization tools:

Potential wetland banking site index (PWBSI): The PWBSI valued each $30m^2$ pixel in terms of its suitability for the wetland creation and reestablishment for mitigation banking based on the prioritization objectives identified by a technical steering committee (see above). Inputs for the PWBSI included restorable land cover and hydric soils layers, which accounted for 'ease of restoration', in addition to the outputs for seven landscape prioritization tools, which accounted for eight other objectives (listed below). All individual layers were weighted equally in the PWBSI, though because many layers incorporated water quality, water quality was more highly valued than other functions. Factors and associated data sources used to prioritize the PWBSI for these objectives are provided in Table 1.[1]

Prioritization objectives assessed:[1]

- Water quality and quantity
- Flood control and flow regulation
- Biodiversity conservation
- Connectivity
- Ease of restoration
- Education
- Recreation
- Scenic value
- Wildlife habitat
- Wetland creation
- Wetland restoration (reestablishment)

Table 1. The PWBSI applied these factors and associated data sources to assess each pixel for the prioritization objectives stated above.[1]

Factor used in analysis	Data source(s)

Restorable land cover classes	
Area was wetland in 1974 but was not in 2005	1974; 2008 GLUT
Land cover was urban, open water > 5 acres, or wetland in 2008	
Hydric soils	
Hydric soil classification	SSURGO
Elevation 2m or less above nearest stream	2008 1:100,000 NHD; NRCS USGS DEM
Jurisdiction	See below
Water Quality and Quantity Index	See below
Connectivity to Existing Conservation Lands	See below
Terrestrial Dispersal Corridors between Potential Wetland Banks	See below
Hydrologic Connectivity between Wetlands	See below
Natural Upland Habitat Surrounding Site	See below
Maintenance of High Biodiversity Streams	See below

GLUT = Georgia Land Use Trends database; NARSAL = Natural Resources Spatial Analysis Laboratory; NHD = National Hydrography Dataset; SSURGO = Soil Survey Geographic Database; NRCS = National Resource Conservation Service; USGS = U.S. Geological Survey; DEM = Digital Elevation Model

Wetland Condition Index (WCI): The WCI combined five of the layers used for the PWBSI: 'connectivity to existing conservation areas', 'terrestrial dispersal corridors between potential wetland banks', 'hydrologic connectivity', 'natural upland habitat surround site', and 'maintenance of high biodiversity streams'. These layers are combined with the potential runoff index (deviation from reference) layer and three wetland condition layers: ‘percentage impervious surface within a basin’, ‘percentage of impaired streams and rivers per HUC-12’, and ‘percentage wetland change’. All individual layers were weighted equally in the WCI, though because many layers incorporated water quality, water quality was more highly valued than other functions. Data sources underlying each of these factors are provided in Table 2.[1]

Prioritization objectives assessed:[1]

- Water quantity quality and quantity protection
- Flood control and flow regulation
- Biodiversity conservation
- Connectivity
- Education
- Scenic value
- Wildlife habitat
- Wetland condition
- Wetland restoration (rehabilitation)
- Wetland enhancement
- Wetland preservation

Table 2. The PWBSI applied these factors and associated data sources to assess each pixel for the prioritization objectives stated above.[1]

Factor used in analysis	**Data source(s)**

Percentage of impervious surface within a basin	2008 Georgia Impervious Surface Cover (NARSAL, 2009)
Percentage of impaired streams and river per HUC-12	NHD; Impaired streams and rivers data (GAEPD, 2007)
Percentage wetland change	1974 GLUT; 2008 GLUT
Jurisdiction	See below
Potential runoff index (deviation from reference)	See below
Connectivity to Existing Conservation Lands	See below
Terrestrial Dispersal Corridors between Potential Wetland Banks	See below
Hydrologic Connectivity between Wetlands	See below
Natural Upland Habitat Surrounding Site	See below
Maintenance of High Biodiversity Streams	See below

GLUT = Georgia Land Use Trends database; NARSAL = Natural Resources Spatial Analysis Laboratory; NHD = National Hydrography Dataset

Jurisdiction: This tool prioritizes potential sites that are less vulnerable to development because they are within the Savannah Corps District's definition of jurisdictional wetlands ("within 100 feet of navigable waters or within the 100 year floodplain") under §404 of the Clean Water Act. Factors and associated data sources underlying this tool are provided in Table 3.[1]

Prioritization objectives assessed:[1]

- Section 404 jurisdiction

Table 3. The jurisdiction assessment, an input for the PWBSI, applied these factors and associated data sources to assess Section 404 jurisdiction.[1]

Factor used in analysis	Data source(s)
Within 100 feet of navigable water	Navigable waters subset of the 1:100,000 NHD.
Within the 100-year floodplain	FEMA Q3 flood data

FEMA = Federal Emergency Management Agency

Water quality and quantity index (WQQI): The WQQI assesses each pixel for water quality protection and flood regulation by evaluating the ability of potential sites to accumulate runoff from non-point sources of pollution. The WQQI is calculated by multiplying the proportion of runoff following a large storm event (i.e., Potential Runoff Index) by a measure of the ability of potential restoration sites to limit non-point source pollution based on landscape position (i.e., Distance to Impairment Index). Factors and associated data sources used to calculate the WQQI are detailed in Table 4.[1]

Prioritization objectives assessed:[1]

- Water quality and quantity protection
- Flood control and flow regulation

Table 4. The WQQI is calculated based on the factors and associated data sources listed below.[1]

Factor used in analysis	Data source(s)
Potential Runoff Index (PRI)	

Land cover types	2008 GLUT database
Hydrologic soils groups	SSURGO
TR-55 curve numbers	USDA (1986)[4]
two-year 24-hour storm event data	Isopluvial maps
Distance to Impairment Index (DII)	
Distance to Impairment Index (DII)	
Streams and rivers (especially small first order and ephemeral streams missed in NHD)	Digital elevation model (DEM)
Lakes and large rivers	NHD
Land use types	2008 GLUT database

GLUT = Georgia Land Use Trends database; NHD = National Hydrography Dataset; SSURGO = Soil Survey Geographic Database; USDA = U.S. Department of Agriculture; DEM = Digital Elevation Model

Potential runoff index (PRI) (deviation from reference): This tool calculated the proportion of runoff produced by a large storm event. In contrast to the WQQI calculation above, here the PRI was subtracted from a reference value so that the metric reflected wetland condition. Factors and data sources underlying calculation of the PRI are listed in Table 5.[1]

Prioritization objectives assessed:[1]

- Water quality and quantity
- Flood control and flow regulation
- Wetland rehabilitation, enhancement, or preservation.

Table 5. The PRI (deviation from reference) is calculated using the factors and data sources listed below.[1]

Factor used in analysis	**Data source(s)**
Land cover types	2008 GLUT database
Hydrologic soils groups	SSURGO
TR-55 curve numbers	USDA (1986)
Two-year 24-hour storm event data	Isopluvial maps

USDA = U.S. Department of Agriculture; SSURGO = Soil Survey Geographic Database; GLUT = Georgia Land Use Trends database

Connectivity to existing conservation lands: This tool used an area-weighted connectivity function to rank areas higher where they were located in closer proximity to conservation areas identified in the Georgia Conservation Lands Database. This was done for several conservation area layers (Table 6), which were summed so that higher ranks indicated potential sites that would enhance connectivity among multiple conservation areas.[1]

Prioritization objectives assessed:[1]

- Connectivity
- Recreation
- Education
- Scenic value

Table 6. Conservation areas were used as part of the 'connectivity to existing conservation lands' metric to assess each pixel for the objectives listed above.[1]

Factor used in analysis	Data source(s)
Conservation areas: local, state, and federal land holdings, existing Corps wetland restrictive covenants, and privately held conservation easements	Georgia Conservation Lands Database

Terrestrial dispersal corridors between potential wetland banks: This tool ranks potential sites for their ability to enhance terrestrial dispersal corridors by assessing wildlife connectivity in two steps: 1) producing a raster layer representing resistance to dispersal by the green frog (*Rana clamitans*) based on literature-derived estimates of green frog resistance to different land cover types and 2) ranking areas on this layer higher as potential restoration sites if they offer paths of lower resistance to migrating amphibians. Factors and associated data sources used to assess this metrics are detailed in Table 7.[1]

Prioritization objectives assessed:[1]

- Connectivity

Table 7. Factors and associated data sources used to assess connectivity as part of the 'terrestrial dispersal corridors between potential wetland banks' model.[1]

Factor used in analysis	Data source(s)
Connectivity analysis	
A map based on an average weighted species model (AWSM) that ranks areas of natural vegetation based on GAP species distribution maps for vertebrate species, their federal status, and their global and state Natural Heritage ranking	The "Comprehensive Wildlife Conservation Strategy for Georgia" (GADNR, 2005)[5]
Wetland land cover	1974 GLUT database
R. clamitans emigration rate based on the juvenile life history stage	Martof (1953)[6]
R. clamitans mean dispersal distance based on the juvenile life history stage	Gray et al. (2004);[7] Lamoureux and Madison (1999);[8] NatureServe (2006)[9]
Habitat resistance layer	See below
Habitat resistance layer	
Land cover types	The 2008 GLUT database
Roads	U.S. Census Tiger Roads Database
Streams	Calculated from flow accumulation models
Resistance coefficients for *Rana clamitans*	Multiple peer-reviewed literature sources and

for land cover types, roads, and streams	expert opinion – see Table 2.5 in Carpendo and Kramer (2008)[10]

GLUT = Georgia Land Use Trends database

Hydrologic connectivity between wetlands: This tool prioritized potential restoration sites based on their flood storage capacity (developed from a map of existing wetlands, Table 8). Fragstats 3.3 was applied to calculate metrics for contiguity and proximity to each wetland included in this map that were in turn used to obtain connectivity rankings for each area of the landscape. A final layer rating each position in the landscape for its ability to reduce flood volumes while maintaining flows was then generated.[1]

Prioritization objectives assessed:[1]

- Connectivity
- Flood control and flow regulation
- Water quality and quantity

Table 8. Factors and associated data sources used to assess the objectives listed above as part of the hydrological connectivity model.[1]

Factor used in analysis	Data source(s)
Wetland land cover	2008 GLUT database

GLUT = Georgia Land Use Trends database

Natural upland habitat surrounding site: This tool ranked $30m^2$ areas in terms of their connectivity to terrestrial habitats that provide important benefits to wildlife. In particular, juvenile amphibians disperse to neighboring wetlands through intervening upland habitat. As adults, terrestrial habitats serve as critical foraging and breeding areas. This tool evaluated sites in terms of percentage of upland vegetation within a 500-meter radius. Factors and associated data sources used to rank sites are listed in Table 9.[1]

Prioritization objectives assessed:[1]

- Biodiversity conservation
- Connectivity
- Wildlife habitat

Table 9. Factors and associated data sources used to evaluate sites for the objectives listed above as part of the 'natural upland habitat surrounding site' tool.[1]

Factor used in analysis		Data source(s)
Natural upland vegetation patches	Natural vegetation patches	GAP vertebrate species models
	Wetland land cover	1974 GLUT database

GLUT = Georgia Land Use Trends database; GAP = Gap Analysis Project data

Maintenance of high biodiversity streams: This tool rates potential sites based on their proximity to high priority, high biodiversity streams – an indicator of the ability of sites to reduce non-point source pollution entering high biodiversity aquatic habitats. Sites closest to high priority, high

biodiversity streams are rated highest. This metric was calculated similarly to the WQQI, except it is based on high priority streams data (Table 10).[1]

Prioritization objectives assessed:[1]

- Biodiversity conservation
- Wildlife habitat

Table 10. Factors and associated data sources used to assess the objectives listed above.[1]

Factor used in analysis	Data source(s)
Potential Runoff Index (PRI)	
Land cover types	2008 GLUT database
Hydrologic soils groups	STATSGO soils data
TR-55 curve numbers	USDA (1986)
Two-year 24-hour storm event data	Isopluvial maps
Distance to High Priority Streams Index (DHPSI)	
Streams that support aquatic species of conservation concern for the "Comprehensive Wildlife Conservation Strategy for Georgia"	Georgia Natural Heritage Program high priority streams.
Lakes and large rivers	NHD
Land use types	2008 GLUT database

GLUT = Georgia Land Use Trends database; NHD = National Hydrography Dataset; STATSGO = State Soil Geographic database; USDA = U.S. Department of Agriculture

Human Development Index (HDI): The Kramer et al. (2012) HDI score quantifies the presence of current and future threats within each HUC-12 by adding together eight spatial datasets, each representing an indicator of past or future development pressures. Areas that receive higher HDI scores are predicted to have higher ongoing development pressure than areas with lower HDI scores and should therefore represent more viable locations in which to site mitigation banks. Factors used to represent threats from development in the model, and their associated data sources, are listed in Table 12.[1]

Prioritization objectives assessed:[1]

- Opportunity for compensatory mitigation

Table 112. The Human Development Index ranked HUC-12s within HUC-8s in terms of their need for mitigation based on the factors and associated data sources listed below.[1]

Factor used in analysis	Data source(s)
Stream fragmentation (assessed using a fragmentation index (Merrill, 2001) to calculate the percentage of stream miles that remain free-flowing in 2008 compared to 1974)	1974 and 2008 NHD; USGS HUC-12 watersheds

Percentage of impaired streams and rivers	GAEPD GIS dataset on 303(d) and 305(b) impaired streams and rivers; NRCS HUC-12 watersheds
Wetland Activity Index: the change in density of wetlands between 1974 and 2008	1974 and 2008 GLUT database; NRCS HUC-12 watersheds
Percentage impervious surface	2008 NARSAL GISC database; NRCS HUC-12 watersheds
Projected future development in 2025 as measured by the difference in urban area per HUC-12 watershed between 2008 and 2025	SLUETH urban growth forecast model results for the state of Georgia for 2008 and 2025; NRCS HUC-12 watersheds
Change in average wetland continuity from 1974 and 2008 (measured using Fragstats)	2008 NARSAL land cover data; NRCS HUC-12 watersheds
Change in average wetland proximity from 1974 to 2008 (measured using Fragstats)	2008 NARSAL land cover data; NRCS HUC-12 watersheds
Riparian fragmentation measured as the change in mean length of riparian buffers using method of Kramer and Bumback (2005)[11]	Full buffered streams 120m; NRCS HUC-12 watersheds

NARSAL = Natural Resources Spatial Analysis Laboratory; GISC = Georgia Impervious Surface Cover; USGS = United States Geological Survey; NRCS = USDA Natural Resource Conservation Service

Validation of the landscape prioritization tool(s): Validation using on-the-ground water quality analyses is desirable but has not yet been completed. The developers of the tools have been working to obtain funding to validate the tools using hydrologic modeling such as the Soil and Water Assessment Tool (SWAT) or Livermore Software Technology Corporation (LSTC) models.[2]

Prioritization products: Output maps for each of the landscape analysis tool described above, including the PWBSI output (Figure 2), are available as static maps and GIS data for the state of Georgia.[1,10] GAEPD is also currently in the process of developing an online map viewer to view the outputs, although GAEPD does not currently know when it will be completed or whether they will make it available to the public.[2]

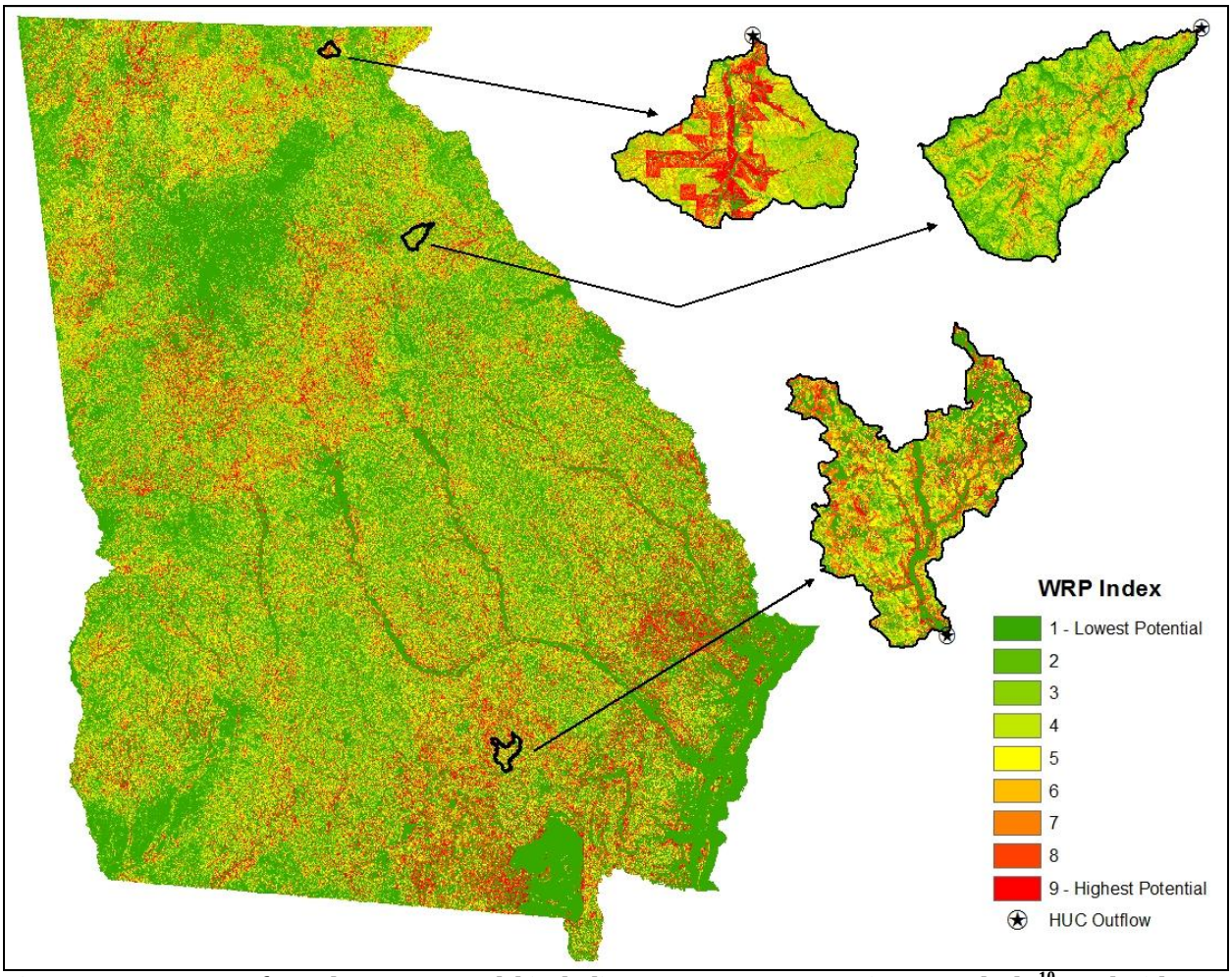

Figure 2. Output map from the PWBSI model including HUC-12 representative watersheds.[10] Used with permission from University of Georgia.

IMPLEMENTATION

Regulatory/non-regulatory programs:

- Section 404 compensatory wetland mitigation:
  - Mitigation bank planning: The PWBSI model can be used by Interagency Review Teams (IRTs) to select potential sites for mitigation banks, select service areas for mitigation banks, and determine the number of credits to allocate to mitigation banks.[2]
  - Mitigation site selection by in-lieu fee (ILF) programs: The WCI model prioritizes sites for enhancement and preservation – mitigation types often used by ILF programs.[2]
  - Watershed approach to mitigation: The PWBSI and WCI models could serve as possible tools for implementing a watershed approach to the selection of wetland mitigation sites, which is increasingly in demand by states. The developers of the tool are already considering how it can be used facilitate the watershed approach in other regions of the country.[2]

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- Water quality/quantity programs (Clean Water Act §319, §303): The tools could be used to identify parcels in which restoration, protection, or enhancement could be undertaken to produce water quality benefits.[2]
- Informing the development of management measures for regional water plans.
- Determining stream buffer rules.[2]
- The tools have been applied by the Natural Resource Conservation Service Wetland Reserve Program to award extra points to proposed projects that fall within areas identified as priorities by the model.[2]

Transferability:

- Because the models are based on datasets that can be interchanged, the approach can be readily adopted by many potential users.[2]

Data gaps:

- A lack of high-resolution LiDAR data for the state of Georgia, which could be used to improve hydrologic modeling.[2]
- Keeping the tool up-to-date. The representatives reported that continually updating the tool's inputs with the new datasets, so that outputs remain as relevant as possible, is the most significant data concern.[2]

Barriers:

- Funding is limited because the goals for the tools are not clearly articulated. Increased interest in the tool is needed, which could lead to the development of new ideas for how to apply it and subsequent funding sources.[2]

Future goals:

- Funding and bureaucratic barriers are likely to continue for the foreseeable future. Nevertheless developers how to keep the tool fully updated and implemented over the course of the next five years.[2]
- Training, data, time, money, and staff are factors that could determine whether developers are able to meet their goals.[2]

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